BONAPARTE MC3D MARINE SEISMIC SURVEY

Environment Plan

Prepared for:

Schlumberger Australia Pty Limited
Level 5
10 Telethon Ave
Perth
WA 6000

SLR Ref: 675.30093.00000-R01
Version No: -v2.0
June 2022

PREPARED BY

SLR Consulting Australia Pty Ltd
ABN 29 001 584 612
Ground Floor, 503 Murray Street
Perth WA 6000 Australia

T: +61 8 9422 5900
E: perth@slrconsulting.com   www.slrconsulting.com

BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Schlumberger Australia Pty Limited (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
675.30093.00000-R01-v2.0	7 June 2022	SLR Consulting Australia Pty Limited	Dan Govier	Dan Govier
675.30093.00000-R01-v1.0	25 May 2022	SLR Consulting Australia Pty Limited	Dan Govier	Dan Govier

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

DOCUMENT REFERENCES

TABLES

CONTENTS

CONTENTS

CONTENTS

FIGURES

CONTENTS

CONTENTS

APPENDICES

CONTENTS

ABBREVIATIONS AND DEFINITIONS

3D	3-dimensional
AASM	Airgun Array Source Model
ABARES	Australian Bureau of Agriculture and Resource Economics and Sciences
AFMA	Australian Fisheries Management Authority
AHO	Australian Hydrographic Office
AIMS	Australian Institute of Marine Science
AIS	Automated Identification System
ALA	Atlas of Living Australia
ALAN	Artificial light at night
ALARP	As Low As Reasonably Practicable
AMP	Australian Marine Park
AMSA	Australian Maritime Safety Authority
Animat	Animal Movement and Exposure Modelling
ANZG	Australian and New Zealand Guidelines
APPEA	Australian Petroleum Production and Exploration Association
ARPA	Automatic Radar Plotting Aids
AS/NZS ISO 31000:2018	Australian & New Zealand International Standard Risk Management – Guidelines 31000:2018
BACI	Before, After, Control, Impact
BCA	Biodiversity Conservation Act 2016
BIA	Biologically Important Areas
BOD	Biochemical Oxygen Demand
Bonn Convention	Convention on the Conservation of Migratory Species of Wild Animals
CAES	Catch and Effort System
COLREGS	International Regulations for Preventing Collisions at Sea 1972
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTS	Commonwealth Trawl Sector
DAWE	Department of Agriculture, Water and the Environment
dB	Decibels
DEPWS	Department of Environment, Parks and Water Security

CONTENTS

DITT	Northern Territory Department of Industry, Tourism and Trade
DMIRS	Department of Mines, Industry Regulation and Safety
DNP	Director of National Parks
DoE	Department of the Environment
DoEE	Department of the Environment and Energy
DPIR	Department of Primary Industry and Resources
DPIRD	Department of Primary Industries and Regional Development
EEZ	Exclusive Economic Zone
EMBA	Environment that May Be Affected
Environment Regulations	Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009
EP	Environment Plan
EPA	Environmental Protection Authority
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
EPBC Regulations	Environment Protection and Biodiversity Conservation Regulations 2000
EPO	Environmental Performance Outcomes
EPS	Environmental Performance Standards
ERA	Environmental Risk Assessment
ERM	Environmental Resources Management
ESD	Ecologically Sustainable Development
GHG	Greenhouse Gas
HFO	Heavy-Fuel-Oil
IAGC	International Associated of Geophysical Contractors
IAPP Certificate	International Air Pollution Prevention Certificate
IMO	International Maritime Organisation
IMS	Invasive Marine Species
IOPP Certificate	International Oil Pollution Prevention Certificate
irMA	Intrinsic Ranging by Modulated Acoustics
ISPP Certificate	International Sewage Pollution Prevention Certificate
ITF	Indonesian Throughflow
IUCN	International Union for Conservation of Nature

CONTENTS

JASMINE	JASCO's Animal Simulation Model Including Noise Exposure
JBG	Joseph Bonaparte Gulf
JRCC	Joint Rescue Coordination Centre
KEF	Key Ecological Features
KPMF	Kimberley Prawn Managed Fishery
LAC	Limits of Acceptable Change
London Protocol	Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972
MARPOL	International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978
MCS	Maximum Credible Scenario
MGO	Marine Gas Oil
MMF	Mackerel Managed Fishery
MMO	Marine Mammal Observer
MoC	Management of Change
MoU	Memorandum of Understanding
MSDS	Material Safety Data Sheets
MSS	Marine Seismic Survey
National Plan	Australian National Plan to Combat Pollution of the Sea by Oil and other Noxious and Hazardous Substances
NDSMF	Northern Demersal Scalefish Managed Fishery
NEBA	Net Environmental Benefit Analysis
NES	National Environmental Significance
NM	Nautical Mile
NMP	Ningaloo Marine Park
NMR	North Marine Region
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NT	Northern Territories
NPF	Northern Prawn Fishery
NWMR	North-west Marine Region
OA	Operational Area

CONTENTS

ODS	Ozone Depleting Substance
OPEP	Oil Pollution Emergency Plan
OPGGS Act	Offshore Petroleum and Greenhouse Gas Storage Act 2006
OPRC	International Convention on Oil Pollution Preparedness, Response and Co-operation
PAM	Passive Acoustic Monitoring
PK	Peak Sound Pressure level
PK-PK	Peak to Peak Sound Pressure Level
Policy Statement 2.1	EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales
POLREP	Pollution report
PSPPS Act	Protection of the Sea (Prevention of Pollution from Ships) Act 1983
PSZ	Petroleum Safety Zones
PTS	Permanent Threshold Shift
QHSE Policy	Quality, Health, Safety and Environment Policy
RADAR	Radio Detection and Ranging
Ramsar Convention	The Convention on Wetlands of International Importance
RMS SPL	Root-Mean-Square Sound Pressure Level
RMS	Root Mean Square
SEEMP	Ship Energy Efficiency Management Plan
SEL	Sound Exposure Level
SEL_{cum}	Cumulative Sound Exposure Level
SLB	Schlumberger Australia Pty Limited
SOLAS	International Convention of the Safety of Life at Sea
SOP	Standard Operating Procedures
SOPEP	Shipboard Oil Pollution Emergency Plan
SPL	Sound Pressure Level
Seismic Vessel	Seismic Survey Vessel
STCW Convention	International Convention of Standards of Training, Certification and Watch Keeping for Seafarers
TACC	Total Allowable Commercial Catch

CONTENTS

TEC	Threatened Ecological Community
TTS	Temporary Threshold Shift
UAM	Underwater Acoustic Modelling
UNCLOS	United Nations Convention on the Law of the Sea 1982
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UXO	Department of Defence's unexploded ordinance register
WA	Western Australia
WAFIC	Western Australian Fishing Industry Council Engagement

1 Introduction

1.1 Overview

Schlumberger Australia Pty Limited (**SLB**) is proposing to acquire the Bonaparte Multiclient 3D Marine Seismic Survey. Hereafter, these activities may also be referred to as the **Seismic Survey**. The Seismic Survey may commence as early as September 2022 and will be completed before 30 June 2024. Up to a maximum of 10,000 km^2 may be acquired per calendar year between 2022 and 2024. It is estimated to take approximately between 120 and 190 days to acquire 12,000 km^2 (including contingency time for potential vessel or equipment down time and adverse weather conditions).

This Environment Plan (**EP**) has been prepared to ensure the Seismic Survey is planned and undertaken in accordance with SLB's Quality, Health, Safety and Environment Policy (**QHSE Policy**), which is discussed further in **Section 1.6**, along with the regulatory requirements of the Offshore Petroleum and *Greenhouse Gas Storage Act 2006* (**OPGGS Act**) and the associated *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009* (the **Environment Regulations**).

1.2 Purpose and Objectives

In accordance with the requirements of the Environment Regulations, the purpose of this EP is to demonstrate that the Seismic Survey will be undertaken in a manner that is consistent with the principles of Ecologically Sustainable Development (**ESD**). This includes assessing the potential risks and impacts to the different receptors within the receiving environment and stakeholders that utilise the area. This assessment considers the controls measures and operational procedures proposed to be implemented in order to reduce the potential adverse environmental impacts and risks associated with the Seismic Survey to As Low As Reasonably Practicable (**ALARP**) and to **Acceptable Levels**. Environmental performance standards (**EPS**) have also been developed as part of this EP to measure the performance of the controls measures and operational measures that will be implemented during the Seismic Survey.

The objective of the proposed Seismic Survey is to provide an improved subsurface image of the eastern flank of the Vulcan Sub-basin and Londonderry High. The new data will provide an improved understanding of the subsurface, which to-date has been limited due to legacy surveys being unable to resolve shallow carbonate intervals and complex faulting.

Ultimately the new data will provide improved confidence in mapping major geological units aiding in the identification and de-risking of petroleum prospectively across the Seismic Survey area.

1.3 Scope of the Environment Plan

The scope of this EP addresses the proposed petroleum activity, that being a marine seismic survey (**MSS**), and the associated activities described in **Section 3**. Specifically, the scope of this EP covers the seismic acquisition and associated line turns, seismic testing and support activities associated with the Seismic Survey within the defined Operational Area (**OA**) (**Figure 1**).

The EP addresses potential environmental impacts which may occur as a result of planned activities and any potential unplanned events. Transit to and from the OA by vessels associated with the Seismic Survey, as well as port activities associated with these vessels, are not considered within the scope of this EP. Vessels supporting the Seismic Survey outside of the OA are subject to relevant maritime regulations and requirements not managed within this EP.

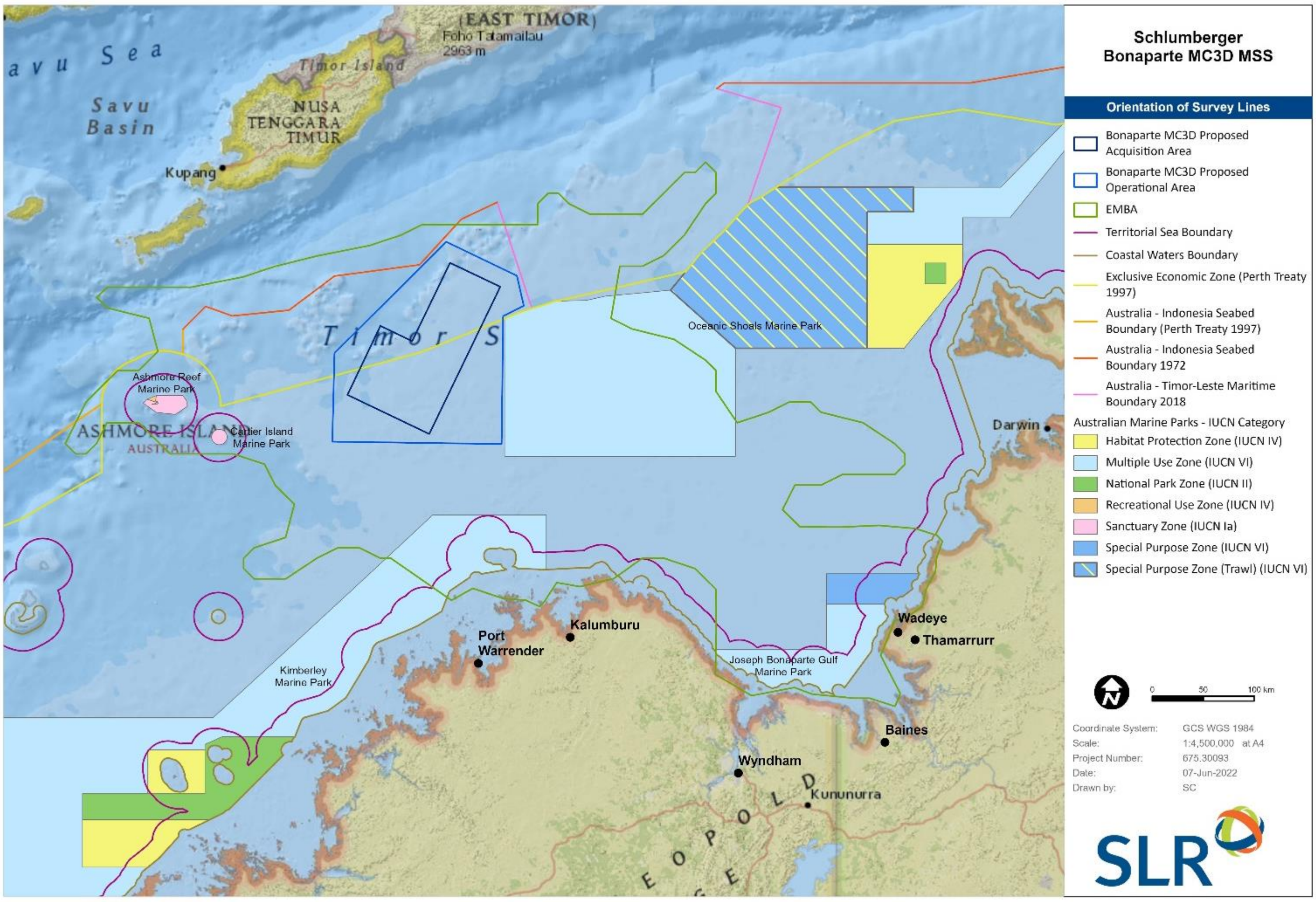


Figure 1 Location of the OA

1.4 Environment Plan Summary

In accordance with the requirements of Regulation 11(4) within the Environment Regulations, an EP summary is provided in **Table 1**.

Table 1 EP Summary

EP summary parameter	Section
Location	**Section 3.2**
Description of the receiving environment	**Section 4**
Description of the activity	**Section 3**
Details of the environmental impacts and risks	**Section 7** (Planned); **Section 8** (Unplanned)
A summary of the control measures for the activity	Throughout **Section 7** (Planned); **Section 8** (Unplanned)

EP summary parameter	Section
A summary of the arrangements for ongoing monitoring of the titleholder's environmental performance	Throughout **Section 7** (Planned); **Section 8** (Unplanned) and **Section 10.6.1**
A summary of the response arrangements in the OPEP	**Section 10.9**
Details of the consultation (already undertaken and proposed)	**Section 5**
Details of the titleholder's nominated liaison	**Section 1.5**

1.5 Titleholder and Nominated Liaison

SLB is the Titleholder for this activity. SLB is the world's leading supplier of technology, integrated project management and information solutions to customers working in the oil and gas industry worldwide. Employing over 100,000 people, representing over 140 nationalities, and working in more than 85 countries, SLB provides the industry's widest range of products and services from exploration through to production. WesternGeco, a business segment of SLB, provides advanced seismic acquisition and data processing services and has extensive experience in conducting MSSs internationally and in Australia. As WesternGeco is a business segment of SLB, it will be referred to as SLB throughout this EP.

In accordance with Regulation 15(1) of the Environment Regulations, details of the titleholder and liaison person are detailed within **Table 2** and **Table 3**, below.

Table 2 Titleholder Details

Environment Regulation Requirements	Description
Name	Schlumberger Australia Pty Limited
Business address	Level 5, 10 Telethon Avenue, Perth, WA 6000
Telephone number	+61 8 6208 3572
Fax number	+61 8 9420 4600
Email address	environment@slb.com
Australian Company Number	002 459 225

Table 3 Liaison Person Details

Environment Regulation Requirements	Description
Name	Kunal Mishra
Business address	Level 5, 10 Telethon Avenue, Perth, WA 6000
Telephone number	+61 8 6208 3572
Fax number	+61 8 9420 4600
Email address	environment@slb.com

As per Regulation 15(3) of the Environment Regulations, the nominated SLB Liaison Person (**Table 3**) or the SLB Project Manager (**Table 106**) will notify the National Offshore Petroleum Safety and Environmental Management Authority (**NOPSEMA**) both verbally and in writing, as soon as practicable, and prior to a change in the titleholder or the liaison person occurring. This protocol will also apply, should the contact details for either the titleholder or liaison person change.

1.6 SLB Environmental Policy

SLB has developed, publicly disseminated and implemented a QHSE Policy which demonstrates the organisations commitment to protecting the environment during all operations, including the proposed Seismic Survey. Environment Regulation 16(a) requires a statement of the titleholder's corporate environmental policy; as such, SLB's corporate QHSE Policy is provided within **Figure 2**.

Quality, Health, Safety, and Environmental (QHSE) Policy **Schlumberger**

The long-term business success of Schlumberger depends on our ability to continually improve the quality of our services and products while protecting people and the environment. Emphasis must be placed on ensuring human health, operational safety, environmental protection, quality enhancement and community goodwill. This commitment is in the best interests of our customers, our employees and contractors, our stockholders and the communities in which we live and work.

Schlumberger requires the active commitment to and accountability for, QHSE from all employees and contractors. Line management has a leadership role in the communication and implementation of, and ensuring compliance with, QHSE policies and standards. We are committed to:

- Protect, and strive for improvement of, the health, safety and security of our people at all times;
- Eliminate Quality non-conformances and HSE accidents;
- Meet specified customer requirements and ensure continuous customer satisfaction;
- Set Quality & HSE performance objectives, measure results, assess and continually improve processes, services and product quality, through the use of an effective management system;
- Plan for, respond to and recover from any emergency, crisis and business disruption;
- Minimize our impact on the environment through pollution prevention, reduction of natural resource consumption and emissions, and the reduction and recycling of waste;
- Apply our technical skills to all HSE aspects in the design and engineering of our services and products;
- Communicate openly with stakeholders and ensure an understanding of our QHSE policies, standards, programs and performance. Reward outstanding QHSE performance;
- Improve our performance on issues relevant to our stakeholders that are of global concern and on which we can have an impact, and share with them our knowledge of successful QHSE programs and initiatives.

This Policy shall be regularly reviewed to ensure ongoing suitability. The commitments listed are in addition to our basic obligation to comply with Schlumberger standards, as well as all applicable laws and regulations where we operate. This is critical to our business success because it allows us to systematically minimize all losses and adds value for all our stakeholders.

Olivier Le Peuch
Chief Executive Officer, Schlumberger Limited

For further information regarding this policy:
CONTACT: Mohamed Kermoud, Vice President HSE
LOCATION: Schlumberger Limited, Houston
EMAIL: Mohamed Kermoud

SLB-QHSE-L001
Released on 5 June 1997
Last update on 9 August 2019

Figure 2 SLBs Corporate QHSE Policy

2 Environmental Management Framework

2.1 Legislation Requirements

Petroleum and greenhouse gas storage activities, including MSSs, in 'offshore areas' – defined as those waters between the outer limit of coastal water (three nautical miles (**NM**)) and the outer limit of the Continental Shelf (at least 200 NM) – are required to be assessed and authorised under the OPGGS Act and the associated Environment Regulations.

The following sections detail the requirements of the Environment Regulations, along with all applicable environmental management requirements that are relevant to the Seismic Survey. **Section 2.1.1.1** provides a summary of the Environmental Regulations, in particular, Regulation 13 and provides a road map to the relevant sections of this EP which describe how each of the requirements have been adhered to.

2.1.1 OPGGS Act

The OPGGS Act provides an effective regulatory framework for petroleum exploration and recovery, and the injection and storage of greenhouse gas substances in Australia's offshore areas. The OPGGS Act confers powers to NOPSEMA to regulate the health and safety, structural integrity and environmental management of petroleum exploration and development activities within Australia's offshore areas.

The OPGGS Act is supported by regulations covering matters such as safety, diving, petroleum resource management and environmental management (see **Section 2.1.1.1**).

In addition to establishing the regulatory regime for environmental management authorisation, the OPGGS Act has other relevant powers, including:

- Requiring that an activity in an offshore area must be undertaken in a manner that does not interfere with navigation, fishing, conservation of the resources of the sea and seabed, any lawfully established activities of another person and the enjoyment of native title rights and interests;
- Requiring operations to be carried out in accordance with good oilfield practices;
- Requiring titleholders, in the event of an escape of petroleum, to eliminate or control the escape, clean up the escaped petroleum and remediate any resulting damage to the environment, and carry out environmental monitoring of the impact of the escape on the environment;
- Providing for NOPSEMA to give written directions to titleholders covering all aspects of petroleum exploration and production;
- Providing for remedial directions by NOPSEMA with regard to the restoration of the environment; and
- Requiring a titleholder to maintain in good condition and repair all structures and equipment that are used in connection with the operations authorised by the permit, lease, licence or authority.

2.1.1.1 Environment Regulations

The Environment Regulations have been developed under the OPGGS Act and provide an objective-based regime for the management of environmental performance for Australian offshore petroleum exploration and production and greenhouse gas storage activities in areas of Commonwealth jurisdiction.

The objectives of the Environment Regulations are to ensure any activity is carried out:

- In a manner consistent with the principles of ESD (outlined further in **Section 2.1.2**);
- In a manner in which the environmental impacts and risks of the activity will be reduced to **ALARP.** To ensure the impacts and risks from the proposed activities are reduced to **ALARP**, a hierarchy of controls have been utilised which follows a tiered system which are defined within **Section 6.6**; and
- In a manner in which the impacts and risks will be of an **Acceptable Level**. The criteria used to determine whether the residual risk of an activity following the implementation of the control measures is at an **Acceptable Level** is provided within **Section 6.7**.

2.1.2 EPBC Act

The Environment Protection and Biodiversity Conservation Act 1999 (**EPBC Act**) is the Australian Government's central piece of environmental legislation which provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places as matters of National Environmental Significance (**NES**). There are nine matters of NES to which the EPBC Act applies (outlined within Sections 12 to 24 of the EPBC Act), which are:

- World heritage properties;
- National heritage places;
- Wetlands of international importance (RAMSAR sites);
- Listed threatened species and ecological communities;
- Listed migratory species;
- Nuclear actions;
- Commonwealth marine areas;
- The Great Barrier Reef Marine Park; and
- Protection of water resources from coal seam gas development and large coal mining development.

The NES listed above are discussed in detail within **Section 4**, where relevant to the Seismic Survey.

In relation to the listed threatened species and ecological communities, the EPBC Act has established a list of categories, including: extinct, extinct in the wild, critically endangered, endangered, vulnerable and conservation dependant. **Section 4.5** includes a description of the biological environment comprising the OA and surrounds, which includes some species that are listed as threatened. Where threatened species occur, this has been identified.

The EP must describe matters protected under Part 3 of the EPBC Act and assess any impacts and risks to these. As outlined within **Section 2.1.1.1**, one objective of the Environment Regulations is to ensure that the activity is carried out in a manner consistent with the principles of ESD, the principles of which are set out in Section 3A of the EPBC Act as:

- Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations;
- 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;
- 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 conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making; and
- Improved valuation, pricing and incentive mechanisms should be promoted.

The EPBC Act has been utilised throughout the development of this EP, particularly in relation to the existing environment (**Section 4**) and within the assessment of the impacts and risks from the proposal (**Section 7** and **Section 8**).

2.1.2.1 EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales

Under the EPBC Act, a number of whale species are listed as threatened and/or migratory species (see **Section 4.5.6**) and are subsequently protected under the EPBC Act as matters of NES. In order to manage the interaction between offshore seismic exploration and whales, the EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales (**Policy Statement 2.1**) was developed, with the aim being to:

- Provide practical standards to minimise the risk of acoustic injury to whales in the vicinity of MSS operations;
- Provide a framework that minimises the risk of biological consequences from acoustic disturbance from MSS sources to whales in biologically important habitat areas or during critical behaviours; and
- Provide guidance to both proponents of MSSs and operators conducting MSSs about their legal responsibilities under the EPBC Act.

The following sections provide an outline of the applicable provisions of Policy Statement 2.1.

2.1.2.1.1 Potential Impacts to be Considered

Section 4 of Policy Statement 2.1 discusses the potential impacts to be considered when planning a MSS, which has been utilised in the preparation of this EP. An important aspect to consider when assessing the likelihood of potential impacts on whales is determining whether the MSS will have a ‘low likelihood’ or a ‘moderate to high likelihood’ of encountering whales. These are defined within Policy Statement 2.1 as:

- Low likelihood – spatially and temporally outside aggregation areas, migratory pathways and areas considered to provide biologically important habitat; and
- Moderate to high likelihood – spatially and/or temporally proximate to aggregation areas, migratory pathways and/or areas considered to provide biologically important habitat.

In addition to the above, identifying whether a proposed survey will occur within a biologically important habitat of a whale species is necessary because displacement from these areas may have a greater impact than elsewhere. An assessment into the likelihood of encountering whale species has been undertaken and included within **Section 4.5.6**, along with the identification of any areas which are biologically important habitats for those whale species.

2.1.2.1.2 Legislative Responsibilities

There are two obligations that need to be considered under the EPBC Act when developing a MSS: referrals and permits. These are defined as follows:

- Referrals – if an MSS has, or is likely to have, a significant impact on a matter of NES or the 'environment' (including threatened and migratory species) then that action should be referred to the Australian Government Environment Minister under the EPBC Act. The Minister may then determine the referral to be either a 'controlled action' in which the action is subject to the assessment and approval processes under the EPBC Act, or not a controlled action where further approval is not required if the action is undertaken in accordance with the referral, or in a particular way specific in the decision notice.

  As part of the development of this EP, a number of control measures has been utilised in assessing the impact of the Seismic Survey (contained throughout **Section 7** for planned activities, and **Section 8** for unplanned activities). Based on these control measures, overall, it is considered that the Seismic Survey activities will not have a significant impact on a matter of NES or on the 'environment' in general, as outlined within **Sections 7** and **8**.

- Permits – an action that will kill, injure, take or interfere with a whale or dolphin within the Australian Whale Sanctuary (described within **Section 4.4.5**) is an offence under the EPBC Act, unless the proposed action has been referred to the Environment Minister and approved, or a permit has been granted. Generally, an MSS will not interfere with whales if it is undertaken in an area and time where the likelihood of encountering whales is low and appropriate measures are implemented.

  As outlined above, the likelihood of encountering whales during the Seismic Survey is discussed within **Section 4.5.6** and the control measures to be implemented are contained within **Sections 7** and **8**. Based on these sections, it is considered that the Seismic Survey will not kill, injure, take or interfere with a whale or dolphin within the Australian Whale Sanctuary.

2.1.2.1.3 Management Measures for Vessels Conducting Seismic Surveys in Australian Waters

Policy Statement 2.1 provides a discussion on the management measures for vessels and organisations looking to conduct MSSs within Australian waters. These measures are divided into two primary areas, precautionary zones and management procedures which are discussed in the following sections.

2.1.2.1.4 Precautionary Zones

Section 6.1 of Policy Statement 2.1 defines three zones (observation, low-power and shut-down) which are to be used during MSSs, based on the likely sound levels surrounding the seismic sound source. There are two levels of precautionary zones, dependant on the sound exposure level (**SEL**) each seismic emission makes which is to be demonstrated through sound modelling or empirical measurements.

If the received sound exposure level will not likely exceed 160 decibels (**dB**) re 1 μPa^2s for 95% of seismic shots at 1 km range, the following precautionary zones are recommended under Policy Statement 2.1:

- Observation zone: 3^+ km horizontal radius from the acoustic source;
- Low-power zone: 1 km horizontal radius from the acoustic source; and

- Shut-down zone: 500 m horizontal radius from the acoustic source.

For all other proposed MSSs, Policy Statement 2.1 recommends the following zones:

- Observation zone: 3⁺ km horizontal radius from the acoustic source;
- Low-power zone: 2 km horizontal radius from the acoustic source; and
- Shut-down zone: 500 m horizontal radius from the acoustic source.

A graphical representation of the three recommended zones is indicated within **Figure 3**.

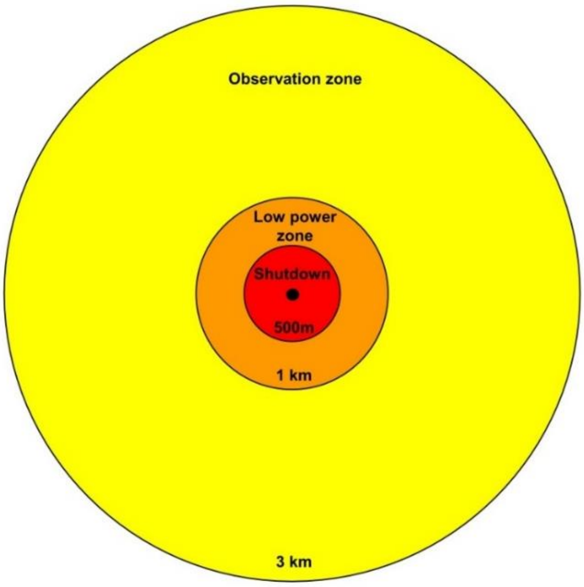


Diagram 1: Precaution zones surrounding the acoustic source for surveys that meet the criteria for a **1km low power zone**.

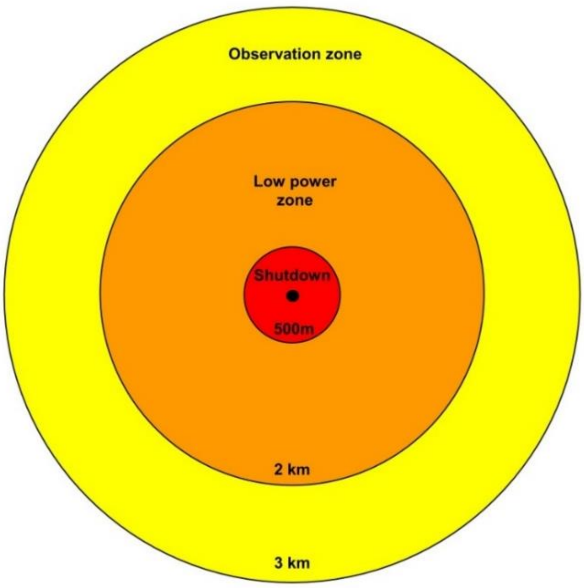


Diagram 2: Precaution zones surrounding the acoustic source for all other surveys (**2km low power zone**)

Source: EPBC Act Policy Statement 2.1 (DoEWHA, 2008)

Figure 3 Policy Statement 2.1 – Recommended Precautionary Zones

Each of the three zones has differing requirements, as follows:

- Observation zone – whales and their movements should be monitored to determine whether they are approaching or entering the 'Low-power Zone';
- Low-power zone – when a whale is sighted within, or is about to enter, this zone, the acoustic source should immediately be powered down to the lowest possible setting; and
- Shut-down zone – when a whale is sighted within, or is about to enter, this zone, the acoustic source must immediately be shut-down completely.

SLB has undertaken Underwater Acoustic Modelling (**UAM**) (**Appendix A**, **Section 7.2.1.2**) which has confirmed that the Sound Exposure Level (**SEL**) exceeds the 160 dB re 1 µPa^{2}s, for 95% of seismic shots at 1 km range, so SLB will implement the more stringent precautionary zone requirements of the Policy Statement 2.1 (**Figure 3**). However, based on the UAM results and sensitivities in and surrounding the OA, additional management procedures will be implemented (**Section 7.2.5**).

2.1.2.1.5 Management Procedures

In addition to the precautionary zones discussed above, Policy Statement 2.1 includes a number of management procedures which should be followed by all Seismic Survey Vessels (**Seismic Vessel**) conducting surveys in Australian waters irrespective of location and time of year. These management procedures are split into 'Standard Management Procedures' and 'Additional Management Procedures' under Section 6.2 of Policy Statement 2.1.

The Standard Management Procedures include:

- Pre-survey planning – ideally, no MSS will be planned to be conducted when whales are likely to be breeding, calving, resting or feeding; if an MSS is proposed to occur during this period, careful consideration of the survey and associated control measures will need to be undertaken;
- Trained crew – sufficiently trained crew, including people with proven experience in whale observation, distance estimation and reporting, are required to undertake relevant requirements during the survey operations;
- During survey – all Seismic Vessels operating in Australian waters are required to follow basic procedures during surveys irrespective of location and time of the year, including:
- Pre-start-up visual observations;
- Soft start;
- Start-up delay;
- Operations;
- Power-down and stop work; and
- Compliance and sighting reports – a record of procedures employed during operations is required, including information on any whales (or other species) sighted during the survey. This information may be useful for future operations.

When an MSS is proposed to operate in areas where the likelihood of encountering whales is moderate to high (discussed in **Section 2.1.2.1.1**) then additional management procedures are required to ensure that impacts and interference are avoided and/or minimised. Suggested additional management procedures under Section 6.2 of Policy Statement 2.1 include:

- Marine Mammal Observer (**MMO**) – MMOs should be trained and experienced in whale identification and behaviour, distance estimation, be capable of making accurate identifications and observations of whales in Australian waters, and can assist other observers on the Seismic Vessel;
- Night-time/poor visibility – appropriate management measures to detect (or predict) whale presence should be included to reduce the likelihood of encounters, including limiting initiation of soft start procedures, daylight spotter vessel or aircraft and pre-survey research;
- Spotter vessel(s) and aircraft – a spotter vessel/aircraft could be used to assist in detecting the presence of whales, including during night-time/poor visibility operations;
- Increase precaution zones and buffer zones – in some locations and circumstances an increased distance for the instigation of power-down procedures (discussed above) is advisable;
- Passive Acoustic Monitoring (**PAM**) – deployment of PAM to detect whales in real-time may provide an additional method of detecting whales during surveys, and particularly during night-time/poor visibility operations; and
- Adaptive management – adaptive management procedures should be considered to manage the potential increased likelihood of encountering whales; for example, ceasing night-time operations if there are three consecutive days on which operators experience three or more whale-instigated shut-down/power down situations.

An assessment of the likelihood of encountering whales has been undertaken within **Section 4.5.6**, based on the 'presence ranking' (as assigned by the Protected Matters Database for both the OA and EMBA) which has concluded that whales are known to occur within the OA and EMBA. Therefore, additional management procedures will be required, and the additional procedures that will be included are discussed in detail within **Section 7.2**

2.1.2.2 Environment Protection and Biodiversity Conservation Regulations 2000

The Environment Protection and Biodiversity Conservation Regulations 2000 (**EPBC Regulations**) implement the provisions of the EPBC Act and provide additional measures to control a range of activities, including the use of vehicles and vessels, littering, commercial activities, research, and commercial and recreational fishing. In particular, Part 8 of these regulations relates to interacting with cetaceans and whale watching. The relevant provisions of Part 8 have been considered when determining the impacts and risks associated with the Seismic Survey (**Section 7**).

2.1.2.3 EPBC Act Management Plans

When a native species or ecological community is listed as threatened under the EPBC Act, conservation advice is developed to assist with its recovery. Conservation advice provides guidance on the immediate recovery and threat abatement activities that can be undertaken to ensure the conservation of a newly listed species or ecological community.

The Minister for the Environment may make or adopt and implement recovery plans for threatened fauna, threatened flora (other than conservation dependent species) and Threatened Ecological Communities (**TEC**) listed under the EPBC Act. Recovery plans define the research and management actions necessary to stop the decline of, and support the recovery of, listed threatened species or TECs. The aim of a recovery plan is to maximise the long-term survival in the wild of a threatened species or ecological community.

The Seismic Survey will be conducted in a manner that is consistent with the conservation advice and recovery plans for species with the potential to be present in the OA. **Section 4.5** describes the species that are listed as threatened and/or migratory under the EPBC Act, which have been identified to occur within the Environment that May Be Affected (**EMBA**) (see **Section 4.1** for a description on how this was established) and identifies the relevant conservation advices and recovery plans. In addition, any relevant measures contained within the conservation advice and recovery plans have been considered as part of the assessment of impacts and risks that may occur as a result of the Seismic Survey (**Section 7**).

2.1.3 Other Relevant Legislation

Regulation 13(4) of the Environment Regulations requires a description of the relevant legislative requirements that apply to the activity and are relevant to the environment management of the activity. A number of legislative instruments exist which are relevant to the Seismic Survey; these are outlined below along with a discussion on how each of these requirements will be achieved.

The key pieces of Commonwealth legislation (other than the OPGGS Act and EPBC Act discussed above) that are relevant to the environmental management of the Seismic Survey are outlined within **Table 4**.

Although the Seismic Survey is located within Commonwealth waters, and hence falls under the Commonwealth legislation, in the unlikely event of a hydrocarbon spill occurring and entering State waters, State legislation would be triggered. As the risk of this unplanned event occurring is considered to be remote (**Section 8.3**) a full assessment of all of the State legislation has not been conducted; however, **Section 10.9** provides an overview of SLBs arrangements for a response to the unlikely event of a hydrocarbon spill, including how the relevant statutory plans will be implemented, should the spill enter State waters.

Table 4 Summary of Key Commonwealth Legislation Relevant to the Seismic Survey

Legislation	Applicability
Aboriginal and Torres Strait Islander Heritage Protection Act 1984	This Act can protect areas and objects that are of particular significance to Aboriginal and Torres Strait Islander people. The Environment Minister can make a declaration to protect an area, object or class of object from a threat of injury or desecration after receiving an application from an Aboriginal or Torres Strait Islander person or group. In addition, this Act requires the discovery of Aboriginal remains to be reported to the Environment Minister, giving particulars of the remains and of their location. An assessment of Aboriginal heritage sites is contained within **Section 4.6.1**.
Australian Heritage Council Act 2003	The Australian Heritage Council Act established the Australian Heritage Council as an independent expert advisory body on heritage matters. The main responsibilities of the Australian Heritage Council relate to assessing places for the National Heritage List and the Commonwealth Heritage List. An assessment of the heritage values associated with the OA is outlined within **Section 4.6.2**.
Australian Maritime Safety Authority Act 1990	This Act established the Australian Maritime Safety Authority (**AMSA**), which has the responsibility of protecting the marine environment from pollution from ships, and other environment damage resulting from shipping activities. These responsibilities include being the lead agency when responding to hydrocarbon spills within the marine environment under the National Plan for Maritime Environmental Emergencies (known as the **National Plan**). Given the Seismic Survey will take place in the marine environment, there is always a remote risk of pollution or other incidents as a result of the operations. The potential risks from an unplanned activity occurring in association with the Seismic Survey is assessed within **Section 8**. This assessment also provides the measures that will be implemented throughout the survey to reduce these risks to **ALARP** and an **Acceptable Level**.
Biosecurity Act 2015 Biosecurity Regulations 2016	This Act details how biosecurity threats to plant, animal and human health in Australia and its external territories are managed. Section 4 of this Act describes the objectives, which are: *(a) To provide for managing the following:* *(i) Biosecurity risks;* *(ii) The risk of contagion of a listed human disease or any other infectious human disease;* *(iii) The risk of human diseases or any other infectious 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, the Ballast Water Convention, the United Nations Convention on the Law of the Sea and the Biodiversity Convention.* There are a number of relevant legislative documents that have been prepared to deal with the issue of biosecurity (discussed in **Section 2.2**); all of which have been considered as part of the preparation of this EP, specifically in relation to the assessment of environmental risks associated with invasive marine species (**Section 8.1**).

Legislation	Applicability
Environment Protection (Sea Dumping) Act 1981	The Environment Protection (Sea Dumping) Act 1981 is administered by the Australian Government Department of the Environment and Energy (**DoEE**) and is aimed at protecting the waters surrounding Australia's coastlines from wastes and pollution dumped at sea. In addition, this Act fulfils Australia's international obligations under the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972, and 1996 Protocol (**the London Protocol**). The aim of this Act is to minimise pollution threats by: • Prohibiting ocean disposal of waste considered too harmful to be released into the marine environment; and • Regulating permitted waste disposal to ensure environmental impacts are minimised. Since the proposed Seismic Survey will involve the use of a Seismic Vessel within Australian waters, the management and operation of the vessel will be subject to this Act. Although no waste or other matter (other than routine vessel discharges e.g. appropriately treated sewage) is proposed to be discharged within Australian waters as part of this EP, there is always a remote chance of an accident occurring where such waste or equipment could be lost overboard. **Section 8.3** outlines the potential risks and associated impacts if an accidental discharge occurs, along with the measures that SLB will implement to reduce the risk to **ALARP** and within **Acceptable Levels**.
Navigation Act 2012	This act covers international ship and seafarer safety, shipping aspects of protecting the marine environment and the actions of seafarers in Australian waters. The Act gives effect to the relevant aspects of the International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978 (**MARPOL**), the United Nations Convention on the Law of the Sea 1982 (**UNCLOS**) and the International Regulations for Preventing Collisions at Sea 1972 (**COLREGS**), among other international treaties, details of which are outlined below: • MARPOL is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. The Annexes of MARPOL that Australia is a party to are given effect to by current legislation; • UNCLOS lays down a comprehensive regime of law and order in the world's oceans and seas establishing rules governing all uses of the oceans and their resources; and • COLREGS set out the navigational rules to be followed by ships and vessels at sea to prevent collisions. These Regulations will be important in maintaining safe operating procedures to ensure collisions don't occur during the survey. In addition to the above international treaties, several Marine Orders are enacted under the Navigation Act 2012 which relate to offshore petroleum activities, including: • Marine Order Part 21: Safety and emergency arrangements; • Marine Order Part 27: Safety of navigation and radio equipment; • Marine Order Part 28: Operations standards and procedures; • Marine Order Part 30: Prevention of collisions; • Marine Order Part 58: Safe management of vessels. Since the Seismic Vessel proposed to be used for the Seismic Survey will be operating within Australian waters, the management and operation of the vessel will be subject to this Act and the associated Marine Orders. The relevant aspects of this Act and subsequent Marine Orders, along with the international treaties that provide control measures to avoid potential risks associated with this activity are discussed within **Section 8**.

Legislation	Applicability
Ozone Protection & Synthetic Greenhouse Gas Management Act 1989	This Act regulates the manufacture, importation and use of ozone depleting substances (**ODS**) which are typically used in fire-fighting equipment and refrigerants. The use of these substances is discussed within **Section 7.4** which stipulates that no ODS will be deliberately released.
Protection of the Sea (Civil Liability of Bunker Oil Pollution Damage) Act 2008	This Act establishes a liability and compensation regime to apply in cases of pollution damage following the escape of bunker oil from a ship that is not an oil tanker. This Act prescribes that ship owners are strictly liable for pollution damage resulting from the escape or discharge of bunker oil from their ships; resulting in the obligation on ships over 1,000 gross tonnages to carry insurance certificates when leaving/entering Australian ports. The Seismic Vessel undertaking the Seismic Survey will hold the necessary insurance certificates.
Protection of the Sea (Harmful Anti-fouling Systems) Act 2006	This Act was developed as part of Australia's commitment to MARPOL and the International Convention on the Control of Harmful Anti-fouling Systems on Ships and regulates the use of anti-fouling compounds and systems in Australian waters. The vessel to be used for the Seismic Survey will have an anti-fouling management regime in place that is consistent with this Act.
Protection of the Sea (Prevention of Pollution from Ships) Act 1983 Maritime Legislation Amendment (Prevention of Air Pollution from Ships) Act 2007	MARPOL includes regulations aimed at preventing both accidental pollution and pollution from routine vessel operations. Australia implements MARPOL through the Protection of the Sea (Prevention of Pollution from Ships) Act 1983 (**PSPPS Act**) and the Navigation Act 2012 (discussed above). The PSPPS Act (and the Navigation Act), along with the following Commonwealth legislation gives effect to MARPOL: • 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; and • Marine Order 98: Marine pollution prevention – anti-fouling systems. The PSPPS Act, and the associated legislation listed above have been considered as part of the impact and risk assessment detailed within **Section 7**.
Underwater Cultural Heritage Act 2018	This Act came into effect on 1 July 2019 replacing the Historic Shipwrecks Act 1976 and continues to protect Australia's shipwrecks. This Act has also been broadened to protect sunken aircraft and other types of underwater cultural heritage including Australia's Aboriginal and Torres Strait Islander Underwater Cultural Heritage in Commonwealth waters. In addition to the general protection provided to underwater heritage sites, this Act also provides for areas containing protected underwater heritage to be declared a protected zone. These may be established for a number of reasons including conservation, management or public safety. Most protected zones cover an area of around 200 hectares, although there is flexibility to declare a larger zone if necessary. The nearest underwater protected zone is over 400 km to the east of the OA.

2.2 Relevant Guidelines, Standards and Codes

Australian Ballast Water Management Requirements 2017

These requirements include legislative obligations under the Biosecurity Act 2015, and the International Convention for the Control and Management of Ships' Ballast Water and Sediments regarding the management of ballast water and ballast tank sediment when operating within Australian waters. These requirements, along with the Biosecurity Act discussed in **Table 4**, have been provided for in relation to the assessment of environmental risks associated with invasive marine species (**Section 8.1**).

Code of Environmental Practice 2008 – Australian Petroleum Production and Exploration Association (APPEA)

This Code provides guidance on ensuring that exploration and production operations are conducted using effective management in order to be sustainable within the Australian environment. This includes the need to avoid or minimise and manage impacts to the environment, focusing on four basic recommendations:

- Assess the risk to, and impacts on, the environment as an integral part of the planning process;
- Reduce the impact of operations on the environment, public health and safety to **ALARP** and to an **Acceptable Level** by using the best available technology and management practises;
- Consult with stakeholders regarding industry activities; and
- Develop and maintain a corporate culture of environmental awareness and commitment that supports the necessary management practices and technology, and their continuous improvement.

These recommendations, which effectively mirror the requirements within the Environment Regulations, have been considered when assessing the potential impacts and risks from the Seismic Survey during the development of this EP (**Sections 7** and **8**, respectively).

Convention on the Conservation of Migratory Species of Wild Animals

The Convention on the Conservation of Migratory Species of Wild Animals (known as the **Bonn Convention**) provides a global platform for the conservation and sustainable use of migratory animals and their habitats. The Bonn Convention was entered into force in 1983, with Australia being a party to the Convention since September 1991. The Bonn Convention includes obligations for parties to it, including:

- Acknowledging the importance of conserving migratory species;
- Promote, cooperate and support research relating to migratory species;
- For endangered species, endeavour to take measures to conserve the species and its habitat, prevent the adverse effects of activities that impede or prevent migration, prevent or minimise factors that endanger the species where possible, and make the taking of the species prohibited (subject to limited exceptions); and
- For species that are defined as having an 'unfavourable conservation status', endeavour to conclude agreements which would benefit and prioritise those species (Parliament of Australia, 2018).

The species of relevance from the Bonn Convention and the associated obligations are addressed under the EPBC Act. An assessment of those migratory species relevant to the Seismic Survey are outlined throughout **Section 4.5**.

Convention on Oil Pollution Preparedness, Response and Cooperation 1990

Parties to the International Convention on Oil Pollution Preparedness, Response and Co-operation (**OPRC**) are required to establish measures for dealing with pollution incidents, either nationally or in co-operation with other countries. The OPRC comprises national arrangements for responding to oil pollution incidents from ships, offshore oil facilities, seaports and oil handling facilities. The convention recognises that in the event of a pollution incident, prompt and effective action is essential.

The OPRC requires ships to carry Shipboard Oil Pollution Emergency Plans (**SOPEP**); in addition, operators of offshore units under the jurisdiction of the parties to the OPRC are required to have Oil Pollution Emergency Plans (**OPEP**), or similar arrangements which must be co-ordinated with national systems for responding promptly and effectively to oil pollution incidents. The vessel contracted to undertake the Seismic Survey will have a SOPEP in place; and in the unlikely event of a spill occurs from a vessel collision/sinking, SLB will implement the response strategy in accordance with the SOPEP, as discussed within **Section 8.3**.

Convention on Wetlands of International Importance especially as Waterfowl Habitat 1971

This convention is commonly known as the **Ramsar Convention** (due to it being signed in the Iranian town of Ramsar in 1971). The Ramsar Convention's broad aims are to halt the worldwide loss of wetlands and to conserve, through wise use and management, those that remain. This has broadened over time to cover all aspects of wetland conservation and wise use (broadly defined as maintaining the ecological character of a wetland), recognising that wetland ecosystems are important for both biodiversity conservation and the well-being of human communities (DoEE, 2018a).

The EPBC Act recognises all wetlands listed under the Ramsar Convention as matters of NES which means approvals are required for actions that will have or are likely to have a significant impact on the ecological character of a Ramsar listed wetland. An assessment of the wetlands in or near the EMBA is outlined within **Section 4.4.6**, with any potential impacts and risks from the Seismic Survey being assessed throughout **Sections 7** and **8**.

International Convention for the Regulation of Whaling

The International Convention for the Regulation of Whaling is the International Whaling Commission's founding document and was signed in 1946. Obligations under this convention include the complete protection of certain species, and the establishment of whale sanctuaries. All of the Commonwealth waters of Australia are assigned as the Australian Whale Sanctuary (**Section 4.4.5**).

International Standards of Training, Certification and Watch-keeping for Seafarers, 1978

International Convention of Standards of Training, Certification and Watch Keeping for Seafarers (**STCW Convention**), 1978, sets the mandatory minimum standards of training, certification and watchkeeping for masters, officers and watch personnel on seagoing merchant ships registered under the flag of a country party to the convention. As the survey vessels proposed to be used for the Seismic Survey will be operating within Australian waters, the masters, officers and watch personnel of the vessels will be subject to this convention. Aspects of the survey vessel operations that relate to this convention are discussed within **Sections 7** and **8**.

National Biofouling Management Guidance for the Petroleum Production and Exploration Industry 2009

This guidance document has been developed to provide useful tools for operations within the petroleum production and exploration industry to minimise the growth of biofouling on vessels, infrastructure and submersible equipment to reduce the risk of spreading marine pests around the Australian coastline. This guidance document has been utilised in determining the **Acceptable Levels** of risks associated with the Seismic Survey, and the environmental performance outcomes (**EPO**) and EPSs (**Section 8.1**).

United Nations Convention on Biological Diversity

Australia is a party to the United Nations Convention on Biological Diversity which has three main objectives which requires the conservation of biological diversity, the sustainable use of the components of biological diversity and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources (CBD, 2018).

This Convention covers a range of topics and requirements which are subsequently implemented in Australia via different means, including Australia's Biodiversity Conservation Strategy 2010-2030 which is the guiding framework for the conservation of Australia's national biodiversity to 2030. An assessment of the biological environment is outlined within **Section 4.5**, with any potential impacts and risks from the Seismic Survey being assessed throughout **Sections 7** and **8**.

United Nations Declaration on the Rights of Indigenous Peoples

The United Nations Declaration on the Rights of Indigenous Peoples was adopted by the General Assembly on 13 September 2007, with the Australian Government announcing its support on 3 April 2009. This Declaration establishes a universal framework of minimum standards for the survival, dignity and well-being of the indigenous peoples of the world and elaborates on the human rights standards and fundamental freedoms as they apply to the specific situation of indigenous peoples (United Nations, 2018). **Section 4.6.1** provides an assessment of the aboriginal heritage associated with the OA to provide an understanding of potential impacts on that heritage from the Seismic Survey.

2.3 Relevant NOPSEMA Guidance Documents

Various guidance documents prepared by NOPSEMA have been utilised through the development of this EP to ensure that it meets all the requirements of the Environment Regulations and the expectations of NOPSEMA. These documents include:

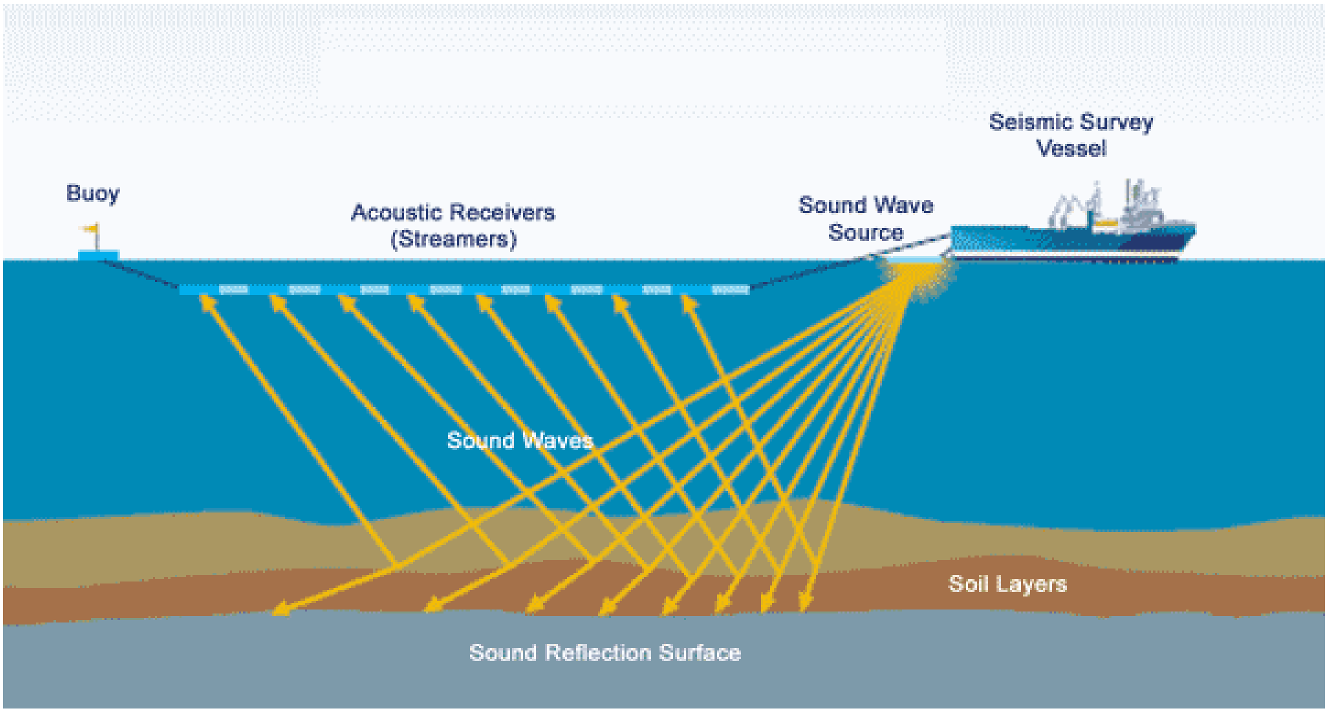
- Guidance Notes:
  - Environment plan content requirements (N-04750-GN1344 A339814, September 2020);
  - Responding to Public Comment on Environment Plans (N-04750-GN1847 A662607, September 2020);
  - Petroleum Activities and Australian Marine Parks (N-04750-GN 1785 A620236, June 2020);
  - Oil Pollution Risk Management (N-04750-GN1488 A382148, July 2021);
  - Notification and Reporting of Environmental Incidents (N-03000-GN0926 A710941, June 2020);
- Guidelines:
  - Making Submissions to NOPSEMA (N-04000-GL0225, A15266, May 2020);
  - Environment Plan Decision Making (N-04750-GL1721, A524696, June 2021);
- Policy:
  - Environment Plan Assessment (N-04750-PL1347, A662608. May 2020);
  - Financial Assurance for Petroleum Titles (N-04730-PL1780, May 2020)
- Forms:
  - Environment Plan Summary Statement (N-04750-FM1848, A662605, September 2020);
  - Titleholder Report on Public Comment (N-04750-FM1896, A662604, September 2020);
- Information Papers:
  - Consultation Requirements under the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (N-04750-IP1411, Revision No 2, December 2014);
  - Operational and Scientific Monitoring Programs (N-04700-IP1349, A343826, October 2020);
  - Acoustic Impact Evaluation and Management (N-04750-IP1765, A625748, June 2020); and
  - Requirements for Consultation and Public Comment on Petroleum Activities in Commonwealth Waters (A626193, August 2018).

3 Project Description

3.1 Survey Overview

As defined in **Section 1.1**, SLB is proposing to carry out the Bonaparte Multiclient three-dimensional (3D) Marine Seismic Survey to collect high-quality geophysical data regarding rock formations and structures beneath the seabed. SLB plans to conduct the Seismic Survey in the Bonaparte Basin within the Commonwealth waters adjacent to Western Australia (**WA**). As mentioned in **Section 1.2**, the objective of the Seismic Survey is to provide an improved subsurface image of the eastern flank of the Vulcan Sub-basin and Londonderry High which will provide an improved understanding of the subsurface. As a result, the new seismic data will provide improved confidence in mapping the subsurface geological structure to aid in the identification and de-risking of petroleum prospectively across the OA.

During the survey, a Seismic Vessel will tow a seismic source array and a series of streamers within the OA, as defined in **Section 3.2.1**. MSSs use data acquired through the use of a controlled seismic source mechanically generating a sound wave that is transmitted downwards towards and into the seabed. The sound wave source uses compressed air to create a pulse of acoustic energy. The pulse of acoustic energy travels through the water column and into the seabed where energy is reflected at different speeds and intensities depending on the sediment type and/or density of the various sedimentary layers. The reflected acoustic signals are detected by an array of sensitive hydrophones located in each streamer, which are towed behind the Seismic Vessel (**Figure 4**). These sound signals are then analysed and processed into visual images of the subsurface structure of the seabed using powerful on-board computers and software. The Seismic Vessel will be assisted by a Support Vessel, a Chase Vessel and helicopter operations.



Source: www.fishsafe.eu

Figure 4 Schematic of an MSS

A summary of the general survey programme is provided in **Table 5**. The following sections outline specific details of the Seismic Survey.

Table 5 Summary of Seismic Survey General Parameters

General Programme Parameter	Description
Location	Northern Western Australia, Offshore
Operational Area	25,827 km^2
Acquisition Area	12,000 km^2
Maximum Sail Line Length within a swath	~155 km
Sail Line Orientation	North East/South West at 159/339°; North West/South East at 26/206°
Water Depths in Acquisition Area	20 – 200 m
Timing	Q4 2022 commencement
Planned Survey Duration	190 days, including continency.

Note: The Acquisition Area covers an area greater than the proposed sail lines, and although the Acquisition Area has water depths ranging from 20 to 200 m, the shallowest depth that the seismic source will be activated is 40 m as outlined in **Section 7.1.4** below.

3.2 Survey Location

The OA is located off the coast of northern Western Australia, in the marine waters between continental Australia and Indonesia and Timor-Leste. The proposed Seismic Survey is to be undertaken in an area with a complex jurisdictional setting as shown in **Figure 1**. The southern half of the OA is located within the Australian Exclusive Economic Zone (**EEZ**) (between 12 and 200 NM from shore) and the northern half is located within the Indonesian EEZ. Importantly, the Australia-Indonesia Maritime Delimitation incorporates an area of overlapping jurisdiction which treats the seabed and water column separately in accordance with the *Perth Treaty 1997*. Within the area of overlap, the seabed and its associated resources, fall under the jurisdiction of Australia. The overlying water column (including fisheries resources) fall under the jurisdiction of Indonesia. To this end, exploration of seabed resources within the OA are wholly regulated under Australian jurisdiction.

Immediately beyond the eastern boundary of the OA, is the maritime boundary between Australia and Timor-Leste.

3.2.1 Operational Area

Regionally, the OA is located ~200 km north of Port Warrender and Kulumburu, Western Australia, and ~175 km northeast of Ashmore Island and comprises water depths in the order of 20-200 m. The OA is approximately 25,827 km^2, with approximately 50% of the total area constituting >100 m deep.

The OA includes both the Acquisition Area and a surrounding buffer that could be used for operational purposes (see **Figure 5**). The coordinates of the OA perimeter are provided in **Table 6**.

Table 6 Coordinates of the OA

Point	Longitude	Latitude
1	125° 33' 9.095" E	10° 48' 48.203" S
2	126° 10' 28.567" E	11° 6' 43.891" S
3	126° 14' 5.936" E	11° 22' 33.467" S
4	126° 3' 11.962" E	11° 28' 1.296" S
5	126° 2' 23.558" E	12° 35' 32.124" S
6	124° 32' 58.906" E	12° 34' 18.924" S
7	124° 34' 9.162" E	11° 47' 27.660" S

Note: Coordinates are in WGS84.

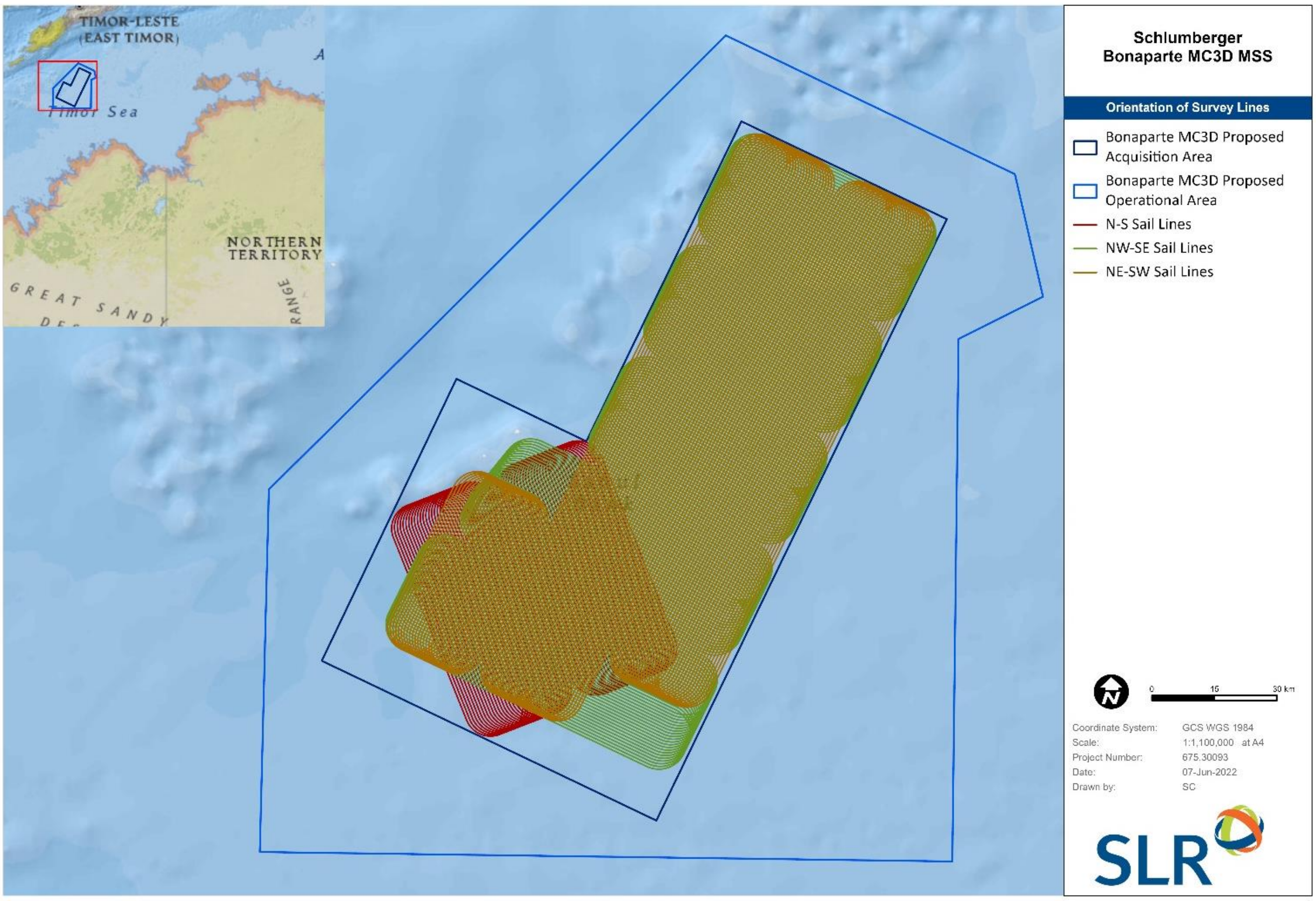


Figure 5 Location of the OA and Orientation of Survey Lines

3.2.2 Acquisition Area

The Acquisition Area is approximately 12,000 km^2, with approximately 50%, of the total area constituting depth to seabed >100 m. To support effective delivery of the Seismic Survey, seismic source testing (e.g., bubble tests) will also occur within the acquisition area.

During data acquisition, the Seismic Vessel traverses the Acquisition Area along a series of predetermined parallel lines called sail lines. Depending on the final activity specifications of the Seismic Survey, there could be between approximately 106 and 206 sail lines proposed to be acquired, with lines oriented at either 26/206° or 159/339°, respectively (**Table 5** and **Figure 5**). Continuous line acquisition will be undertaken through the Seismic Survey, which is essentially where the seismic source will remain active through the line turns as data will be acquired through these turns. This mode of acquisition results in a 'racetrack' survey pattern (**Figure 5**) and avoids having to shut down the source at the end of each line and then commencing start up procedures. As a result, this will reduce the duration of the Seismic Survey. This process is repeated until the required full-fold coverage is completed across the Acquisition Area. To this end, the area over which the seismic source will be active represents only a portion of the total OA.

3.3 Timing and Duration

The Seismic Survey may commence as early as September 2022 and will be completed before 30 June 2024. It is estimated to take between approximately 120 to 190 days to acquire 12,000 km^2, including contingency time for potential vessel or equipment down time and adverse weather conditions. Though the exact survey duration is dependent upon final activity scope, up to a maximum of 10,000 km^2 may be acquired per calendar year between 2022 and 2024. The precise timing of the survey commencement is subject to NOPSEMA's acceptance this EP, weather conditions, vessel availability, and other operational considerations. However, the survey programme and management procedures will take into account the seasonality of environmental sensitivities, wherever practicable.

To minimise survey duration, geophysical data will be acquired 24 hours a day, seven days per week utilising continuous line acquisition. When recording the data, the Seismic Vessel traverses the Acquisition Area along a series of predetermined sail lines at a speed of approximately 4-5 knots (7-9 km/h). Each survey line, with up to 12 streamers being towed behind the Seismic Vessel (also referred to herein as 'swath') is up to 155 kilometres long and could take up to approximately 32 hours to complete. Data for a pre-determined swath only needs to be acquired once unless there is a stop in data acquisition due to a marine mammal mitigation procedure. Therefore, where no infill is required, for example due to adaptive management measures, the Seismic Vessel will not need to collect data in that area again.

For completeness, this EP has been developed with consideration to all sensitivities, seasonality and receptors that could be influenced by the Seismic Survey commencing in September 2022 and extending until 30 June 2024.

3.4 The Bonaparte Basin Seismic Survey Specification

3.4.1 Acoustic Source Configuration

The proposed Seismic Survey will comprise a single Seismic Vessel towing up to twelve seismic streamers with 120 m spacings up to 8 km long, at a speed of approximately 4 – 5 knots (7-9 km/h). The acquisition parameters are provided in **Table 7**, while **Figure 6** indicates the source array proposed for the Seismic Survey.

Table 7 Acquisition Parameters

Parameter	Seismic Survey Parameters
Volume	3,000 in^3
Nominal working pressure	2,000 psi
Source depth	8 m
Vessel speed	4-5 knots
SP Interval	16.667 m
Number of streamers	12
Streamer length	Up to 8,000 m (8 km)
Spacings between streamers	120 m
Streamer depth	15 – 20 m Flat
Sail line spacing	Approximately 720 m
Full-fold Acquisition Area	Approximately 12,000 km^2
Time to traverse a single sail line	Up to approximately 32 hours
Total expected duration	190 days, including continency

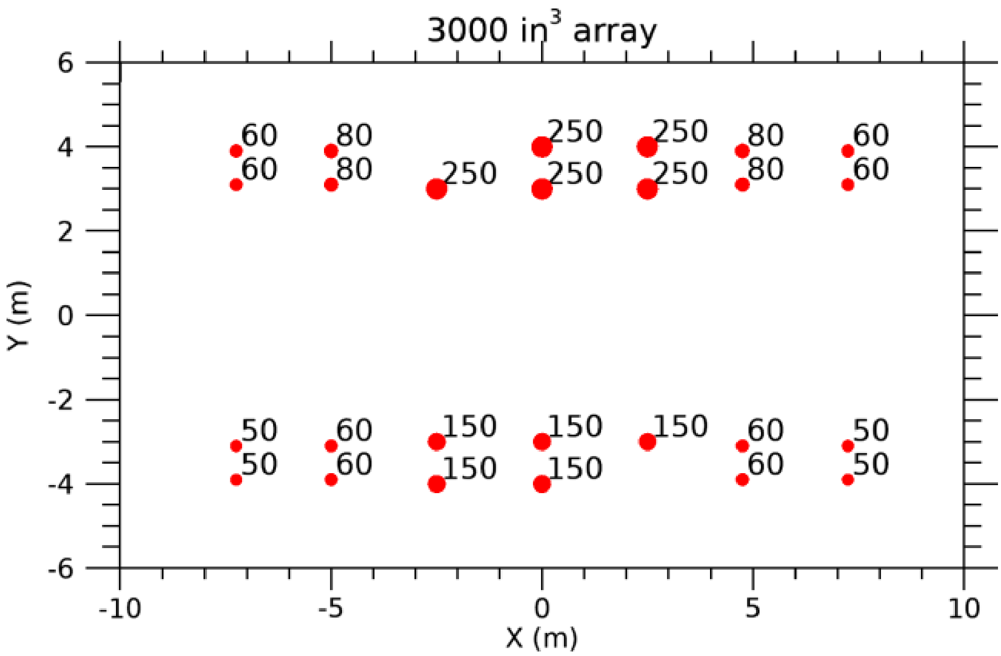


Figure 6 Seismic Source Array Proposed for the Seismic Survey

The acoustic source will have an effective volume of up to 3,000 in^3 and will comprise of two sub-arrays, with thirteen acoustic sources per sub-array (26 in total). The source is attached to a hanger by chains of a fixed length and the hanger is attached by ropes to a surface buoy for flotation. The acoustic source array will be towed approximately 555 m behind the Seismic Vessel on an umbilical line at a depth of 8 m below the sea surface.

The acoustic source comprises two high pressure chambers; an upper control chamber and a discharge chamber. High pressure air (~2,000 psi) from compressors on-board the Seismic Vessel is continuously fed to the source, forcing a piston downwards and filling the chambers with high-pressure air while the piston remains in the closed position.

The acoustic source is activated by sending an electrical pulse to a valve which opens, and the piston is forced upwards, allowing the high-pressure air in the lower chamber to discharge to the surrounding water. The discharged air forms a spherical bubble, which oscillates according to the operating pressure, the depth of operation, the water temperature and the discharge volume, ultimately forming a pressure wave. Following this discharge, the piston is forced back down to its original position by the high-pressure air in the control chamber, allowing the sequence to be repeated. The compressors are capable of re-charging the acoustic source rapidly and continuously enabling the source arrays to be fired every few seconds. The proposed firing interval for the Seismic Survey is every 16.7 m, which translates to the release of the acoustic source every ~7 seconds.

The required size of the acoustic source volumes is determined by a number of factors such as the objectives of the survey, complexity of seabed geology and the water depths of the OA and are designed to provide sufficient seismic energy to 'illuminate' the geological objective of the survey (OGP, 2011). SLB considered a number of different source volumes used in preceding surveys in the area as part of a survey design and modelling exercise in order to determine the most appropriate size to minimise impacts while achieving the objectives for the Seismic Survey. The preferred source size for illumination was an array with a volume of 3,000 in^3. This is in line with source volumes used in recent marine seismic surveys in the area and sufficient to achieve the goals of the survey and reach the deep targets that SLB is trying to assess in the deep waters. In summary, the selected size was found to be sufficient for the required data resolution and achieving objectives, while minimizing impacts.

Acoustic arrays are designed to direct most of the sound energy vertically downwards, although some residual energy dissipates horizontally into the surrounding water. The amplitude of sound waves generally declines with lateral distance from the acoustic source, and the weakening of the signal with distance (attenuation) is frequency dependent, with stronger attenuation occurring at higher frequencies. The decay of sound in the sea is dependent on the local environmental conditions such as water temperature, water depth, seabed characteristics and depth at which the acoustic signal is generated.

Acoustic arrays used by the oil and gas industry are designed to emit most of their energy at low frequencies, typically ranging between 10 – 300 Hz with declining energy at frequencies above 200 Hz (APPEA 2015, Popper *et al.*, 2014). Array source sound pressure levels can range from ~241 – 265 dB peak-to-peak at one metre when measured relative to a reference pressure of one micro-Pascal (re 1 µPa m_{p-p}) (Richardson *et al.*, 1995). The overall source level amplitude of a system depends on how many elements are in each array and interaction between elements.

Peak-to-peak pressure is the primary output from the acoustic source (measured by pressure units of bar/m) caused by the expanding high pressure at release, which is measured at a stated reference point (usually 1 m from the source). Using standardised measuring protocols (peak-to-peak) and a reference point enables a comparison of the pressure produced by different acoustic sources. While the units for source level pressure are often reported in bar/m these values have little biological/environmental meaning and sound levels in the water emanating from an acoustic source involved with an MSS are more often presented as dB, calculated from peak-to-peak pressure measurements.

A detailed description of the modelled source signature determined to represent the seismic array is provided in **Section 7.2.1**, including source levels outputs with various directivity. The modelled source signature was characterised by the following maximum levels:

- Peak sound pressure level (**PK**) –256 dB re 1 µPa @ 1 m;
- Sound Exposure Level (**SEL**) of 231 dB re 1 µPa^2.s @ 1 m.

The source signature modelling enabled conversion between the different parameters (i.e. SEL vs PK), in accordance with the different metrics which define the threshold criteria for sensitive receptors. Using this information, the sound fields from single pulses and accumulated SEL are calculated and used to inform the assessment of potential effects (**Section 7.2**). This source signature simulation, including predictive source levels and directivity, was conducted using JASCOs Airgun Array Source Modeland performed by JASCO (**Appendix A**).

3.4.2 Streamer Configuration

A streamer array and associated tail buoys are towed behind the Seismic Vessel (**Figure 4**). When the acoustic source is activated, hydrophones within the streamers detect the low-level sound waves that are reflected back up from the geological formations below the seabed. The hydrophones convert the reflected pressure signals into electrical signals that are digitised and transmitted along the streamers to the recording system on-board the Seismic Vessel. The streamer array will comprise of up to 12 individual streamers, each spaced 120 m apart and will have a tail buoy on the end of each streamer to mark its location (**Figure 7**). The streamers will be up to 8km long which allow for the time delay to adequately capture signals reflected from deep, target subsurface lithologies.

Both the seismic source and the streamers are towed beneath the surface (**Figure 4**). Towing the streamers underwater reduces the potential for acoustic interference from the sea surface. The deeper a streamer is towed, the lower the background surface noise recorded; however, this can also result in a narrower bandwidth of received data. Typical streamer operating depths range from 4 – 5 m for shallow, high-resolution surveys in relatively good weather but can be 8 – 12 m for deeper penetration below the seabed and lower frequency targets in more open waters. Streamer depth is controlled from the Seismic Vessel utilising units called ‘birds’, which provide an accuracy of +/-1 m for the required operating depth (OGP, 2011). Electronically controlled ‘wings’ on the birds pivot in response to changes in pressure (depth) as detected by a pressure transducer inside each bird, automatically pivoting the wings up or down if the streamers pulls too deep or shallow (OGP, 2011).

The tail buoy (**Figure 7**) is a large hydrodynamically-shaped buoy that is towed at the rear end of each streamer where it serves several functions:

- Keeping the streamer straight;
- Keeping the rear of the streamer up/afloat;
- Providing a visual reference for the end of each streamer for the vessel and survey crew (which allows the crew to determine that correct coverage is being met); and

- Holding a flag, radar reflector and flashing light and an Automated Identification System (**AIS**) transponder to allow other vessels to locate the rear of the streamers.

Each of the 12 streamers used within the Seismic Survey will be towed with a tail buoy for each comprising a radar reflector and flashing light to mark the end of the array. The tail buoy will also be fitted with marine fauna deflectors on the front, ensure marine fauna, in particular marine turtles, are not injured or trapped within the tail buoy.

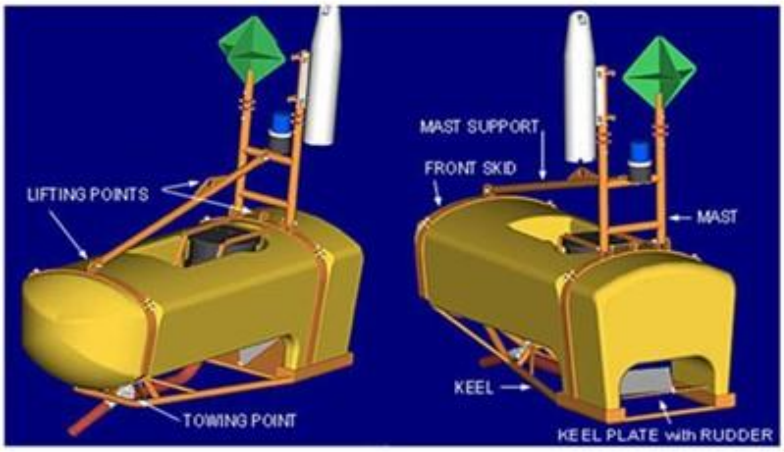


Figure 7 Example of a Seismic Streamer Tail Buoy, with Light, Radar Reflector, and AIS Transponder

3.4.3 Sail Lines, Line Turns and Infill Lines

The proposed Seismic Survey will acquire data along a series of adjacent and parallel lines, termed sail lines. As the vessel manoeuvres from a completed sail line to reach the adjacent, the seismic source will remain active, and data will continue to be acquired forming a 'racetrack' survey pattern. As indicated in **Section 3.2.2**, this approach is defined as continuous line acquisitions and these manoeuvres between adjacent and parallel sail lines constitute line-turns. The number and density of sail lines (termed the line plan) and acquisition geometry are carefully designed to allow suitable coverage of target areas within the Acquisition Area, whilst optimising the efficiency of the survey.

Between approximately 106 and 206 sail lines are proposed to be acquired for the Seismic Survey, depending on the final activity specifications, with lines oriented at either 26/206° or 159/339°, respectively. Sail lines will be spaced at 720 m intervals, to provide full-fold coverage of seismic data resulting in a total Acquisition Area of 12,000km² (**Figure 5**). During data acquisition, the Seismic Vessel will travel at approximately 4 – 5 knots (7 – 9 km/h), and with sail line lengths of approximately 140 km, the survey of each line will take approximately 32 hours (assuming no delays, shut-downs or deviations are required).

The Seismic Vessel has limited ability to manoeuvre whilst towing the streamer and acoustic array, which is mitigated through the presence of a Support Vessel and Chase Vessel for the duration of the Seismic Survey to ensure the area ahead of the survey vessel is clear and engage with any fishers in the area.

During the Seismic Survey, there may be situations where the seismic source must be shut down. For example, in response to a marine mammal entering the shut-down zone, such as a pygmy blue whale sighting (see **Section 7.2.5**). In the event the shutdown procedures are enacted, the Seismic Vessel will return to acquire the un-surveyed portion of the sail line at a later time. These return acquisitions are termed infill lines.

It is anticipated that in most cases any infill lines required would be completed on a different day, with a 24-hr delay or more, in an effort to avoid standby time that would be required to mitigate cumulative effects arising from infill lines completed in quick succession.

Prior to commencing the survey or after a break in the source being active, a soft start will be undertaken which consists of gradually increasing the source's power, starting with the lowest capacity acoustic source, over a period of at least 20 minutes and no more than 40 minutes. The operational source capacity will not be exceeded during the soft start period.

For the purpose of this assessment, a worst-case scenario is assessed whereby infill lines are completed as soon as possible, in order to identify the increased zones of impact that would be realised under these conditions.

Sail lines, line turns and infill lines will all be constrained to the Acquisition Area, as shown in **Figure 5**. The Acquisition Area and associated buffer which constitute the OA are bounded by the coordinates provided in **Table 6**.

3.4.4 Project Vessels

3.4.4.1 Seismic Survey Vessel

The selection of the Seismic Vessel to undertake the Seismic Survey has not yet been finalised so specific vessel details cannot be provided. However, for the purpose of this application and the risk assessment completed throughout this EP, specifications of a typical Seismic Vessel are provided in **Table 8**. These specifications are considered broadly representative of the Seismic Vessel that will be contracted and used by SLB. Likewise, the Support Vessel and Chase Vessel provider(s) have not been contracted and, therefore, the same information limitations apply. The specifications of a typical Seismic Vessel, Support Vessel and Chase Vessel that is capable of operating in the Bonaparte Basin is provided in **Table 8** and discussed further in **Section 3.4.4.2**.

Table 8 Typical Specifications of the Seismic Vessel, Support Vessel and Chase Vessel

Specification	Seismic Survey Vessel	Support/Chase Vessel
Length	108.3 m	64 m
Width	28 m	16 m
Draught (max)	7.5 m	5.4 m
Operational speed	4 – 5 knots	5 – 10 knots
Double hull	No	No
Accommodation	Up to 69 persons	Up to 54 persons
Fuel type	Marine Gas Oil (**MGO**)	MGO
Fuel capacity (total)	2,500 m^3 (95% full)	999 m^3
Largest fuel tank	257.4 m^3	133 m^3
Fuel consumption	28 m^3/day	4 m^3/day
Incineration	65 L sludge/hr	N/A
Treated sewage	15 m^3/day max	4.2 m^3/day max
Bilge water	2.5 m^3/hr	0.5 m^3/hr

3.4.4.2 Support Vessel and Chase Vessel

During the survey there will be one Support Vessel and one Chase Vessel accompanying the Seismic Vessel at all times. The role of the Support Vessel and Chase Vessel is to manage any possible interactions between the Seismic Vessel, the seismic array (acoustic source and streamers), and other vessels, receptors or activities occurring in the area. The engagement process and advanced notification has and will be implemented to ensure all users of the area are aware of the survey. Effective communication of the survey's location and proposed activities will continue throughout the Seismic Survey to help to reduce potential conflict between the survey and other marine users at all times.

Both the Support Vessel and Chase Vessel will be positioned at a safe distance from the Seismic Vessel and towed seismic array and will maintain 24-hour watch, using visual and electronic means, for other vessels or activities which might be approaching or in the path of the Seismic Vessel. The Support Vessel will undertake refuelling operations for the Seismic Vessel (**Section 3.4.5**) and may also re-supply the Seismic Vessel during the Seismic Survey; however, it is likely a smaller vessel will fill this role providing fresh stores every 2 – 3 weeks.

Importantly, during acquisition in the blue whale migratory BIA and 17 km buffer, two Marine Mammal Observers (**MMOs**) will be stationed on the Chase Vessel, which will travel 3 km ahead of the Seismic Vessel and will conduct visual surveillance for marine mammals during the daylight hours (**Section 7.1.4** and **7.2.5**). It is noted that the requirement for being 3 km ahead of the Seismic Vessel is defined as an 180° arc ahead of the Seismic Vessel, noting that the Chase Vessel should focus on the portion of the arc closest to the blue whale migratory BIA and buffer when relevant. Additional control measures will be implemented when operating in the blue whale migratory BIA and buffer zone, which are discussed further in **Section 7.2.5**.

In addition to the Support Vessel and Chase Vessel, helicopters may be utilised to transport equipment, supplies and crew to and from the Seismic Vessel during the Seismic Survey, and also provide emergency medical evacuation, if required.

At the time of submission of this EP, the specific Support Vessel and Chase Vessel have not been contracted. However, both vessels will be smaller than the Seismic Vessel, of suitable class for safely operating in the offshore environment comprising the OA, be crewed by competent persons, have all required operational procedures and systems in-place, and carry all required communication and safety equipment. SLB will undertake a vessel audit before commencement of the Seismic Survey.

3.4.5 Refuelling Operations & Crew Changes

All crew changes and refuelling (bunkering) for the survey vessels will be undertaken at-sea. To reduce the risk of a fuel spill event, at-sea refuelling operations will occur within the OA and in accordance with the control measures outlined in **Section 8.4** and **Section 8.5**.

To reduce the number of transfers required, the vessels will take on fresh provisions for the next swing offshore during crew changes and bunkering. These provisions will not last the duration of each swing, so a vessel will visit the Seismic Vessel every 2 – 3 weeks to deliver fresh provisions given they would perish and not last the duration if all fresh supplies were taken at once. Crew change, and bunkering operations will take place every five weeks.

3.4.6 Helicopter

In the event of an emergency, helicopters may be used to support recovery and transfer of crew. Helicopters are predicted to operate out of the Kalumburu Helipad.

4 Existing Environment

This section describes the key physical, biological, socio-economic and cultural characteristics of the existing environment and the sensitivities and receptors that may be affected, both from planned activities and unplanned events associated with the Seismic Survey. Consequently, the description of the existing environment applies to two areas:

- The OA, as presented in **Figure 1** and described in **Section 3.2.1**.
- The EMBA, as shown in **Figure 8** and further described in **Section 4.1**.

4.1 Environment that May Be Affected

Most planned activities and unplanned events associated with the Seismic Survey may affect the environment up to a few hundred metres from the source location. However, a significant unplanned event, such as a vessel hydrocarbon spill, has the potential to impact the existing environment substantially beyond that seen through impacts from planned activities. Therefore, the EMBA was derived utilising stochastic hydrocarbon dispersion and fate modelling which is described in detail within **Section 8.3**.

SLB commissioned Oceanum and Calypso Science to model the oceanic dispersal and beaching potential of a hydrocarbon spill from the unlikely situation of a spill event during the proposed Seismic Survey (**Section 8.3**, **Appendix B**). This modelling simulated the occurrence of 100 realistic spill events of 1,000 m^3 of marine gas oil (**MGO**) from three locations within the OA, randomly distributed over the previous decade. An output of this modelling was the maximum extent at which various environmental thresholds were reached, including for floating, entrained, dissolved and shoreline accumulations of hydrocarbons.

The extent of the EMBA (**Figure 8**) was based on a combination of the maximum extent of the spill trajectory at which entrained hydrocarbons were above the low threshold from each of the three modelled release locations. Utilising the maximum extent from all three spill locations results in a worst-case scenario for the spatial extent of impacts from the Seismic Survey.

Acoustic modelling shows that noise levels exceeding predefined impact thresholds do not exceed the boundary of the unplanned vessel hydrocarbon spill EMBA detailed above. Therefore, the unplanned hydrocarbon EMBA represents the overall EMBA for the activities associated with the proposed Seismic Survey.

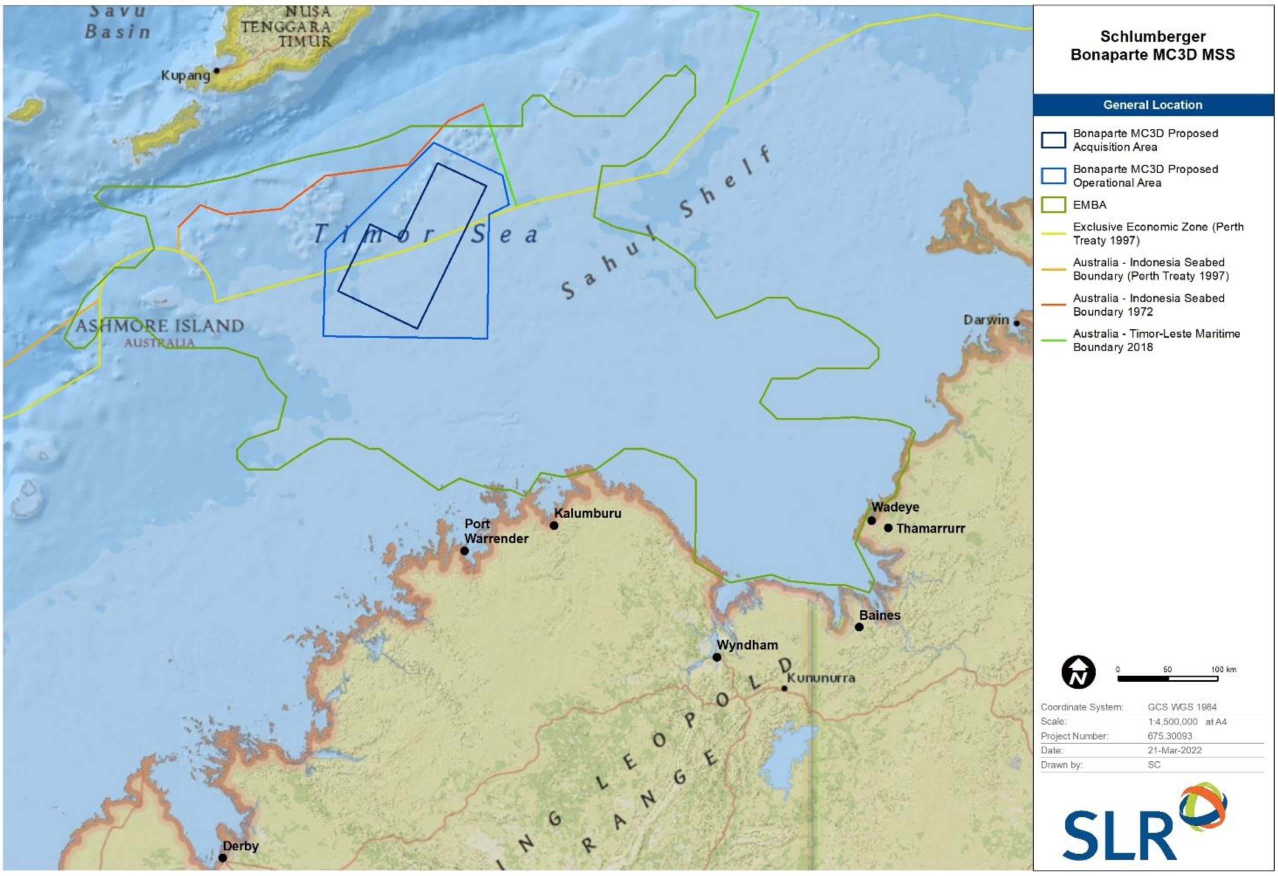


Figure 8 EMBA Associated with the proposed Seismic Survey

4.1.1 Environmental Values and Sensitivities

As required by Regulation 13(3) of the Environment Regulations, a comprehensive description of the environmental values and key sensitivities within the EMBA has been provided within the following sections. These sections have been guided by the results of a search utilising the Protected Matters Search Tool from the Department of Agriculture, Water and the Environment (**DAWE**). The full results from this search are found within **Appendix C**.

4.2 Regional Environment

4.2.1 Marine Regions

In 2008, the Australian Government conducted marine bioregional planning to facilitate consistent and improved decision-making processes under the EPBC Act. Six discrete marine regions were identified and designated through the marine bioregional planning process. Marine bioregional plans have been developed for four of the six bioregions and describe the marine environment and conservation values of each region, set out broad biodiversity objectives, identify regional priorities and outline strategies and actions to address these priorities. The plans are intended to support ecologically sustainable use of ocean resources by marine-based industries while conserving a healthy and resilient marine environment.

The OA and EMBA are located within the North-west Marine Region (**NWMR**); in addition, the EMBA also overlaps with the North Marine Region (**NMR**) as shown in **Figure 9**.

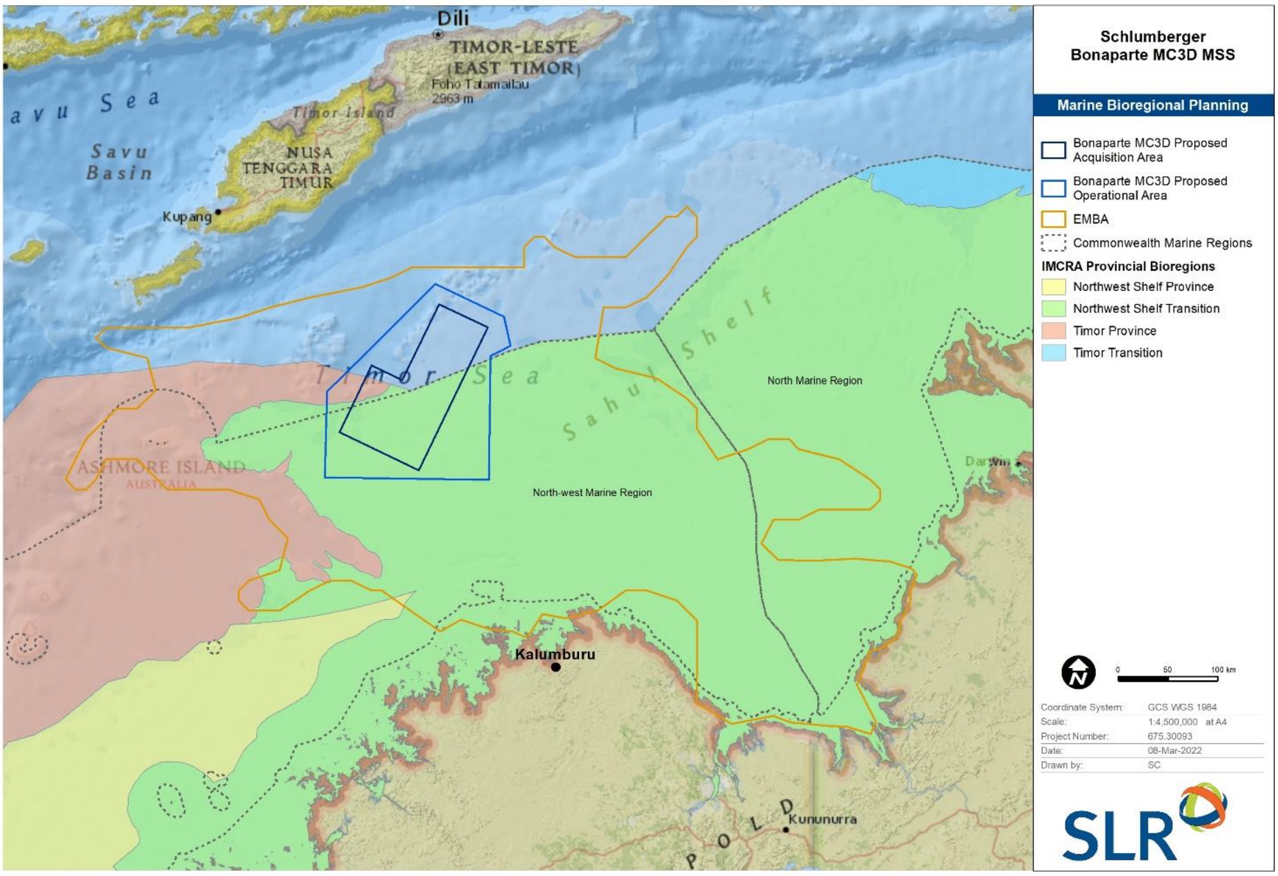


Figure 9 Marine Bioregional Planning in relation to the EMBA

4.2.1.1 North-west Marine Region

The NWMR comprises Commonwealth waters extending from the border of WA and Northern Territories (**NT**) to Kalbarri, south of Shark Bay. The region includes extensive areas of continental shelf and continental slope, highly variable tidal regions and high cyclone incidence. The NWMR is characterised by shallow-water tropical marine ecosystems with high species richness, due in part to the interaction between seafloor features and the prevailing currents of the region and the diversity of habitat available. Hard habitats such as the limestone pavements of the Northwest Shelf and pinnacles and reefs on the edge of the shelves support a high diversity of benthic filter feeders and producers. Soft-bottom substrates support infaunal communities in the Joseph Bonaparte Gulf (**JBG**) and deep sessile communities of filter and deposit feeders in the abyssal plains. The region is also home to globally significant populations of internationally threatened species and protected species established under the EPBC Act, including cetaceans, dugong, marine reptiles, seabirds, shorebirds, sharks, sawfish and Syngnathidae.

Key physical features of the marine region include (DSEWPC, 2012a):

- Extensive areas of continental shelf and slope, plateaux and terraces including the Northwest and Sahul shelfs, the Exmouth and Scott plateaux, the Wallaby Saddle and the Rowley Terrace;
- The narrowest continental shelf on Australia's coastal margin, which occurs near Northwest Cape where the shelf is just 7 km wide;
- Coralline algal reefs, and carbonate pinnacles and shoals in the far north of the region;
- Coral reefs including Ashmore, Hibernia, Scott, Seringapatam, Ningaloo and the Rowley Shoals, all of which have a high diversity of corals and associated fish and other species of both commercial and conservation importance;
- The JBG, a muddy basin with sparse coverage of sessile filter-feeding organisms and mobile invertebrates;
- A number of major canyons on the continental slope that act as conduits for sediment and nutrient transport, including Cape Range, Cloates, Carnarvon and Swan canyons;
- Two areas of abyssal plain (Cuvier and Argo) with depths in excess of 5,000 m; and
- The Indonesian Throughflow (**ITF**), a low-salinity water mass that is one of the major elements of the global transfer of heat and water between oceans and which plays a key role in initiating the Leeuwin Currents.

4.2.1.2 North Marine Region

The NMR comprises Commonwealth waters from west Cape York Peninsula to the WA – NT border. The area includes tropical waters of the Gulf of Carpentaria, Arafura Sea and the Timor Sea and abuts the coastal waters of Queensland and NT. The NMR is known for its high diversity of tropical species but relatively low endemism. The NMR is increasingly recognised as an area of global conservation significance for marine species and as an important aggregation area and stopover habitat for migratory birds, where waters provide important bird, marine turtle and dugong breeding, feeding and nursery sites.

Key physical features of the NMR within proximity to the OA and EMBA include (DSEWPC, 2012b):

- A wide continental shelf with water depths generally less than 70 m, although water depths range from approximately 10 m to a maximum known depth of 357 m;
- The Van Diemen Rise, characterised by complex geomorphology with features including shelves, shoals, banks, terraces and valleys like the Malita Shelf Valley, which provides a significant connection between the JBG and the Timor Trough;
- To the north of the NMR, a series of shallow canyons approximately 80–100 m deep and 20 km wide that lead into the Arafura Depression, which consists mainly of calcium carbonate–based sediments (e.g. carbonate sand and subfossil shell fragments);
- Numerous limestone pinnacles up to tens of kms in length and width, which lie within the Bonaparte Basin;
- The Arafura Shelf, an area of continental shelf up to 350 km wide and mostly 50–80 m deep that is characterised by sea-floor features such as canyons, terraces, the Arafura Sill and the Arafura Depression;
- Currents driven largely by strong winds and tides, with only minor influences from oceanographic currents such as the IFT and the South Equatorial Current; and
- Complex weather cycles and a tropical monsoonal climate, with high temperatures, heavy seasonal yet variable rainfall and cyclones, alternated with extended rain-free periods.

4.2.2 Provincial Bioregions

The Integrated Marine and Coastal Regionalisation of Australia is a biogeographic regionalization of Australia's marine jurisdiction based on spatial patterns in the benthic and pelagic environment and at scales appropriate to support effective marine planning. Provincial bioregions are principally based on the broad-scale distribution of demersal fish.

As seen in **Figure 9**, the OA overlaps the Northwest Shelf Transition. Additionally, the EMBA overlaps the Northwest Shelf Province and Timor Province. A brief description of these three provinces is contained in the following sections.

4.2.2.1 Northwest Shelf Province

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

- Located mostly on the continental shelf between Northwest Cape and Cape Bougainville;
- Water depths range between 0 – 200 m;
- Dynamic oceanographic environment, influenced by strong tides, cyclonic storms, long-period swells and internal tides. Warm, oligotrophic waters derived from the ITF; and
- The biological communities include diverse benthic and pelagic fish communities associated with different depth ranges, seabird breeding sites and cetacean (humpback whale) migration route.

4.2.2.2 Northwest Shelf Transition

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

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

4.2.2.3 Timor Province

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

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

4.3 Physical Environment

4.3.1 Meteorology

The region experiences monsoonal climate patterns comprising two distinct seasons, the Northwest Monsoon or “wet season” (late October to mid-March) and the Southeast Monsoon or “dry season” (May to mid-October). The Northwest Monsoon is characterised by high cloud cover, high temperatures and regular and high rainfall, particularly over coastal areas and during cyclones. Conversely, the Southeast Monsoon originates from the Southern Hemisphere high-pressure belt and is relatively dry and cool (DSEWPC, 2012a).

The high incidence of cyclones within the region can result in severe storms, characterised by gale force winds and a rapid rise in water levels. These can generate large swell and storm surges. Tropical cyclones usually form in an active monsoon trough, between December and April (BoM, 2022a). On average, about five cyclones occur each year in the NWMR, two of which make landfall and one of which is severe (Category 3 or higher). The chance of a severe cyclone occurring is highest in March and April (BoM, 2022a).

The Kalumburu, Truscott and Troughton Island weather stations are located within the nearshore and marine environment of the NWMR, providing an overview of local climatic conditions. A summary of the seasonal ranges in mean temperature, rainfall and wind speed observations are provided in **Table 9.**

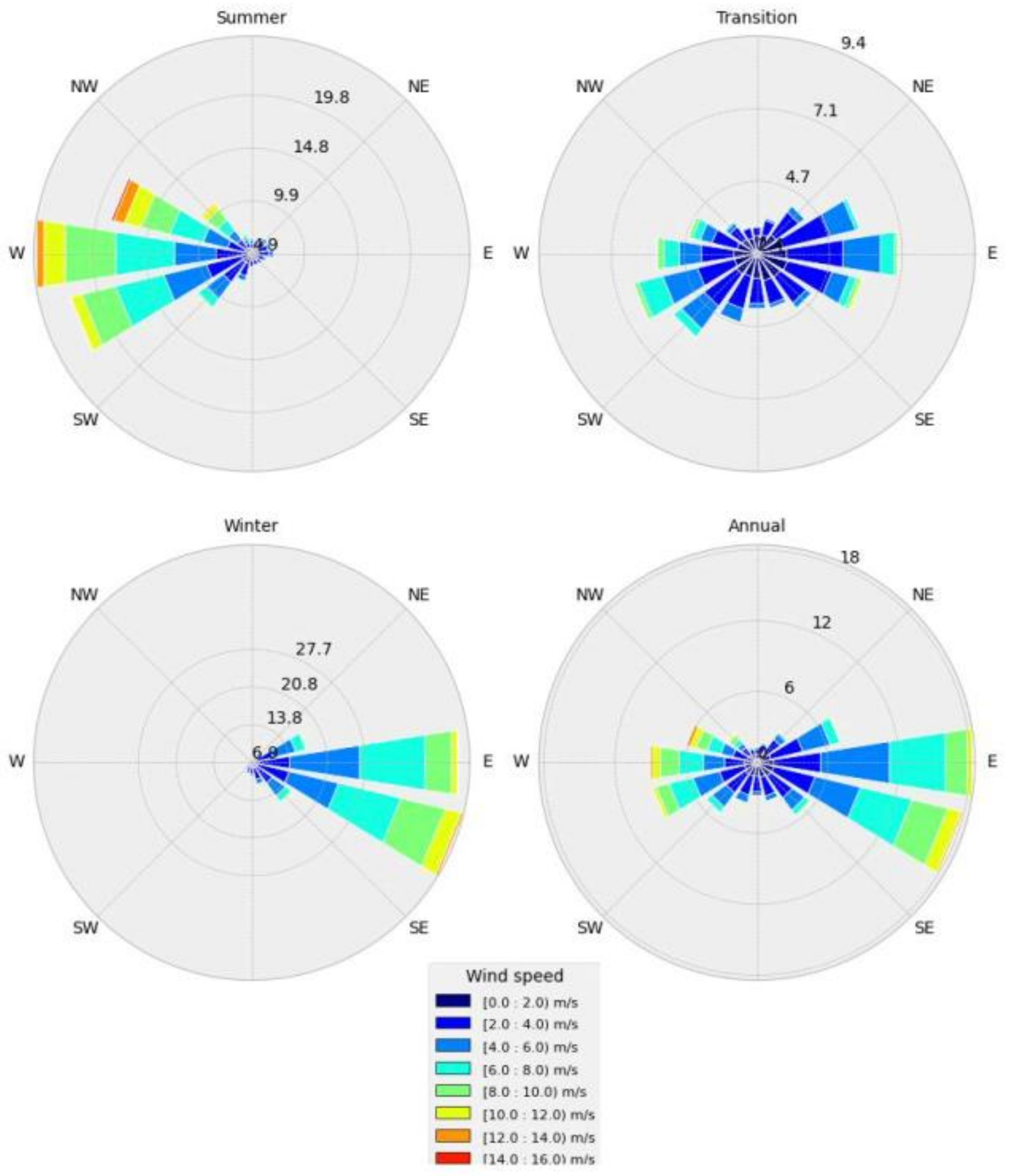
Table 9 Seasonal Mean Temperature, Rainfall and Wind Speed Ranges

Weather Station	Distance from OA	Season	Temperature (° C)	Monthly Rainfall (mm)	Wind Speed (km/hr)
Kalumburu ID 001019	300 + km SSE	Wet	21.2 – 37.3	36.1 – 336.8	8.0 – 19.2
		Dry	13.9 – 36.0	0.3 – 35.7	9.5 – 21.5
Truscott Airbase ID 001020	200 + km SSE	Wet	32.2 – 35.2	18.3 – 340.9	NA
		Dry	30.4 – 33.5	0.3 – 67.6	NA
Troughton Island ID 001007	200 + km SSE	Wet	26.3 – 33.1	10.8 – 278.6	13.7 – 22.6
		Dry	22.3 – 31.9	0.3 – 37.3	11.9 – 22.5

Source: All data obtained via BoM (Climate Data Online), (BoM, 2022b) accessed 26 January 2022. Wind Speed ranges include both 9AM and 3PM observations.

4.3.2 Wind

High resolution surface wind data collected from 2008 to 2017 (inclusive), across the OA, derived from the European Centre for Medium range Weather Forecasting (ECMWF, 2019) were hindcast for the purpose of facilitating Oil Spill Modelling (Calypso Science, 2022). **Figure 10** illustrates the seasonal and annual wind rose distributions across the monitoring period, which clearly indicate a seasonal reversal in prevailing wind direction and speed whereby moderate eastern winds dominate the region throughout summer and strong westerly winds prevail in winter. Under extreme cyclone conditions, winds can reach 180 km/h (Condie *et al*., 2006).



Note: The wind directional convention is 'coming from'

Figure 10 Annual and Seasonal Wind Roses at the Centre of the OA, from Hindcast Data 2008-2017

4.3.3 Air Quality

There is no publicly available data on air quality within the proposed OA. However, given the distance from land and limited development within the OA, air quality is expected to be relatively high. Potential sources of air pollution include those associated with anthropogenic emissions generated by shipping activity and oil and gas operations. These are considered to be localised in relation to the regional setting.

4.3.4 Oceanography

4.3.4.1 Currents

Three oceanic currents dominate circulation in the offshore waters between northwest WA and Indonesia: the ITF, the Holloway Current and the Leeuwin Current. The ITF influences the Timor Sea region, transporting warm, low saline waters from the Pacific Ocean into the Indian Ocean. The strength of the ITF is seasonal; it is weakened during the wet season when the strong south-westerly winds cause intermittent reversals of the currents (Brewer *et al*., 2007). The strengthening of the ITF in the dry season coincides with the development of the prevailing south-westerly flowing Holloway Current, which transports waters from the Banda and Arafura seas and the Gulf of Carpentaria southwards along the shelf (DEWHA, 2008b). The Holloway current is a surface current that flows parallel to the coastline and provides a conduit to transport ITF waters from Norther Australia into the Leeuwin current (Bahmanpour *et al*., n.d.). The region is also impacted by El Nino Southern Oscillation cycles, with weakened ITF and a lower incidence of tropical cyclones under El Nino conditions (Condie *et al*., 2006).

Hindcast current conditions produced by Calypso Science (2022) across the OA are generally reflective of changes in surface winds, with the maximum current speed observed during winter when strong southeasterly winds dominate the region. Maximum current speeds reported through the modelling ranged between 0.4 and 0.7 m/s across both summer and winter. Under extreme cyclone conditions, ocean currents can exceed 3 m/s (Condie *et al*., 2006).

In the southeast portion of the EMBA, circulation is influenced primarily by large tidal currents and less by ocean currents. Here, circulation occurs in a clockwise direction and current speeds increase towards the shoreline and become increasingly directed longshore.

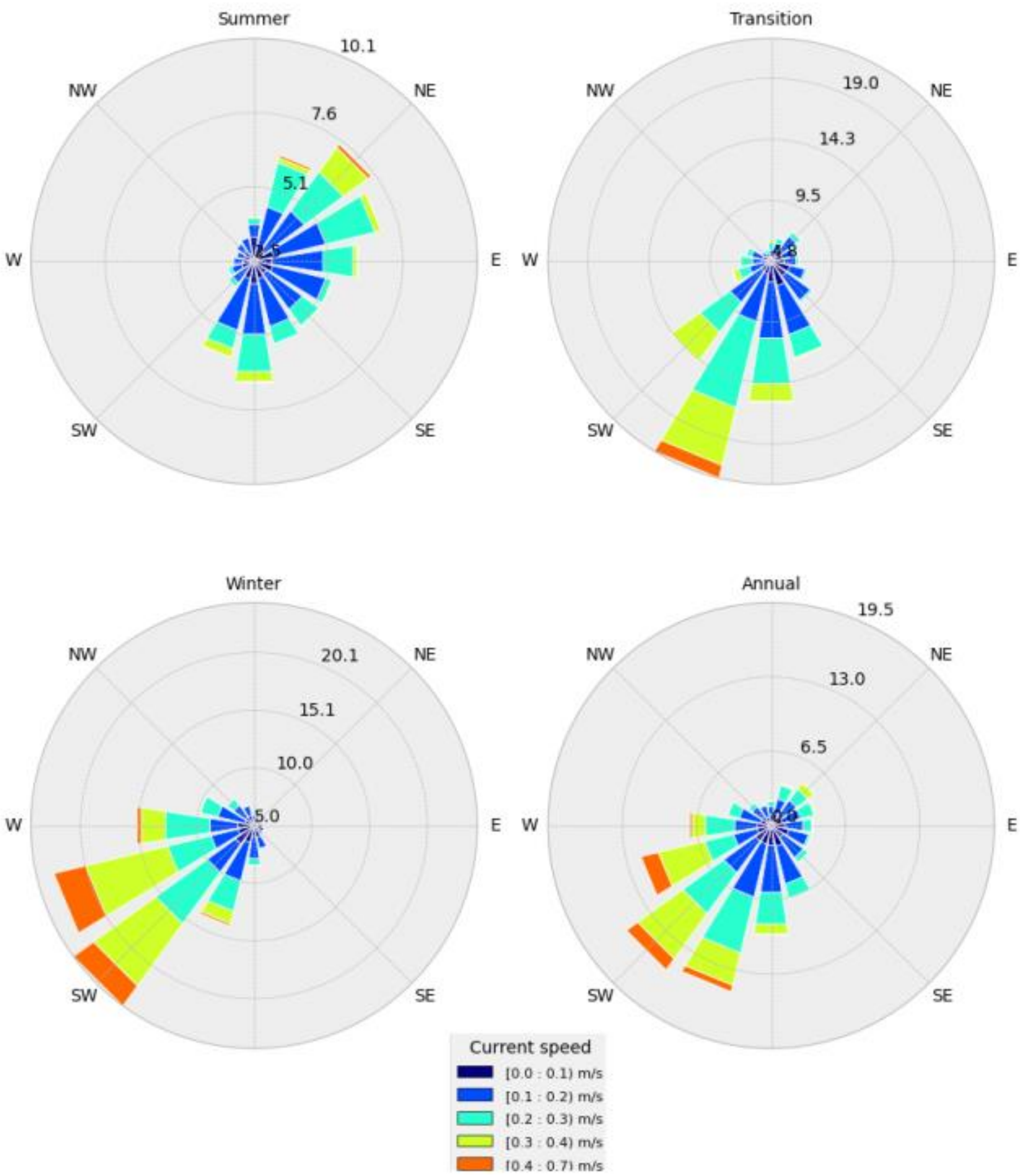
4.3.4.2 Tides

The North-west Marine Region has some of the largest tides along a coastline adjoining an open ocean in the world (DEWHA, 2008b). Tides increase in amplitude from south to north, corresponding with the increasing width of the shelf (Holloway, 1983). Tides within the OA and broader EMBA are semi-diurnal, comprising of two high tides and two low tides per day, with well-developed spring to neap tidal variation (DSEWPC, 2012a). Within the EMBA, tides are expected to range from 2 -3 m offshore (micro-tidal) rising to 3 – 4 inshore (meso-tidal) with the exception of the area overlapping the JBG, which is subject to the highest tidal range in the region. Here, tidal range can reach up to 7 – 8 m during the spring tide (CSIRO, 2005).

The combination of large tides and strong stratification also generates large internal tides over the upper slope. A shock forms on the leading face of the internal tide and propagates onshore as it dissipates over the outer shelf (Holloway, 1984 and 1987). These tides generate internal waves, further described in **Section 4.3.4.3**.

4.3.4.3 Waves

Surface waves may comprise locally generated wind waves or distant generated swell waves. Locally generated wind waves of the North-West Shelf are characterized by low mean heights and smaller periods (Hayes *et al*., 2005). Modelled wave conditions generated from surface wind speed measurements collected for the period 1997 – 2000, inclusive, indicate a mean wave height of 1 – 2 m with mean periods of 6 -8 seconds across the OA (Hayes *et al*., 2005). **Figure 11** illustrates the seasonal and annual rose plots for the distribution of surface currents (tidal and non-tidal) at the centre of the OA, based on hindcast data from 2008-2017. The roses clearly indicate a seasonal reversal in prevailing current direction whereby north to southeasterly currents dominate the region throughout summer and south-westerly currents prevail in winter.



Note: The current directional convention is 'going to'.

Figure 11 Annual and Seasonal Current Roses for the Sea Surface (Tidal and Non-tidal) at the Centre of the OA, from Hindcast Data 2008-2017

In general, mean sea swells are larger during the dry winter season than the summer wet season, as a result of the strong easterly wind-generated seas and larger winter swell from the Southern and Indian Oceans. Occasional monsoonal storms and cyclones can result in much larges waves and swell. Extreme winds associated with cyclones can generate maximum wave heights up to 21 m from any direction (RPS Metocean, 2008).

Regionally significant features also include the occurrence of internal waves, generated by the interaction between internal waves and seafloor topography. Internal tides occur at the delineation between water bodies with marked differences in density, such as at the thermocline. When water moving along the thermocline as a result of the internal tide intersects topographic features associated with significant changes in water depth, such as a continental shelf break, internal waves are generated. Internal waves are large in amplitude, reaching up to 75 m in height, and encourage vertical mixing (DEWHA, 2008b; Condie *et al*., 2006).

4.3.4.4 Thermoclines and Sea Surface Temperature

Sea temperature in the central Timor Sea typically range between 26 ^{o} and 30^{o} C at the surface, decreasing to 22^{o} and 25^{o} C at the seafloor. The sup-tropical water temperatures in the region are largely influenced by the ITF and a highly pronounced thermocline which is controlled by the ITF (Brewer *et al*., 2007). During the Northwest Monsoon, a thermocline flow of relatively cool water dominates resulting in the tropical Indian Ocean being cooled rather than warmed.

Water quality monitoring at the Montara Venture reported surface water temperatures ranging from 28.0^{o} to 28.7^{o} C, with a slight reduction of <1^{o} C at 20 m depth. Salinity of surface waters were consistently reported around 33.9 PSU, with low variability (Jacobs, 2017). This is broadly consistent with modelled seawater salinity profiles generated for the Bonaparte Basin, which indicate that there is little variation in salinity through the water column, monthly, or seasonally (RPS, 2011).

4.3.4.5 Water Quality

Water quality within the NWMR is regulated by the ITF, a low-salinity water mass that plays a key role in initiating the Leeuwin Current (DSEWPC, 2012a; **Section 4.3.4.1**) and brings in oligotrophic (low in nutrients) waters from the western Pacific Ocean through to the Indian Ocean (DEWHA, 2008b).

Localised elevations in nutrient conditions occur consistent with local and regional upwelling activity, typically associated with the seasonal weakening of the Leeuwin Current and where seabed topographic features force the surrounding deeper, cooler, nutrient rich waters to the surface (DEWHA, 2008b). Upwelling of nutrient-rich waters may increase phytoplankton productivity in the photic zone, which may in-turn increase local turbidity (Semeniuk *et al*., 1982; Wilso *et al*., 2003). However, understanding of the nature and spatial distribution of biological productivity in the region is limited (DEWHA, 2008b). Periodic events, such as major sediment transport associated with tropical cyclones, may also influence turbidity on a regional scale (Brewer *et al*., 2007).

Water quality profiles recorded within the EMBA during marine baseline studies conducted by ERM (2010 – 2011), O2 Marine (2018) and Jacobs (2017) were consistent with those expected to occur within the tropical offshore environment. The marine baseline studies undertaken by ERM in 2010 and 2011 showed that water quality in the Bonaparte Basin is relatively pristine. The surveys measured dissolved oxygen concentrations and total suspended solids. The reported dissolved oxygen concentrations ranged from a minimum of 3.64 mg/L (49.8%) near the seabed to 7.80 mg/L (117.2%) at the sea surface, where dissolved oxygen was consistently found to decrease with depth. This is often linked to higher photosynthetic activity at the seawater surface and wave/wind generated mixing. These values are typical of unpolluted seawater (ERM 2011). The reported total suspended solids levels were low across the area during the time of sampling. The data represents relatively low suspended solid values as would be expected for offshore waters in the region (ERM 2011). Likewise, marine baseline studies undertaken by O2 Marine in 2018 within petroleum permit area AC-RL7, located within the western portion of the OA, indicated concentrations did not exceed the ANZG values for any of the water quality parameters tested (ANZG – Australian and New Zealand Guidelines for Fresh and Marine Water Quality).

4.3.5 Geology

The OA is located wholly within the Bonaparte Basin, the easternmost basin comprising the Northwest Shelf, offshore of the North and Northwest Region of Australia. The Bonaparte Basin belongs to series of extensional basins, which formed during late Paleozoic-early Meszoic rifting in the context of the Gondwana break-up. The fan-shaped basin originated from the Cambrian, forming during two phases of Palaeozoic extension and Mesozoic (Late Triassic) compression (Geoscience Australia, 2021).

The basin emerges from continental Australia at the JBG and extends into the waters of the Timor Sea. The basin is bounded to the north by the Timor Trough and to the west it is contiguous with the Browse Basin. The basin encompasses 270,000 km² and consists predominantly of interbedded shale and sandstone and late cretaceous to tertiary aged carbonates (Geoscience Australia, 2021).

The Bonaparte Basin contains several sub-basins and regional structural elements, each of which represent a distinct geological domain. The following four geological domains overlap the OA:

- Vulcan Sub-basin;
- Ashmore Platform;
- Londonderry High; and
- Sahul Syncline.

These sub-basins and structures vary in thickness, ranging from 2.0 km within the Ashmore Platform to 10.0 km within the Vulcan Sub-basin extent.

4.3.6 Geomorphology and Bathymetry

The Northwest Shelf can be further divided into several distinct provinces, based on the geomorphic characteristics of the seabed. Of relevance is the Sahul Shelf province, a shallow platform of complex topography which underlies the OA, which consists of a series of rises, depressions, banks/shoals, terraces and channels.

An extensive system of drowned carbonate banks and shoals exist within and immediately beyond the OA. Shoals and banks within the OA form abrupt geological features which rise steeply (at a gradient of 0.1) from depths of approximately 150 m to emerge within 30 m of the water's surface, allowing light dependent organisms to thrive (**Figure 12**) (Haris *et al.*, 2003)**.** The plateau of each shoal is typically ovate, covers approximately 10 -15 km² and consists of hard substrate which provides critical benthic habitat to which organisms can adhere in an otherwise soft sediment environment. Individual banks are intersected by narrow channels up to 150 m in depth.

A subset of banks and shoals identified within the OA and EMBA are further described in **Table 10**, along with outlining the available information on the banks and shoals which have been surveyed, as described by Australian Institute of Marine Science (**AIMS**), 2012; CSIRO, 2009; and AIMS, 2017.

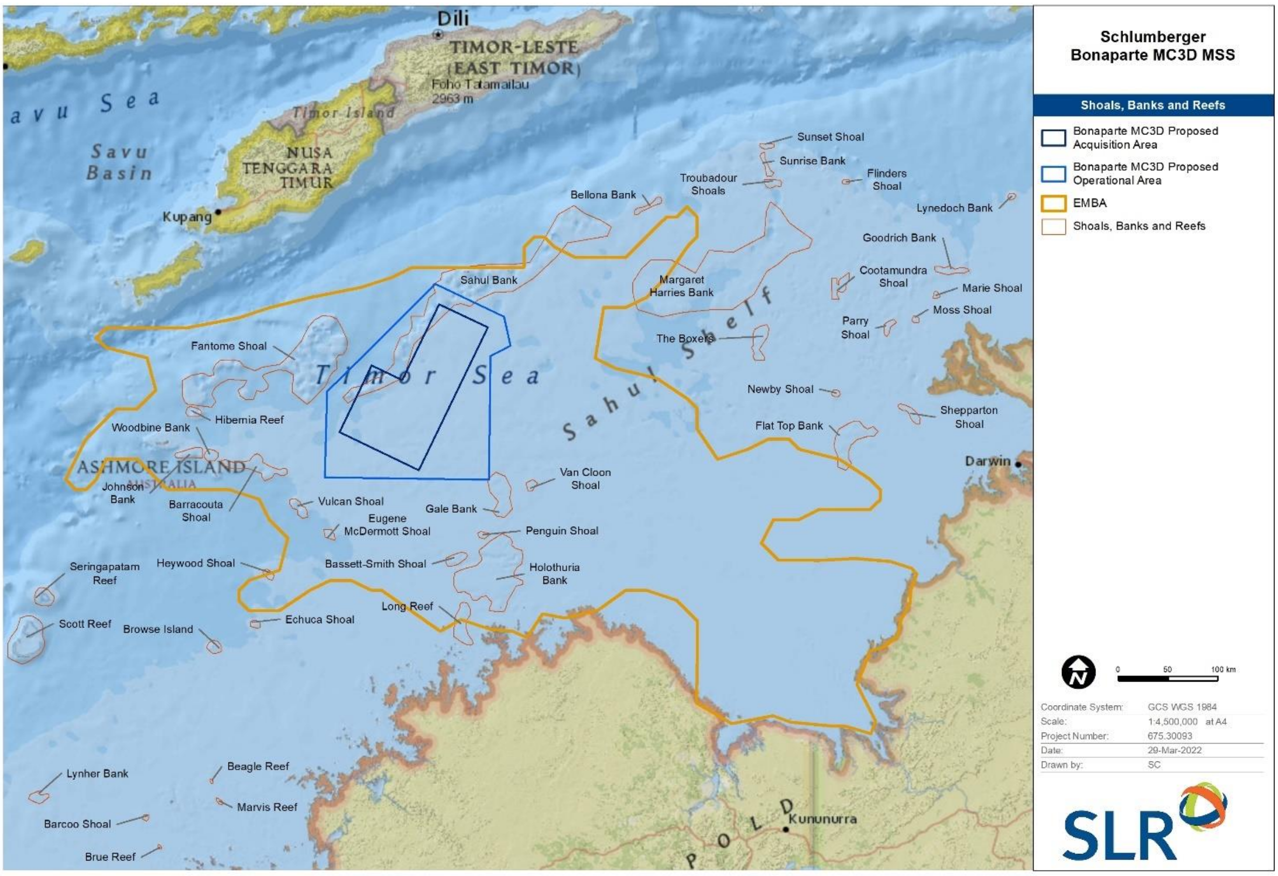


Figure 12 Shoals, Banks and Reefs in the vicinity of the EMBA

A portion of these carbonate banks and terraces form part of the Sahul Shelf Key Ecological Feature (**KEF**), which overlaps the southeast portion of the OA, and is regionally important in enhancing productivity. Roughly 24% (approx. 9,900 km^2 of approx. 41,150m^2 total) of the Sahul Shelf KEF overlaps with the OA. The carbonate bank and terrace system of the Sahul Shelf KEF is further described in **Section 4.4.3.**

The region comprises large areas of seabed that are dominated by soft sediments, such as those within continental shelf and plateau environments abutting the network of carbonate banks and shoals. The soft sediments typically consist of sandy and muddy substrate, occasionally made up of patches of coarser sediments (DEWHA, 2008b). Both the identified banks/shoals and the Sahul Shelf system provide a variety of carbonate substrates (Heyward *et al*., 2011) compared to the surrounding sandy and muddy substrate characteristic of deeper waters within the OA, particularly between the 100 m and 200 m isobaths (**Figure 13**).

Depth to seabed within the OA ranges from approximately 20 m to 200 m (Haris *et al*., 2003). However, over 95% of the OA constitutes water depths greater than 60 m (**Figure 13**).

Table 10 Subset of Banks, Shoals and Reefs identified within the OA and EMBA

Banks/Shoals	Location and Description
Heywood Shoal	Heywood Shoal is located 110 km southwest of the OA, but within the EMBA. The shoal is ovate and covers an area of approximately 32 km^2. Video surveys conducted in 2010 and 2011 indicate it is characterized by high cover of algae (48.3 %) and bare substrate (31.5%) such as sand, bare rock and rubble. Hard coral constituted 9.6% of benthic cover, with fungiidae and euphylliidae the most abundant coral families (Heyward *et al*., 2011).
Eugene McDermott Shoal	Eugene McDermott Shoal is located 52 km south of the OA, but within the EMBA. The shoal is ovate and covers approximately 5.6 km^2. Video surveys conducted in 2010 and 2011 indicate it is characterized by high cover of algae (43.4%), hard coral (17.7%) and bare substrate (16.4%) such as sand, bare rock and rubble. Algal composition was dominated by coralline and turf forms. Most major coral families were resented on the shoal, with Acroporidate and Poritidae were the most abundant (Heyward *et al*., 2011).
Vulcan Shoal	Vulcan Shoal is located 35 km southwest of the OA, but within the EMBA. The shoal covers approximately 12.5 km^2. Video surveys conducted in 2020 and 2011 indicate it is characterized by high cover of algae (38.8%) and bare substrate (33.5%) such as sand, bare rock and rubble. Of note, is that dense seagrass beds were observed at Vulcan Shoal within the 2010 surveys and constituted the only seagrass recorded across the monitoring program (Heyward *et al*., 2011).
Barracouta Shoals (East and West)	The Barracouta shoals are located 37 km west of the OA, but within the EMBA and cover a combined area of 8.6 km^2 (West: 2.8 km^2; East: 5.7 km^2). Benthic cover at both shoals is predominated by algae and bare substrate. Distinctions in benthic cover between the two shoals occurred for communities such as hard coral, sponges and soft corals which were, though minor contributors to seabed cover in each case, more prevalent at Barracouta East Shoal. Major taxonomic groups for each benthic community were similar between the two shoals (Heyward *et al*., 2011).
Woodbine Bank	Woodbine Bank is located 106 km west of the OA, but within the EMBA. Video surveys conducted in 2015 reported It is characterised by *Halimeda* sand with areas of reef habitat, namely along the southern shoal margins and covers an area of approximately 94 km^2 (CSIRO 1999)
Hibernia Reef	Hibernia Reef is located 124 km west of the OA, but within the EMBA. Towed video surveys indicate it is characterised by deep lagoon and deep reef flat habitat, comprising high cover of hard (13%) and soft corals and algae (38.5%) with some coral rubble present. Hibernia Reef covers an area of approximately 11 km^2 (CSIRO 1999).
Fantome Shoal	Fantome Shoal is located 7 km west of the OA, but within the EMBA.
Sahul Banks	The Sahul Banks are located within the northeast portion of the OA.

Banks/Shoals	Location and Description
Margaret Harries Banks	Margaret Harries Banks is located 130 km northeast of the OA, but within the EMBA. Towed video surveys conducted in 2015 identified benthic habitat dominated by limestone and hard coral outcrops, with some rubble present. Forms of low relief algae were also identified, comprising varying densities of *Halimeda* (Woodside, 2021).
Gale Bank	Gale Bank is located in the southeast corner of the OA.
Van Cloon Shoal	Van Cloon Shoal is located 36 km east of the OA, but within the EMBA.
Flat Top Bank	Flat Top Bank is located 340 km east of the OA, partially within the EMBA.
Penguin Shoal	Penguin Shoal is located 52 km south of the OA, but within the EMBA.
Basset-Smith Shoal	Basset-Smith Should is located 73 km south of the OA, but within the EMBA.
Holothuria Banks	Holothuria Banks are located 57 km south of the OA, but within the EMBA.
Long Reef	Long Reef is located 123 km south of the OA, but within the EMBA.
Johnson Bank	Johnson Bank is located 121 west of the OA, but within the EMBA. Video surveys conducted in 2015 reported It is characterised by *Halimeda* sand with areas of reef habitat, namely along the southern shoal margins, and covers an area of approximately 138 km² (Skewes, 1999b).

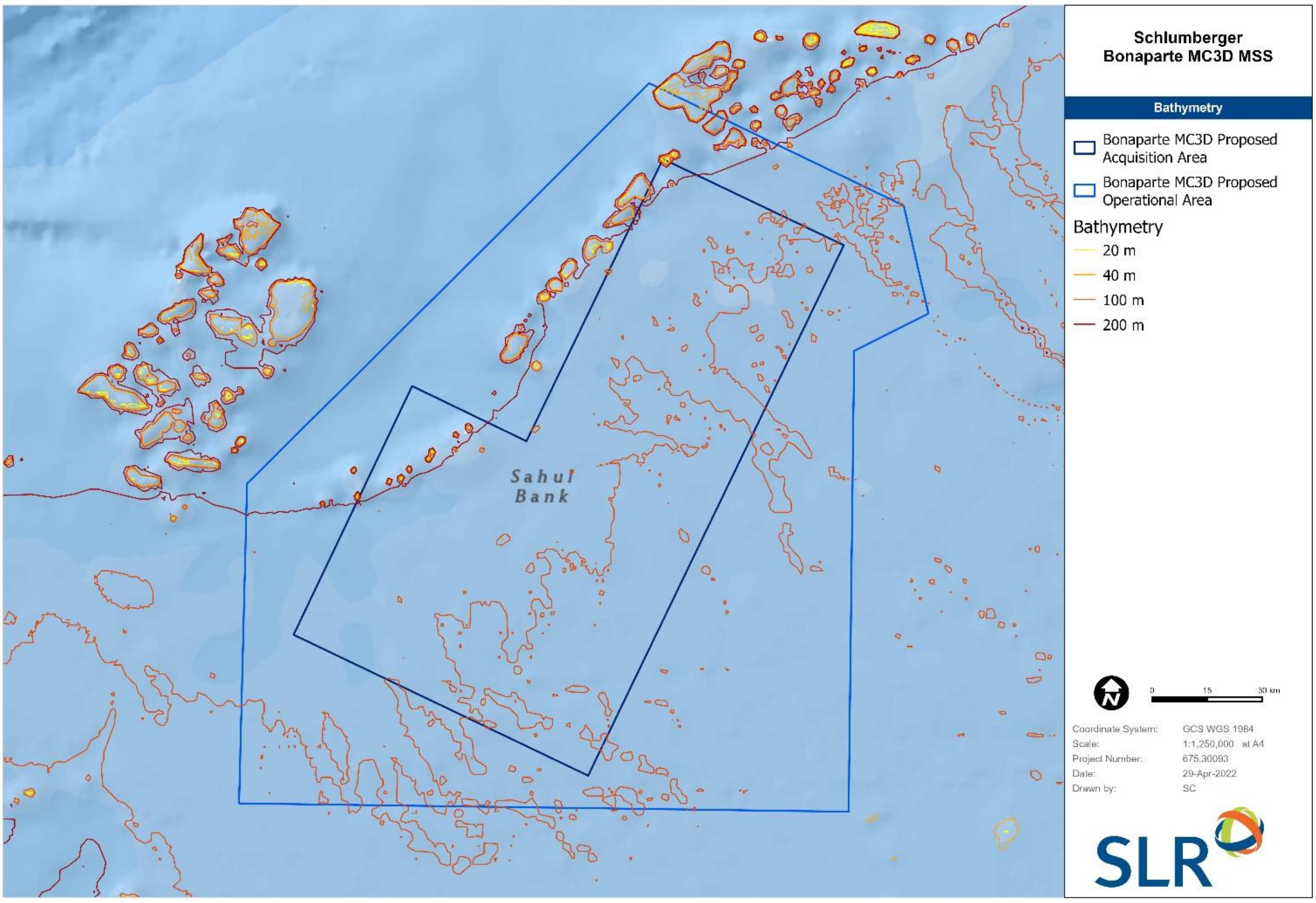


Figure 13 Bathymetry in the OA

4.3.7 Sedimentology

The sedimentology of the wider NWMR and relevant sections of the NMR is varied, owing to the diversity of geological and topographical features which it comprises. Regional sedimentology is broadly characterized by calcareous sediment consisting of varying proportions of gravel, sand and silt. Sediments show a broad zoning and fining with water depth, grading from sand and gravel dominant on the shelf to muds on the slope and abyssal plain/deep ocean floor (CSIRO, 2015; Baker *et al*., 2008).

Sediments of the middle shelf region, which underly the OA, are predominantly influenced by a tidal process. Sediment transport is driven by a combination of processes from the inner and outer shelf including winds, tides and waves and coastal turbidity.

Limited sampling data interpolated by Baker *et al*., (2008) suggest surficial sediments of the OA comprise broadly similar proportions of carbonaceous sand and mud, characterized as muddy sand. This is broadly consistent with measurements reported through the Australian Government's Marine Sediments (MARS) database (Heap 2009), which indicate silty sand is present throughout the OA. Sediment composition is expected to be largely homogenous, with changes in the proportion of mud, sand and bulk carbonate content to occur in accordance with changes in the spatial extent of prevailing geomorphology (i.e. in broad accordance with the boundaries of banks/shoals, terraces and shelf environments).

4.3.8 Sediment Quality

Sediment quality was undertaken during multiple surveys to characterise the marine sediments within the Montara and Ichthys Fields located immediately beyond and surrounding the OA, respectively. The reported concentrations of metals, metalloids, hydrocarbons and phenolic compounds in sediment samples were either below the laboratory limit of reporting and/or the ANZG Sediment Quality Guidelines detailed in Simpson *et al*., 2013 or attributed to biogenic sources (Ross *et al*., 2017; Jacobs, 2017).

No sediment quality data collected within the OA was available for review at the time of reporting.

4.3.9 Ambient Noise

Ambient noise refers to all-encompassing sound at a given place and usually comprises a composite of sound from many sources originating from the immediate surrounds and vast distances (McPherson *et al.*, 2019). Within the marine environment, ambient noise is characterised by a mix of anthropogenic and natural sounds, with the latter broken down into physical sources such as wave activity, rain, tidal turbulence, movement of sediments on the seabed and earthquakes, and biological sources such as fauna that produce sound. Animals such as invertebrates, fish and marine mammals produce sound through various modes of action such as physical movement, choruses, and vocalisations, respectively (Kent *et al.*, 2016). Consequently, ambient noise levels will vary spatially and temporally based on their prevailing environmental characteristics including between deep waters versus coastal waters and across different diel cycles (Cato and McCauley, 2002; Harland *et al.*, 2005).

Underwater noise monitoring conducted within the Timor Sea, approximately 300 km north of Darwin (McPherson *et al.*, 2019), recorded ambient noise levels varying between 80 and 115 dB re 1 µPa (96 dB re 1 µPa average). Variations in ambient sound were primarily affected by weather events, with notable contributions from fish, whales and occasional anthropogenic noise sources.

Ambient noise monitoring was conducted at other offshore locations in the region, including within the Browse Basin approximately 250 km from the OA. Monitoring data was collected by the Centre for Marine Science and Technology at Curtin University on behalf of INPEX Ltd, between September 2006 and September 2008. The monitoring revealed the average ambient noise level of 90 dB re 1 µPa under low sea states, although the level was greater than 100 dB re 1 µPa for 70% of the time as a result of the anthropogenic contributions (McCauley, 2009). Biological noise sources recorded within the surveyed area included regular fish choruses and several calls from humpback whales, blue whales, minke whales and other unidentified species (McCauley, 2009).

Results from the various surveys in the region are indicative of typical ambient noise levels within the OA and surrounding offshore waters which comprise the EMBA. Therefore, ambient noise levels in offshore, open water locations are expected to be between 90 and 100 dB re 1 µPa in low wind conditions. These levels may increase significantly during weather events, fish and whale vocalisations and as a result of vessel presence.

4.4 Marine Protected Areas and Sensitive Areas

4.4.1 Australian Marine Parks

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

In accordance with the EPBC Act, the AMP Network, and any zones within it, must be assigned to an International Union for Conservation of Nature (**IUCN**) Category consistent with the management intent and objectives for that site. IUCN categories include the following:

- Ia – Strict Nature Reserve, no resource extraction;
- Ib- Wilderness Area, First Nations traditional harvesting and collection for scientific research allowed;
- II- National Park, First Nations traditional harvesting and collection for scientific research allowed;
- III – Natural Monument or Feature, First Nations traditional harvesting and collection for scientific research allowed;
- IV – Habitat/species Management Area, sustainable resource extraction allowed;
- V- Protected Landscape or Seascape, sustainable resource extraction allowed;
- VI- Protected Areas with Sustainable Use of Natural Resources, sustainable resource extraction allowed; and
- Y – Assigned, pending further information.

The OA does not overlap with any AMP boundaries (**Figure 14**); however, the EMBA overlaps with seven AMPs. A summary of the relevant AMP and IUCN Category are presented in **Table 11**, and are discussed in further details within the following sections**.**

Table 11 AMP of Relevance to the OA

AMP	IUCN Category Zone	Distance from OA
Oceanic Shoals Marine Park	Multiple Use Zone (IUCN VI)	1.5 km
	Special Use Zone (Trawl) (IUCN VI)	142 km
Ashmore Reef Marine Park	Sanctuary Zone (IUCN Ia)	140 km
	Recreational Use Zone (ICUN II)	167 km
Cartier Island Marine Park	Sanctuary Zone (IUCN Ia)	100 km
Kimberley Marine Park	Multiple Use Zone (IUCN VI)	69 km
	National Park Zone (IUCN IV)	290 km
	Habitat Protection Zone (IUCN IV)	324 km
Joseph Bonaparte Gulf Marine Park	Special Use Zone (IUCN VI)	335 km
	Multiple Use Zone (IUCN VI)	290 km

The Kimberley, Cartier Island and Ashmore Reef Marine Parks are formally managed under the guidance of the NWMR management framework, whilst the Oceanic Shoals and Joseph Bonaparte Gulf Marine Parks are formally managed under the NMR management framework.

A summary of the environmental, social and cultural values identified for each AMP are described below, in accordance with the North-west Marine Parks Network Management Plan (Director of National Parks, 2018a) and North Marine Parks Network Management Plan (Director of National Parks, 2018b)

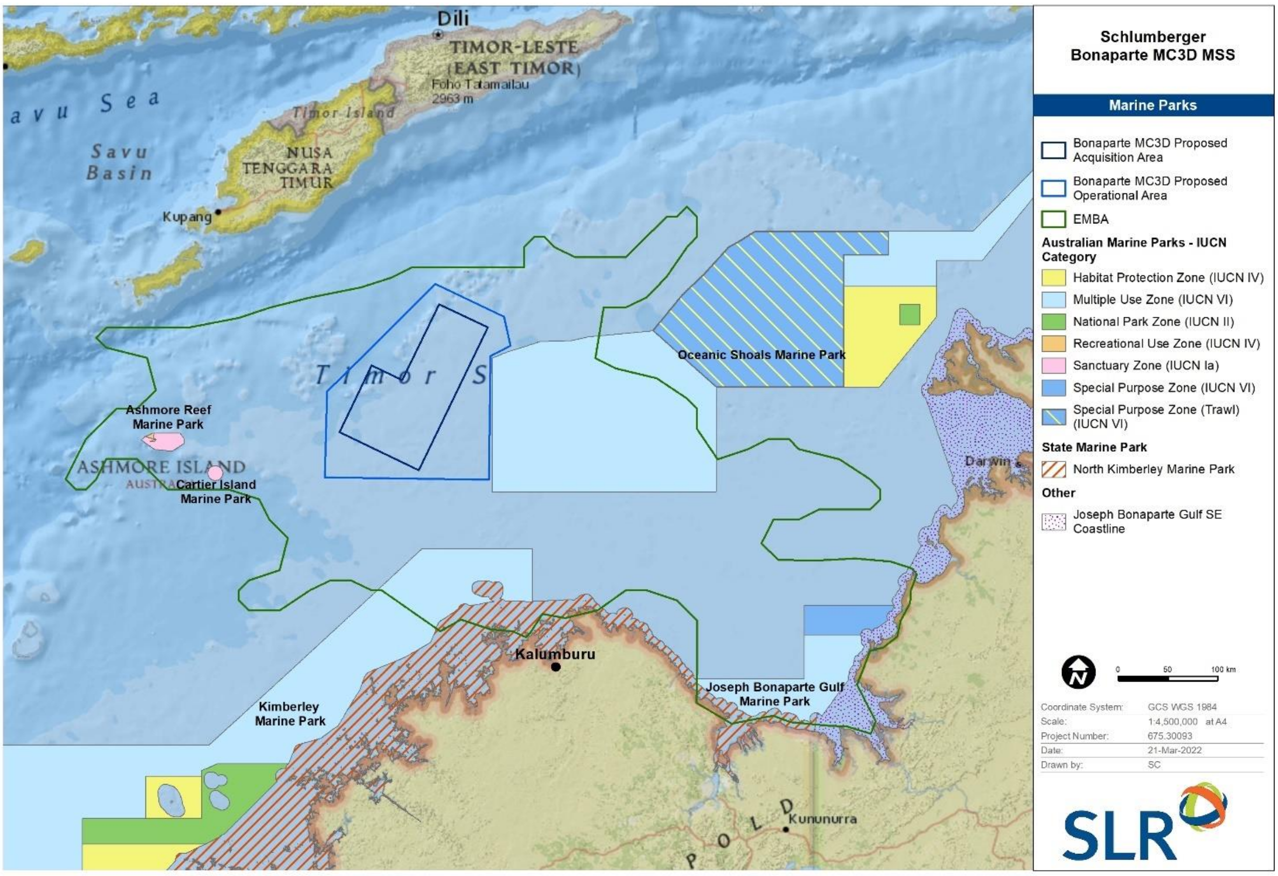


Figure 14 Marine Parks of Relevance to the Seismic Survey

4.4.1.1 Oceanic Shoals

The Oceanic Shoals Marine Park is located within the Timor Sea, extending southwest from its eastern-most point north of the Tiwi Islands and concluding offshore of the Bonaparte Archipelago. It extends to the limit of Australia's EEZ. Immediately beyond the northern boundary of the park, is the maritime boundary with Timor-Leste.

The Oceanic Shoals Marine Park covers 71,743 km^2, with water depth ranging from 15 to 500 m. The Oceanic Shoals Marine Park comprises National Park, Habitat Protection, Multiple Use and Special Purpose (Trawl) zones IUCN categories; however, zones which overlap or are immediately adjacent to the EMBA comprise Multiple Use (IUCN IV) and Special Use (Trawl) (IUCN VI) only.

The Oceanic Shoals Marine Park is significant because it contains habitats, species and ecological communities associated with the Northwest Shelf Transition. It contains four KEFs, including the Carbonate Bank and Terrace Systems of the Sahul Shelf which overlap the OA (see **Section 4.4.3**). This area is characterised by terraces, banks, channels and valleys which support a diverse range of sponges, soft coral, polychaetes, ascidians, turtles, snakes and sharks.

The Oceanic Shoals Marine Park supports a range of species, including species listed as threatened, migratory, marine or cetacean under the EPBC Act. Biologically Important Areas (**BIAs**) within the Oceanic Shoals Marine Park include foraging and interesting habitat for various marine turtles (see **Section 4.5.5**).

Sea country within the marine park is valued for indigenous cultural identity, health and wellbeing. Social and economic values include commercial fishing and mining (Director of National Parks, 2018).

4.4.1.2 Ashmore Reef Marine Park

The Ashmore Reef Marine Park is situated within Australia's External Territory of Ashmore and Cartier Islands, between Australia and Indonesia, approximately 630 km north of Broome and 110 km south of the Indonesian Island of Roti.

The Ashmore Reef Marine Park covers an area of 583 km² and water depths from less than 15 m to 500m, and contains three emergent, vegetated sand cays: West, Middle and East Islands. The Ashmore and adjacent Cartier Island are located within an area subject to a Memorandum of Understanding (**MoU**) between Indonesian and Australia, known as the MoU Box (shown in **Figure 28**).

The Ashmore Reef Marine Park is considered a unique biodiversity hotspot with high natural value. The Ashmore Reef Marine Park is an area of enhanced biological productivity, supporting a range of pelagic and benthic marine species and an important biological steppingstone facilitating the transport of biological material to the reef systems along the WA Coast via the south-flowing Leeuwin Current which originates in the region. It comprises two KEFs (see **Figure 15** and **Table 12**), including:

- The Ashmore Reef and Cartier Island and surrounding Commonwealth waters; and
- The Continental Slope Demersal Fish Communities**.**

The reef ecosystems comprising the Ashmore Reef Marine Park support the highest number of coral species of any reef of the WA coast. Likewise, the Ashmore Reef Marine Park supports a range of species listed as threatened, migratory, marine or cetacean under the EPBC Act including marine turtles, dugongs, blue whales and sea snakes. Of note, is that the Ashmore Reef Marine Park supports breeding, foraging and resting habitat for a range of seabirds and migratory shorebirds.

Multiple BIAs overlap the Marine Park and are further described in **Section 4.4.4.**

Sea country within the marine park is valued for Indigenous cultural identity, health and wellbeing. The Marine Park also contains Indonesian artefacts and grave sites and Ashmore lagoon is still access as a rest or staging area for traditional Indonesian fishers travelling to and from fishing grounds within the MoU box.

The Marine Park supports tourism, recreation, and scientific research activities.

4.4.1.3 Cartier Island Marine Park

The Cartier Island Marine Park is located approximately 45 km southeast of Ashmore Reef Marine Park, and 610 km north of Broome, WA. The Marine Park covers an area of 172 km² and water depths from less than 15 m to 500 m. Cartier Island is managed under the same regulatory framework as Ashmore Island, is situated within the MoU area and is assigned an IUCN Sanctuary Zone. It is located 108 km west from the OA.

Overall, the key ecological features and natural values of Cartier Island Marine Park are broadly comparable to those cited for Ashmore Reef Marine Park, above. Notably distinctions include differences in the BIAs which overlap Cartier Island, including breeding and foraging habitat for seabirds, interesting, nesting and foraging habitat for marine turtles and foraging habitat for whale shakes. Additionally, the marine park is important for a range of other species and internationally significant for its abundance and diversity of sea snakes, some of which are listed species under the EPBC Act. In contrast, sea snake populations at Ashmore Reef have been in steep decline since 1998.

Sea country within the marine park is valued for Indigenous cultural identity, health and wellbeing. In contrast, no known Indonesian Indigenous artefacts exist at the site.

From a social and economic perspective, scientific research is an important activity in the Marine Park.

4.4.1.4 Kimberley Marine Park

The Kimberley Marine Park is approximately 100 km north of Broome, WA and the central part of the Kimberley Marine Park is adjacent to the Western Australia Camden Sound State Marine Park. It covers 74,469 km^2, with depths from less than 15 m to 800 m. The northernmost extent of the Kimberley Marine Park is located 70 km south of the OA. Whilst the Marine Park comprises National Park, Habitat Protection and Multiple Use Zones, the portion considered within the vicinity of the OA constitutes a Multiple Use Zone (IUCN IV) only.

The marine park provides connectivity between deeper offshore waters and the inshore waters of the comprises two key ecological features:

- The Ancient Coastline at 125 m depth contour, as described in **Section 4.4.3**; and
- The Continental Slop Demersal Fish Communities.

The Kimberley Marine Park is characterised by high numbers of marine mammals such as dolphins, whales and dugong. The humpback whale breeds and calves in the Kimberley Marine Park annually after undertaking an extensive migration from Antarctica whilst the pygmy blue whale migrate through the park on their annual migration between key breeding and foraging grounds. Three dolphin species (Australian snubfin dolphin, Info-Pacific humpback dolphin and spotted bottlenose dolphin) use the Kimberley Marine Park to forage within and travel to coastal waters to calve and raise their young in inshore, protected waters. BIAs within the Marine Park also include breeding and foraging habitat for seabirds, interesting and nesting habitat for marine turtles and foraging habitat for whale sharks.

Sea country within the marine park is valued for Indigenous cultural identity, health and wellbeing. The national heritage listing for the West Kimberley recognises the following key cultural heritage values:

- Wanjina Wunggurr Cultural Tradition which incorporates many sea country cultural sites;
- Log-raft maritime tradition, which involved using tides and currents to access warruru (reefs) far offshore to fish;
- Interactions with Makassan trades around sea foods; and

- Important pearl resources that were used in traditional trade.

The park supports tourism, commercial fishing, mining, recreation, including fishing and traditional use.

4.4.2 State Marine Parks, Marine National Parks, Marine Sanctuaries, Marine Reserves and Fisheries Research Areas

Based on a review of the available State Government resources[1,2] relating to Marine Parks and Reserves, only one State Marine Park is located within the vicinity of the OA and overlaps the EMBA: the North Kimberley Marine Park.

The North Kimberley Marine Park is located in the Indian Ocean and the Timor Sea, in the waters of the Kimberley region in WA. The park extends northeast from York Sound, following the coastline, to the WA – NT border. The North Kimberley Marine Park covers approximately 18,450 km^2, extending from the mainland high water mark to the limit of State coastal waters.

The North Kimberley Marine Park comprises a complex array of coastal and marine habitats, connected through a variety of ecological processes. Rivers and estuaries are important features, influencing much of the coastline. Beyond this are thousands of islands with diverse and rich habitats, including many which support marine turtle nesting sites and breeding sites for seabirds and shorebirds. The productive deep waters that surround the islands and open sea reefs provide foraging habitat for marine mammals and pelagic finfish, such as mackerel (DPAW, 2016a). Complex coastal features such as intertidal reefs also are known to be important for dugongs, Australian snubfin dolphins and Australian humpback dolphins.

The North Kimberley Marine Park contains many places of cultural and spiritual importance to Traditional Owners, including those with artefacts, ceremonial and mythological paintings, fish traps, burial grounds, quarrying, man-made structures and middens. These values are further described in the North Kimberley Marine Park Management Plan (DPAW, 2016a) and herein, in **Section 4.6.1**.

The North Kimberley Marine Park supports a significant tourism industry, commercial fishing and recreational use.

At the time of this report, no Fisheries Research Areas were identified within the OA or EMBA.

[1]https://www.dpaw.wa.gov.au/management/marine/marine-parks-and-reserves
[2]https://www.fish.wa.gov.au/Sustainability-and-Environment/Aquatic-Biodiversity/Marine-Protected-Areas/Pages/default.aspx

4.4.3 Key Ecological Features

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

The OA overlaps with one KEF, the Carbonate Bank and Terrace System of the Sahul Shelf. There are five KEFs within the EMBA. A summary of the relevant KEFs within the OA and EMBA and area of overlap is described in **Table 12** and reflected in **Figure 15.**

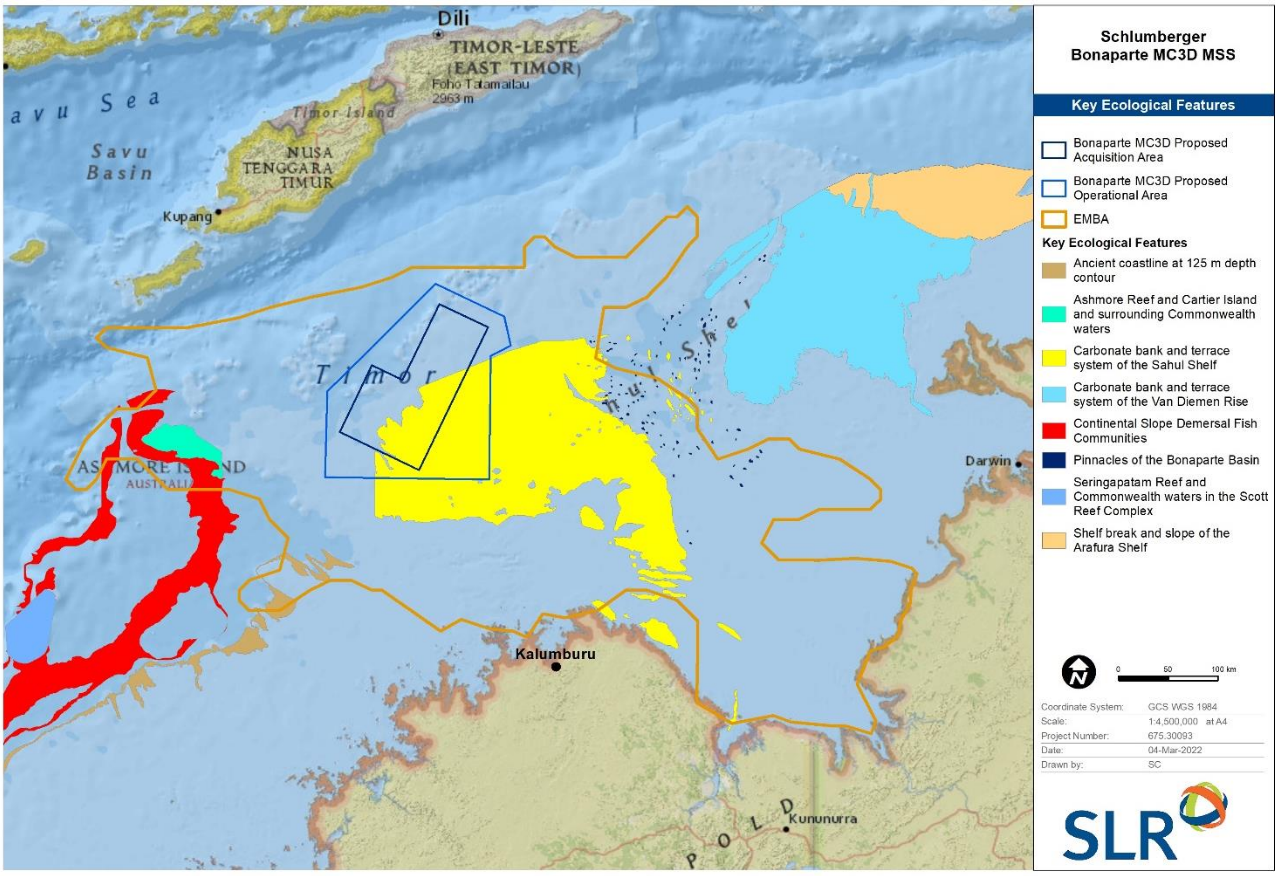


Figure 15 KEFs identified within the OA, EMBA and surrounding waters

Table 12 KEFs within the OA, EMBA and surrounding waters

KEF	Description	Values and/or Sensitivities
Carbonate bank and terrace system of the Sahul Shelf	• The carbonate banks and terraces comprising the KEF are part of a larger complex that occurs on the Van Diemens Rise, to the northeast. • The KEF covers an area of approximately 41,160 km². • The OA overlaps with approximately 9,900 km² (24%) of the KEF.	• Recognised for its role in enhancing biodiversity and local productivity relative to its surrounds, the KEF is a unique seafloor feature with ecological properties of regional significance. Biodiversity values apply to both benthic and pelagic habitats. • Rising steeply from depths of approximately 80 m, some banks emerge to within 30 m of the water's surface, the carbonate banks provide areas of shallow, hard substrate to which organisms can adhere allowing light dependant species to thrive (Brewer *et al*., 2007). • Prevailing geomorphologic and oceanographic conditions are thought to drive high nutrient conditions in the KEF. • Banks that rise to at least 45 m water depth support more biodiversity, such as communities of sessile benthic invertebrates including hard and soft corals, sponges, whips, fans and bryozoans (Brewer *et al*., 2007). • The banks are recognised as a biodiversity hotspot for sponges, comprising greater species diversity and contrasting communities than the surrounding seafloor. • The KEF is a known foraging area for flatback, olive ridley and loggerhead turtles (Donovan *et al*., 2008). • Humpback whales and green and freshwater sawfish are likely to occur in the area (Donovan *et al*., 2008).
Ancient Coastline at 125m Depth Contour	• The KEF consists of steps and terraces forming an escarpment along the NWS and Sahul Shelf at a water depth of 125 m. • The nearest part of the KEF is located approximately 73 km south of the OA.	• 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 high diversity and enhanced species richness relative to soft sediment habitat (DSEWPC, 2012a).

KEF	Description	Values and/or Sensitivities
		• Parts of the ancient coastline, comprising rocky escarpment, are considered to provide biological important habitat in an area otherwise made up of soft sediment. • Migratory pelagic species (e.g., humpback whales, blue whales and whale sharks) may use the KEF as a guide.
Pinnacles of the Bonaparte Basins	• Limestone pinnacles are located in the western JBG. • The nearest part of the KEF is located approximately 78 km east of the OA.	• The KEF is a unique seafloor feature with ecological properties of regional significance to both the benthic and pelagic habitats (DSEWPC, 2012a). • Pinnacles typically rise steeply form depths of about 80 m and emerge to within 30 m of the water surface, allowing light dependent organisms to thrive (Brewer *et al*., 2007). • The pinnacles provide areas of hard substrate in an otherwise soft sediment environment and are, therefore, important for sessile species. • Pinnacles that rise to at least 45 m water depth support more biodiversity, such as communities of sessile benthic invertebrates including hard and soft corals, sponges, whips, fans and bryozoans (Brewer *et al*., 2007, Nichol *et al*., 2013). • The banks are recognised as a biodiversity hotspot for sponges, comprising greater species diversity and contrasting communities than the surrounding seafloor. • Demersal fish communities occur in larger and more diverse populations on shallower, less turbid pinnacles (Nichol *et al*., 2013, NERP MBH, 2014). • The pinnacles are thought to be a feeding area for flatback, loggerhead and olive ridley turtles, while green turtles may traverse the area. Freshwater and green sawfish as well as humpback whales may also occur in the area (Donovan *et al*., 2008).
Continental Slope Demersal Fish Communities	• This KEF is located along the Australian continental slope, between the North-west Cape and the Montebello Trough. • The nearest part of the KEF is located approximately 93 km west of the OA.	• The continental slope demersal fish communities KEF provides important habitat for demersal fish communities and is characterised by high endemism and species diversity (DEWHA, 2008b).

KEF	Description	Values and/or Sensitivities
		• The KEF supports two distinct demersal community types (biomes) associated with the upper slope (water depth of 225 – 500 m) and the mid-slope (750 – 1,000 m) (DAWE, 2021). • Demersal slope communities are thought to rely on bacteria and detritus-based systems comprised of infauna and epifauna, which in turn become prey for a range of teleost fish, molluscs and crustaceans. (Brewer *et al.*, 2007). Higher-order consumers may include carnivorous fish, deep-water sharks, large squid and toothed whales (Brewer *et al.*, 2007).
Ashmore Reef and Cartier Island and surrounding Commonwealth Waters	• Ashmore Reef and Cartier Island are situated on the shallow upper slope of the Sahul Shelf. They form part of a series of submerged reef platforms along the outer edge of the continental slope of the NWMR. • The nearest part of the KEF is located approximately 100 km west of the OA.	• The combined area constitutes a KEF owing to its ecological function, integrity and biodiversity values which apply to both benthic and pelagic habitats. • The KEF is recognised as a regionally important site for feeding and breeding aggregations of birds and other marine life, including a high diversity of sea snakes, genetically distinct breeding population of green turtles and foraging grounds for green, loggerhead and hawksbill turtles (Limpus, 2008). • The emergent reefs are areas of enhance primary productivity in an otherwise low-nutrient environment. Localised upwelling and turbulent mixing in the surrounding Commonwealth waters provide nutrients to support the reef structure and ecology (DEWHA, 2008b). • Ashmore Reef is the largest of only three emergent oceanic reefs present in the northeastern Indian Ocean and is the only oceanic reef in the region with vegetated island. • Ashmore Reef supports the highest number of coral species of any reef off the west Australian coast. • The reef system is an important staging post for seabirds and migratory shorebirds. As such, it has been designated as a Ramsar site of international importance.

KEF	Description	Values and/or Sensitivities
Carbonate bank and terrace system of the Van Diemen Rise	• The carbonate banks and terrace system of the Van Diemen Rise comprise part of a larger system associated with the Sahul Banks to the north and Londonderry Rise to the east. • The nearest part of the KEF is located approximately 198 km east of the OA and outside of the EMBA.	• This key ecological feature is recognised for its ecological role in enhancing biodiversity and local productivity, relative to its' surrounds. • The Van Diemen Rise system is characterised by terrace, banks, channels and valleys. Channel systems range from approximately 60 -15 m to between 10 – 40 m in depth (Anderson *et al*., 2011) and supports sponge and octocoral gardens by providing epifauna habitat in an otherwise flat environment (Przeslawski *et al*., 2011). • The KEF is recognised as a sponge biodiversity hotspot (Przeslawski *et al*., 2014), with sponge diversity generally highest further offshore and on raised geomorphic features, particularly banks. • Localised areas of dense hard corals were found on the banks of the Van Diemen Rise and are considered to occur rarely throughout the broader JBG. • Pelagic fish such as mackerel, red snapper and a distinct gene pool of goldband snapper are found in the Van Diemen Rise (Blaber *et al*., 2005; Salini *et al*., 2006). • Olive ridley turtles, sea snakes and sharks are reported to occur in the area (DAWE, 2022b).
Shelf break and slope of the Arafura Shelf	• The shelf break and slope of the Arafura Shelf is characterised by continental slope and the presence of patch reefs and hard substrate pinnacles (Harris *et al*.; 2005). Seaward of the Van Diemen Rise, the shelf edge occurs at water depths of 12- -180 m. On the outer shelf and upper shelf slope, carbonate sediments are mixed with terrigenous clays from Indonesian rivers. • The nearest part of the KEF is located approximately 347 km northeast of the OA and outside of the EMBA.	• This key ecological feature is recognised for its ecological functioning and productivity. It also forms part of a unique biogeographic province with regard to biodiversity (DSEWPC, 2012a). • Prevailing oceanographic processes, including the ITF and surface wind-driven circulation, are thought to strongly influence ecological processes. The transport of warm water associated with the ITF is likely to influence pelagic dispersal of nutrients, species and biological productivity. Pelagic dispersal in turn drives long-term patterns of transport and dispersal of larvae, juvenile and migrating adult organisms within the area. • The shelf break and slope are situated in a major biogeographic crossroad where biota is largely affiliated with the Timor-Indonesian-Malay region (Hooper and Ekins 2005). Primary production of phytoplankton is likely to form the basis of offshore food webs (DEWHA ,2007).

4.4.4 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). Whilst BIAs are not matters of national environmental significance and have no legal status, they provide useful biological information intended to help inform regulatory and management decisions under the EPBC Act.

Based on the BIA maps and descriptions reported via the Australian Government Conservation Values Atlas[3], BIAs associated with 21 different threatened or migratory species were identified as potentially occurring within the OA and EMBA. The species with BIAs that overlap the OA include the Pygmy Blue whale, Whale shark and Flatback Turtle.

A brief summary of the relevant BIA and locational information is provided in **Table 13**. Further information on these BIAs is provided in the individual species descriptions in **Section 4.5.3** to **Section 4.5.7**, where relevant.

Table 13 Marine Threatened and Migratory Species BIAs within the OA and EMBA

Class	Species	BIA activity	Distribution of BIAs	Distance of closest BIA from OA (km)
Sharks and Rays	Whale Shark	Foraging	NWS 200 m isobath	Overlaps OA
Mammals	Pygmy Blue Whale	Distribution	South and West Australian Waters	Overlaps OA
		Migration	WA waters	Overlaps OA
		Foraging	South Australian Waters, localised areas within WA waters	294 km southwest of OA
	Humpback Whale	Calving, resting	Northwest WA and Queensland waters	210 km south of OA
		Migration	Western and Eastern Australian Waters	210 km south of OA
	Australian Snubfin Dolphin	Breeding	Northern Australian Waters	129 km south of OA
		Foraging (various)	Northern Australian Waters	129 km south of OA
	Indo-Pacific Humpback Dolphin	Calving	Northern Australian Waters	193 km south of OA
		Foraging (various)	Northern Australian Waters	129 km south of OA
	Indo-Pacific/Spotted Bottlenose Dolphin	Calving	Northern and Eastern Australian Waters	285 km south of OA
		Foraging (various)	Northern and Eastern Australian Waters	285 km south of OA
	Dugong	Breeding, Calving, Nursing	Western Australian Waters	155 km west of OA

3 https://www.awe.gov.au/environment/marine/marine-species/bias, accessed 15 February 2022

Class	Species	BIA activity	Distribution of BIAs	Distance of closest BIA from OA (km)
		Foraging (various)	Northern and Western Australian Waters	155 km west of OA
Reptiles	Flatback Turtle	Breeding (various)	Northern Australia	240 km southeast of OA
		Foraging (2 BIAs)	Northern Australian Waters	Overlaps OA 9 km east of OA
	Green Turtle	Breeding (various)	Northern Australia	87 km west of OA
		Foraging	Northern Australian Waters	153 km west of OA
	Hawksbill Turtle	Breeding (various)	Northern Australia	139 km west of OA
		Foraging	Northern Australian Waters	107 km west of OA
	Loggerhead Turtle	Foraging	Northern Australian Waters	9 km east of OA
	Olive Ridley Turtle	Foraging	Northern Australian Waters	9 km east of OA
		Breeding (various)	Northern Australia	414 km east of OA
Marine Birds	Brown Booby	Breeding, Foraging	Northern Australia	114 km west of OA
	Greater Frigatebird	Breeding, Foraging	Northern Australia	50 km west of OA
	Lesser Crested Tern	Breeding	Northern and Western Australia	87 km southwest of OA
	Lesser Frigatebird	Breeding, Foraging	Northern Australia	17 km south of OA
	Little Tern	Resting	Northwest Australia	146 km west of OA
		Breeding	Northwest Australia	156 km south of OA
	Red-footed Booby	Breeding, Foraging	Northern Australia	50 km west of OA
	Roseate Tern	Resting	Northern and Western Australia	148 km south and west of OA
		Breeding	Northern and Western Australia	125 km southwest of OA
	Wedge-tailed Shearwater	Breeding, Foraging	Northern, Western and Eastern Australia	56 km west of OA
	White-tailed Tropicbird	Breeding	Northwest Australia	60 km west of OA

4.4.5 The Australian Whale Sanctuary

The Australian Whale Sanctuary has been established to protect all whales and dolphins found in Australian waters, which are protected under the EPBC Act 1999. The Sanctuary includes all Commonwealth waters from the three nautical mile State Waters limit out to the boundary of the Exclusive Economic Zone. All States and Territories provide similar protection for cetaceans within Coastal Waters (up to 3NM), and it is the responsibility of the state and territory governments to protect whales and dolphins. The OA and EMBA, therefore, overlap the Australian Whale Sanctuary.

Within the Sanctuary it is an offence to kill, injure or interfere with a cetacean and severe penalties apply to anyone convicted of such offences. In all Australian waters, activities with the potential to significant impact on listed or migratory species, such as cetaceans, are regulated under the EPBC Act 1999 (see **Section 2.1.2**). Migratory species within the EPBC Act are those that are listed under international agreements as species whose protection requires or would significantly benefit from international cooperation. Any such proposed activity should therefore be referred to the Minister for the Environment and Heritage for assessment.

Australia is a signatory to the International Convention for the Regulation of Whaling. Obligations under this Convention include provision for the conservation of whales through the complete protection of select species, and the designation of whale sanctuaries (Director of National Parks, 2013).

4.4.6 Ramsar Wetlands of International Importance

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

No Ramsar wetlands occur within the OA; however, the Ashmore Reef National Nature Reserve Ramsar site is located within the EMBA, approximately 140 km west of the OA (**Figure 16**).

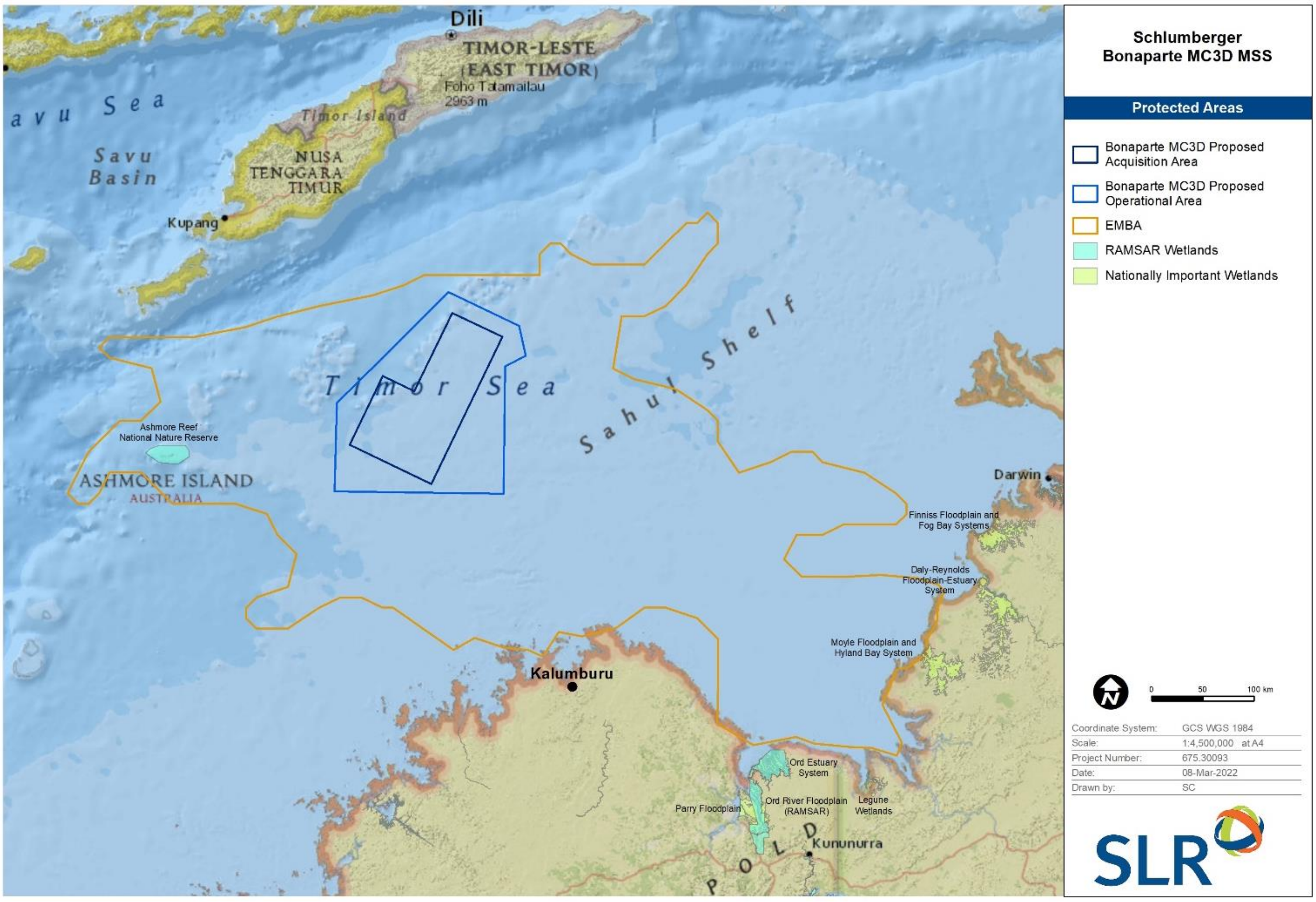


Figure 16 Ramsar and Nationally Important Wetlands of relevance to the OA and EMBA

Following the designation of the Ashmore Reef Marine Park as a Ramsar site in 2002, a final Ecological Character Description of the site was published in 2013. A summary of the components and process identified therein as important to the ecological character of the Ashmore Reef Ramsar Site and, in the case of Critical components, for which Limits of Acceptable Change (**LAC**) have been derived (see **Table 14**). Critical and Supporting components and processes were selected on the basis of their role in maintaining the ecological character of the site, the ecosystem services they support and the Ramsar criteria for which the site is listed (Hale and Butcher, 2013).

Table 14 Components and Processes Important for Maintaining the Ecological Character of the Ashmore Reef Ramsar Site

Component/Process	Description
Supporting	
Climate	• Arid tropical monsoonal climate; • Located outside of the main belt of tropical cyclones in the Timor Sea.
Geomorphic Setting	• Located in an area of high oil and gas reserves, with active hydrocarbon seeps (O'Brien *et al*., 2002); • Geomorphic groups within the site include reef slope, reef crest, reef flat, back reef sands, lagoons and islands (Glenn and Collins, 2005).
Tides and currents	• Strong seasonal influences of the ITF and Holloway currents (DEWHA, 2008b); • Internal waves area f feature of the region and Ashmore Reef Ramsar site may act to break these resulting in increased nutrients from bottom waters.
Water Quality	• Seasonal variations in temperature and salinity in ocean and lagoon water (Weinberg *et al*., 2009); • Water clarity, turbidity and other water quality parameters remain a knowledge gap.
Vegetation	• Give species of seagrass recorded with T*halassia hemprichii* dominant, comprising over 85% of total cover; • Total cover of 470 ha, but much of this is sparse and there is only 200 ha with a mean cover of greater than 10%; • Over 3,000 ha of macroalgae, mostly on the reef slope and crest areas; • Algae are dominated by turf and coralline algae with fleshy macroalgae comprising typically <10% of the total algal cover (Skewes *et al*., 1999b).
Critical	
Marine invertebrates	• 275 species of hard coral, covering an area of around 700 ha (Vernon, 1993; Griffith, 1997; Skewes *et al*., 1999a); • 39 taxa of soft coral, covering an area of around 300 ha (Marsh, 1993; Skewes *et al*., 1999b); • Total coral cover was low around the time of listing following the 1998 bleaching event but recovered in recent years to baseline levels (Ceccarelli *et al*., 2011); • Over 600 species of mollusc, including two endemic species (Wells, 1993; Willan, 2005); • Over 180 species of echinoderm, including 18 species of sea cucumber (Marsh *et al*., 1993; Skewes *et al*., 1999a); • Sea cucumber density is highly variable, but on average exceeds 30 per ha (Skewes *et al*., 1999a); • 99 species of decapod crustacean (Morgan and Berry, 1993).

Component/Process	Description
Fish	• Over 750 species of fish, including five species of fish and three species of shark listed as threatened (Allen, 1993; Russel *et al*., 2005); • Predominantly shallow water, benthic taxa that are common throughout the Indo-Pacific; • Density of small reef fishes is around 20,000 to 40,000 per ha (Kospartov *et al*., 2006; Heyward *et al*., 2012); • Low density of sharks (less than one per ha) (Skewes *et al*., 1999a; Richards *et al*., 2009; Heyward *et al*., 2012).
Seasnakes	• Prior to listing there was a high diversity and population, peaking in 1998 with an estimate total population of 40,000 snakes in the site (Guinea and Whiting, 2005); • However, by the time of the listing in 2002 the site was on a downward trajectory with regard to diversity and abundance was low (Guinea, 2008).
Turtles	• Three species of marine turtle: green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and loggerhead (*Caretta caretta*), all of which are listed threatened species; • Green turtles are the most abundant, with a total estimated population of around 10,000 individuals; • Nesting by two species: green turtles and hawksbill turtles (Whiting and Guinea, 2005).
Seabirds and Shorebirds	• 72 species of wetland dependant bird recorded within the Ramsar site; • 47 species listed under international migratory agreements; • Average of around 48,000 seabirds and shorebirds annually; • Six species are regularly record in numbers great than 1% of the population; • Nesting of 20 species, 14 of which regularly breed in the site (Milton, 2005; Clarke, 2010).
Dugong	• Small but significant population that may breed within the site (Whiting and Guinea 2005); • Data deficient.

4.4.7 Nationally Important Wetlands

There are no national important wetlands within the OA. One Nationally Important Wetland, the Moyle Floodplain and Hyland Bay System, was identified along the southern boundary of the EMBA (see **Figure 16**). However, as there is limited to no overlap between the two boundaries, this environmental value is not further described.

4.4.8 World, Commonwealth and National Heritage Places

World heritage sites are natural or man-made sites, areas, or structures recognised as being of outstanding universal value by the United Nations Educational, Scientific and Cultural Organisation (**UNESCO**). No listed World Heritage or National Heritage places were identified within the OA or the EMBA. However, the West Kimberley National Heritage Place is located south of the OA, extending from Wyndham to Derby and including inland, riverine, estuarine and coastal environments.

No Commonwealth Heritage listed places occur within the OA. The closest Commonwealth Heritage site is Ashmore Reef National Nature Reserve, located 140 km west of the OA but within the wider socio-cultural EMBA. It is managed under the Ashmore Reef National Nature Reserve and Cartier Island Marine Reserve Management Plans (Commonwealth of Australia 2002)[4]. The Ashmore Reef Marine Park is designated as a Commonwealth Heritage List site under Criterion A (Process), Criterion B (Rarity) and Criterion C (Research) for several values, including:

- Faunal diversity, including species not previously, or only rarely, recorded in WA and potentially endemic species;
- Staging point for migratory waders and high concentrations of breeding seabirds;
- Habitat for sea snakes, including one species endemic to the reef;
- Breeding and feeding habitat for green turtles and hawksbill turtles;
- Higher diversity of marine habitats compared with other Northwest Shelf reefs;
- Significant for its history of human occupation and use; archaeological significance; and
- Important scientific reference area.

No other Commonwealth Heritage listed places were identified within the EMBA.

4.4.9 Threatened Ecological Communities

There are no TECs within the OA or the EMBA.

[4] The names of the Ashmore Reef National Nature Reserve and Cartier Island Marine Reserve have subsequently changed to the Ashmore Marine Park and Cartier Island Marine Park, respectively, however the Management Plans use the former names.

4.5 Biological Environment

4.5.1 Plankton and Primary Producers

The term ‘plankton’ describes the drifting organisms that inhabit aquatic environments. Plankton travel with the ocean currents and although some plankton can move vertically within the water column, their horizontal distribution is primarily determined by the surrounding currents. This assessment considers two broad functional planktonic groups:

- Phytoplankton – free-floating organisms ranging from 0.2 to 200 mm in size, capable of photosynthesis, which includes diatoms and dinoflagellates. Phytoplankton fulfil the primary producer role in the ocean and form the basis of the marine food web; and
- Zooplankton – free-floating animals which includes copepods, jellyfish and larval stages of larger animals.

Oceanic productivity occurs when phytoplankton (or algae/seagrasses) photosynthesise and form the basis of the marine food web. The amount of productivity results from many factors including currents, climate and bathymetry. Nutrient rich waters and areas of upwelling enhance productivity and such conditions are ideal for the growth of plankton and plankton-consuming animals. Areas of high productivity are associated with aggregations of marine organisms (Hosack and Dambacher, 2012).

Within the NWMR, surface waters typically have low nutrient availability, owing to the dominance of the ITF which transports warm oligotrophic, low-salinity water from the Pacific Ocean to the Indian Ocean. The interplay between environmental conditions such as bathymetry, prevailing oceanographic processes, seasonality and the presence of complex geomorphic features drive localised increases in productivity. The weakening of the ITF and Leeuwin Current in the dry season, along with seasonal reversal in wind and cyclones, results in seasonally enhanced productivity through increased mixing with the underlying deep, cold, nutrient-rich waters.

Within the OA and EMBA, there are two notable features that promote enhanced primary productivity:

- Carbonate bank and terrace system of the Sahul Shelf; and
- Ashmore Reef and Cartier Island and surrounding Commonwealth waters, where localised upwelling and turbulent mixing in the Commonwealth waters around the reef systems provide nutrients.

4.5.1.1 Phytoplankton

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

Phytoplankton assemblages were surveyed by Environmental Resources Management (**ERM**) in 2021 and 2011 in the JBG, located east of the OA. These data were considered broadly representative of plankton assemblages which may be expected to occur within the OA. Consistent with the limited survey data which has been collected along the North-west Shelf, phytoplankton assemblages were dominated by cyanobacteria during the 2010 wet season survey and diatoms (Bacillariophyceae) during the dry season, which comprised 99.7% of identified algal cells. During the 2011 dry season survey, diatoms (Bacillariophyceae) dominated the phytoplankton assemblage. Overall, phytoplankton densities were typical of offshore oceanic waters and indicative of a classically oligotrophic (low nutrient) system, as is the case across offshore WA and the Timor Sea (ERM, 2011). These findings were consistent with the limited survey data which has been collected along the Northwest Shelf and within the OA (Eriksen *et al*., 2019; Conoco Phillips, 2018)

4.5.1.2 Larval fish and zooplankton

The Kimberley has one of the least studied marine pelagic ecosystems off Australia and, in particular, the nature and extent of zooplankton is poorly known. Limited sampling undertaken within the JBG (ERM, 2011) and the Dampier Peninsular (Holliday *et al*., 2011) indicated that copepods represented the most dominant group within the macro-zooplankton assemblage. Holliday *et al*. (2011) found that euphausiids were also ubiquitous, however, higher concentrations were recorded for coastal waters, compared to shelf an oceanic waters. *Pseudeuphausia latifrons* was the dominant krill species in shelf waters. Whereas the more speciose oceanic assemblages were dominated by the species of the genus *Stylocheiron*.

ERM observed seasonal variation in the density of macro-zooplankton across the 2010 wet season and 2011 dry season monitoring periods, with an overall greater density recorded during the 2010 wet season. The greater density of macro-zooplankton may be indicative of higher primary productivity in the summer months fuelling population increases of the zooplankton (secondary productivity) at this time. Zooplankton density varied at the level of the assemblage with statistically distinct assemblages found within both the 2010 wet season and 2011 dry season (ERM, 2011).

Besides the common macro-zooplankton taxa such as copepods, euphasiids and chateognaths, the diversity of zooplankton within the Kimberley is enhanced by the occurrence of pelagic larval stages of a number of benthic invertebrates and fish (Eriksen *et al*., 2019, Holliday *et al*., 2011). Sampling undertaken by ERM (2011) indicated that larval fishes in the JBG were found to be dominated by Serranidae (cods) and Lutjanidae (snappers), both of which are commercially targeted species in the region. Similarly, Holliday *et al*., (2011) reported the occurrence of Lutjanidae, Serranidae and Scombridae throughout the Kimberley shelf and offshore waters during autumn.

Larval fish density varied seasonally with the 2011 dry season recording highest densities of larval fishes in the zooplankton. This seasonal effect is consistent with the notion of an extended spawning season (and possibly planktonic larval duration) of the species dominating the larval fish assemblage in the area (ERM, 2011).

4.5.2 Benthic Habitats and Communities

The benthic ecosystem relates to the seafloor, its substrates and colonising biota (benthos). Benthos represents a large component of marine biodiversity and ecosystem productivity. The composition and distribution of benthic habitat and communities is influenced by many environmental factors, including substrate and sediment characteristics, depth, water temperature, wave action, currents and food availability.

4.5.2.1 Banks, Shoals and Reef Communities

Due to the remoteness of the region, information on benthic habitats and communities within the bank and terrace systems comprising the southeastern portion of the OA is limited. However, the extensive network of limestone banks consisting of hard substrate are expected to support a diverse range of sessile benthos such as hard and soft corals, gorgonians, encrusting sponges and macroalgae; and consequently, a more reef associated fish and elasmobranch fauna (Brewer *et al.*, 2007). See banks, shoals and reefs located within EMBA in **Section 4.3.6**, **Figure 12** and **Table 10**.

Studies conducted by AIMS between 2010 – 2016 indicate that shoals in the Timor Sea support diverse tropical ecosystems analogous to that of coral reefs (AIMS, 2016). Shoals were characterised by high levels of biological variation within and between shoals, even where physical constraints such as depth and seabed morphology were broadly comparable between sites. Based on the findings of these studies, benthic primary producers such as algae and reef building corals are the predominant community to depths of 50 – 60 m. At all of the shoals studied, algae were the most abundant benthic community with respect to percentage cover, ranging from 38.8 % at Vulcan Shoal to 53.8% at Wave Governor Bank Shoal (located nearby Cartier Island), followed by hard coral, which ranged from 6.1% at Barracouta West Shoal to 17.7% at Eugene McDermott Shoal. Hard coral assemblages varied between shoals, but broadly grouped into shallower shoals consisting of Acropora (a diverse number of branching and tabulate, fast-growing corals) and Portitidae, while deeper shoals were strongly characterised by an abundance of mushroom coral species in the family Fungiidae. The benthic communities observed are typical of shallow tropical reef systems studied elsewhere, with many coral and algal species shared between the shoals and emergent coral reefs in the region.

4.5.2.2 Soft Sediment Habitat

Benthic habitat mapping and macrofauna sampling was undertaken by ERM in 2010 – 2011 and O2 Marine in 2017, within permit area AC/RL7 which overlaps a small portion of the OA at its northwestern apex (ERM 2012, O2 Marine 2018). Within the AC/RL7 permit area, surveyed benthic habitat comprised of white sandy substate and shell grit. Sites were characterised by homogeneous, flat and featureless soft-sediment habitats. Epibenthic macrofauna were sparse, with sea stars and small bony fish the only fauna recorded. The absence of hard substrate is considered a limiting factor for recruitment of epibenthic organisms. In both surveys, Annelida (polychaete bristleworms) and Malacostracea (crabs, shrimp) were recorded as the two most abundant taxa. Also reported were sea squirts, ostracods, sea spiders, echinoderms, molluscs, bryozoa, round worms ribbon worms, peanut worms, flatworms, sea anemones and sponges. These findings are considered to be broadly representative of soft sediment habitats which may be expected to occur throughout the OA, given the similar water depths and geomorphology.

4.5.3 Fish, Sharks and Rays

4.5.3.1 Fish

Over 5,000 species of fish are currently known to occur in Australia's marine environment, and these play important ecological roles in coastal and offshore waters. Fish populations from the OA are represented by demersal and pelagic species, with a number of larger migratory pelagic species visiting the area seasonally.

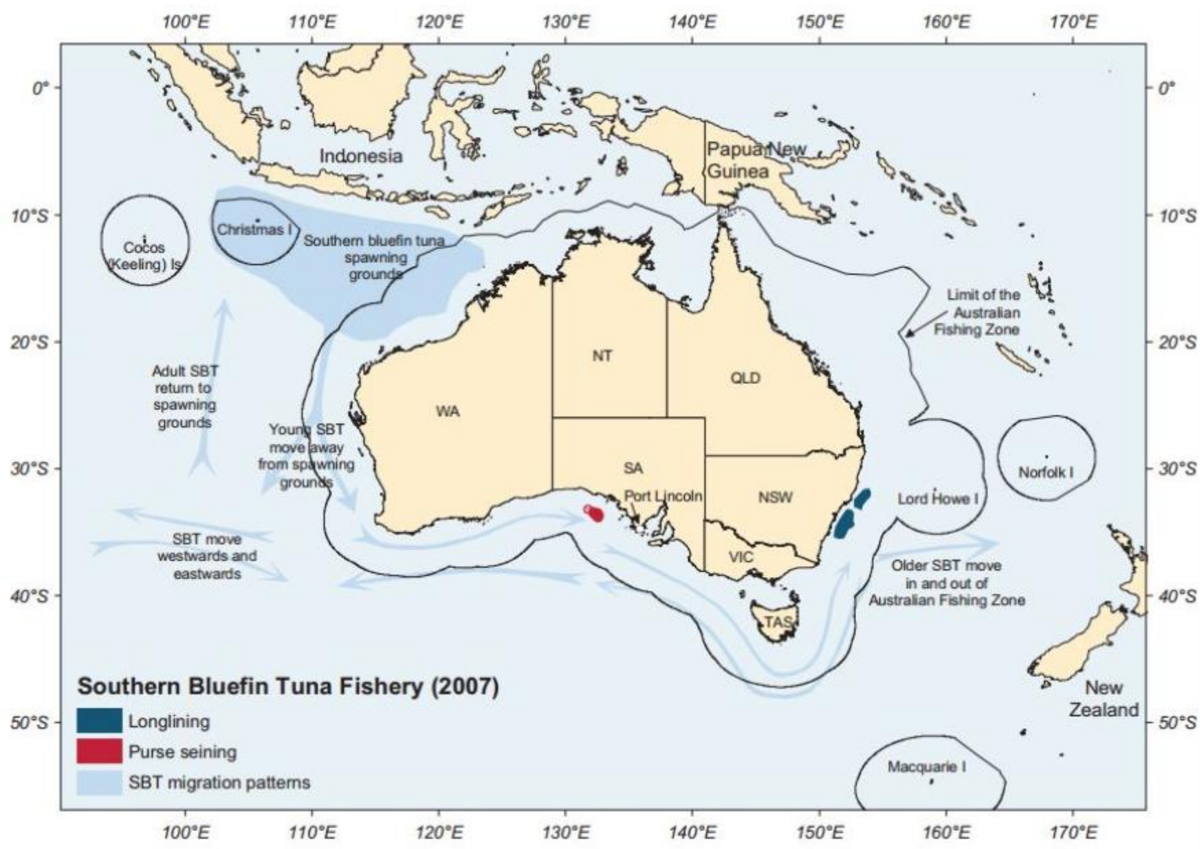
Coral reefs in the wider Indo-Pacific region support a high biomass of fish species, including coral trout, emperors, snappers, as well as larger pelagic species such as trevally, dolphinfish, marlin and sailfish (DEWHA, 2008a). Demersal fish surveys undertaken in 2010-11 and 2017 within permit area AC/RL7 (overlaps the OA, in comparable water depths and seabed habitats) indicate that low numbers of fish are present within the permit area (ERM, 2012; O2 Marine, 2018). The number of fish in the OA is expected to be similar.

The OA overlaps with one KEF, the Carbonate bank and terrace system of the Sahul Shelf, which is recognised for its role in enhancing biodiversity and local productivity in the area. The KEF is a unique seafloor feature with ecological properties and biodiversity values apply to both benthic and pelagic habitats.

Shoals, banks and reefs within the wider EMBA (**Section 4.3.6**) are linked to high productivity and habitats that is likely to provide spawning grounds for some species. Potential spawning grounds also exist in the EMBA for commercially important species such as goldband snapper, and red emperor. The spatial occurrence of spawning is variable and poorly understood. None of these species are listed as threatened; however, they are commercially valuable.

An EPBC Act Protected Matters Database search (3 March 2022) (**Appendix C**) identified Southern Bluefin Tuna (*Thunnus maccoyii*) as a species known to occur in the region, listed as Conservation Dependent under the EPBC Act. Southern bluefin tuna are large pelagic migratory fish that can reach up to 2.25 m in length and 200 kg in weight. These slow-growing apex predators have a long lifespan, living for over 40 years and reaching sexual maturity at 11 – 12 years where they feed opportunistically on a wide variety of prey including fish, crustaceans, cephalopods and salps (DAWE, 2022).

In Australia, this species occurs from northwestern Australia to south Australian waters, including Tasmania, and to north New South Wales. Migration and spawning locations take place just south outside of the OA and EMBA. Southern bluefin tuna spawn from August to April, close to the surface of warm waters (>24°C). Only one spawning ground is known, which lies in the Indian Ocean between northern WA and Java (Caton, 1991; Basson *et al.,* 2012) (**Figure 17**), located 125 km southwest of EMBA.



Source: AFMA, 2018a

Figure 17 Southern Bluefin Tuna Spawning Grounds and Migration Routes

Southern bluefin tuna migrate along the West Coast of Australia before passing through the Great Australian Bight then head to the east into the Tasman Sea, or west into the Indian Ocean (Basson *et al*., 2012). Migrating southern bluefin tuna tend to be found in deeper waters seaward of the continental shelf but will come in very close to shore in locations where the deep-water/shelf is close to shore. Over the summer period (December – April), southern bluefin tuna, of a range of ages and sizes are found to aggregate in large schools near the surface in the coastal waters off the southern coast of Australia, but tend to migrate to spend winters in deeper, temperate oceanic waters (DAWE, 2022).

As part of the stakeholder engagement programme, the Australian Southern Bluefin Tuna Industry Association were contacted who confirmed the OA is not used for feeding or breeding by southern bluefin tuna (**Appendix I**).

A marine baseline survey undertaken by ERM (2011) showed that the most common fish families by density present within the NMR which is in proximity to the OA, were Terapontidae (grunters), Nemipteridae (threadfin breams), and Lutjanidae (snappers). These species are known to occur in coastal waters to depths of approximately 200 m and are widely distributed through the WA (ERM, 2011).

The search in the EPBC Act Protected Matters Database also generated 25 pipefish species, five seahorse species, three pipehorse species and one seadragon that may occur within the EMBA. None of these species are listed as threatened or migratory under the EPBC Act. The species group report card – bony fishes (DEWHA 2008b), states that almost all syngnathids (pipefish, seahorses and pipehorses) live in nearshore or inner shelf habitats.

A review of information on habitat preference and water depth range has been undertaken for the 34 syngnathid species identified in the protected matters search (see **Table 15**). The water depths of the Acquisition Area range from 20 – 200 m. Most of the syngnathid species are associated to reef habitats and only six of them have been recorded in water depths greater than 50 m, therefore, the majority of the identified species are not expected to occur within the OA.

Table 15 Summary of Habitat Preference and Depth Range for Syngnathid Species that may occur within the OA and EMBA

Species	Assemblage and Habitat	Depth Range (m)
Mud pipefish *Halicampus grayi*	Deep Inhabits silty and muddy soft bottoms on the continental shelf from inshore bays to deep offshore areas.	0 – 100
Thorny seahorse *Hippocampus histrix*	Deep Inhabits areas with both hard and soft bottoms, often attached to soft corals or sponges and rocky reef areas.	5 – 95
Hedgehog seahorse *Hippocampus spinosissimus*	Deep Benthic in inner reef waters on rubble substrates and in sponge and seagrass habitats near coral reefs.	20 – 70
Pallid pipehorse *Solegnathus hardwickii*	Deep Mostly known from trawled specimens captured in depths of up to 180 m.	12 – 180
Gunther's pipehorse, *Solegnathus lettiensis*	Deep/shelf Benthic inhabitant of outer continental shelf waters and has been captured from depths up to 180 m.	42 – 180
Straightstick pipefish, *Trachyrhamphus longirostris*	Deep Most specimens have been trawled or dredged from muddy to sandy-bottom habitats in depths up to 90 m.	15 – 90
Barbed pipefish *Bhanotia fasciolata*	Low reef Demersal individuals are most common in reef and tidepool habitats.	3 – 25
Three-keel pipefish *Campichthys tricarinatus*	Low reef Occurs in inshore reef habitats.	3 – 10
Pacific Short-bodied pipefish, *Choeroichthys brachysoma*	Low reef Commonly occurs in seagrass, reef and coral habitats in depths of less than 5 m.	< 5
Pig-snouted pipefish *Choeroichthys suillus*	Low reef Occurs in inshore reef habitats.	1 – 15
Redbanded pipefish *Corythoichthys amplexus*	Low reef This species prefers protected coral habitats and shallow reefs.	0 – 30
Reticulate pipefish *Corythoichthys flavofasciatus*	Low reef Association with fringing coral reefs, rocky shores, pools and caves.	0 – 30

Species	Assemblage and Habitat	Depth Range (m)
Australian Messmate pipefish *Corythoichthys intestinalis*	Low reef They occur on sheltered coastal reefs. Associated with sand, coral or 'grass' bottoms.	0 – 10
Schultz's pipefish *Corythoichthys schultzi*	Low reef Common on rubble and in corals.	0 – 30
Roughridge pipefish *Cosmocampus banneri*	Low reef Occurs on coral reefs lagoons, rock and sand.	6 -30
Banded pipefish *Doryrhamphus dactyliophorus*	Low reef Free-swimming fishes that are usually found at the front of caves or reef overhangs.	10 – 25
Bluestripe pipefish *Doryrhamphus excisus*	Low reef Free-swimming benthic fishes found in various reef habitats in coastal to outer reefs, and close to small caves.	0 – 50
Cleaner pipefish *Doryrhamphus janssi*	Low reef Found in various reef habitats in coastal to outer reefs, and usually close to small caves or narrow crevices.	5 – 30
Tiger pipefish *Filicampus tigris*	Low reef Usually seen in estuaries on rubbly, sandy or weedy bottoms.	2 – 30
Brock's pipefish *Halicampus brocki*	Low reef Occurs on coral and rocky reefs with algae.	3 – 45
Ridgenose pipefish *Halicampus dunckeri*	Low reef A reef associated species usually found on sandy and algal-rubble habitats.	1 – 25
Spiny-snout pipefish *Halicampus spinirostris*	Low reef Inhabits shallow coral rubble areas in lagoons and intertidal zones of inshore coral reefs.	5 – 10
Ribboned pipehorse *Haliichthys taeniophorus*	Low reef Inhabits a variety of inshore shallow water areas including coral reefs, rocky, sandy and muddy substrates.	0 – 18
Beady pipefish *Hippichthys penicillus*	Shallow Found in lower reaches of streams and rivers and seagrass beds in estuaries.	0 – 5
Spotted seahorse *Hippocampus kuda*	Low reef Inhabits coastal bays, harbours and lagoons, sandy sediments in rocky littoral zones, and shallow reef flats.	0 – 50
Flat-face seahorse *Hippocampus planifrons*	Low reef Inhabits algal and rubble reefs in shallow bays from the intertidal.	0 – 20
Tidepool pipefish *Micrognathus micronotopterus*	Low reef Usually inhabits shallow inshore reefs and tidepools.	1 – 10
Robust ghost pipefish *Solenostomus cyanopterus*	Low reef Inhabits shallow protected coral and rocky reefs, along with deep, clear estuaries with seagrass or macro-algae.	0 – 28

Species	Assemblage and Habitat	Depth Range (m)
Double-end pipehorse *Syngnathoides biaculeatus*	Low reef Inhabits shallow, protected waters of bays, lagoons and estuaries.	0 – 10
Blue-speckled Pipefish *Hippichthys cyanospilos*	Low reef Inhabiting brackish shallow-water environments in estuaries and lower reaches of coastal rivers and streams.	0 – 5
Short-keel Pipefish *Hippichthys parvicarinatus*	Low reef Inhabits coastal fresh and brackish habitats.	0 – 5
Reef-top Pipefish *Corythoichthys haematopterus*	Low reef Inhabits protected rubble and sandy areas in shallow reef lagoons, reef flats and slopes.	1 – 20
Girdled Pipefish *Festucalex cinctus*	Low reef Usually inhabits sheltered coastal bays and estuaries.	1 – 30
Western Spiny Seahorse *Hippocampus angustus*	Low reef Inhabits sheltered algal-covered reefs and seagrass beds.	10 – 30

Sources: DoEE (2019); Bray and Thompson (2022); Austin and Pollom (2019); Froese and Pauly (2022)

4.5.3.2 Elasmobranchs

Over 300 species of elasmobranchs (sharks, skates and rays) are known to inhabit Australian waters. Half of these are found nowhere else in the world. The NWMR and NMR experiences high species richness of shark, sawfish and rays (DEWHA, 2008a).

Thirteen different threatened and/or migratory shark and ray species were identified by a search of the EPBC Act Protected Matters Database (3 March 2022) as potentially occurring in the OA and/or the wider EMBA (**Table 16**). A description of the identified sharks and rays species is provided in **Table 16**.

The OA overlaps with the northernmost section of a whale shark migration and foraging BIA (**Figure 18**). The whale shark (*Rhincodon typus*) is a protected species within all WA state waters. A seasonal aggregation of whale sharks occurs in the waters of Ningaloo Marine Park (**NMP**) each year between the months of March and July, sometimes extending into August. The aggregation has been linked to productivity events associated with mass coral spawning episodes and the unique current system along the northwest coastline where the Leeuwin current and Ningaloo current interact. This aggregation is one of the largest in the world and its uniqueness has contributed to the Ningaloo Coast being inscribed on the World Heritage List, acknowledging it as one of the outstanding natural places in the world and reaffirming the whale shark as a conservation icon (DPAW, 2013).

The whale shark BIA follows the continental shelf and extends from NMP to waters in the north Kimberley region. Individuals observed at Ningaloo Reef have been shown to use both inshore and offshore habitats while migrating northwards (Reynolds *et al*., 2017; Sleeman *et al*., 2010). The foraging BIA represents waters where whale sharks may forage during the migration from Ningaloo, which occurs primarily in spring (September to November).

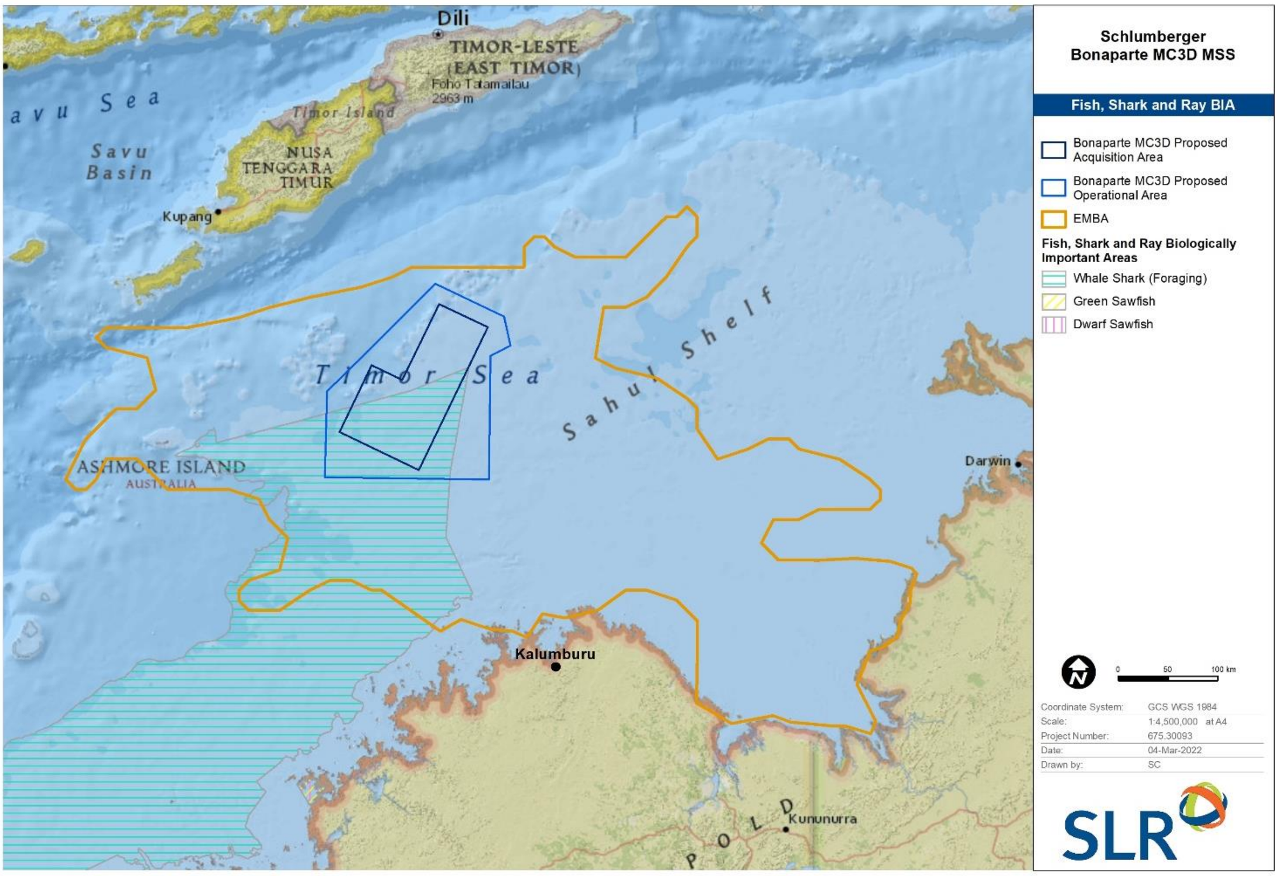


Figure 18 Biologically Important Area for Whale Shark

Table 16 EPBC Act List of Threatened and Migratory Species Known to/ Likely to Occur within the OA and Wider EMBA

Species	EPBC Act Status/ Migratory Status	Description of Species and Potential to Occur within the OA and EMBA
Great White Shark *Carcharodon carcharias*	V M	The Great white shark grows to a minimum of 6 m in length and can weigh up to 3,000 kg (Mollet and Cailliet, 1996; Last and Stevens, 2009). The white shark is widely, but sparsely, distributed in all seas in both hemispheres. They have been sighted in all Australian coastal areas apart from in the NT. It is most frequently observed and captured in coastal temperate and subtropical regions. Accurate population assessments are not yet possible for any region (Bruce, 2008). Great white sharks are frequently recorded in waters around fur seal and sea lion colonies (DoEE, 2022). Due to the species preference for cold temperate waters and feeding grounds in waters around seal colonies further south, the presence of the species within the OA and EMBA is likely to be infrequent.
Northern river shark *Glyphis garricki*	E N/A	The northern river shark is known to occur in WA and the NT. Northern river sharks are elasmobranchs capable of living and moving between freshwater and seawater. Within Australia, northern river sharks are known to occur in rivers, tidal sections, inshore and offshore marine habitats (DoE, 2014; Pillans *et al*., 2009). Given the species preferred estuarine habitat, the presence of the species within the OA is expected to be low. The species may be present in the coastal region of the EMBA.
Freshwater sawfish *Pristis pristis*	V M	The Freshwater Sawfish is mainly confined to the main channels of large rivers of northern Australia, WA and Queensland (DAWE, 2022a). Juvenile freshwater sawfish mainly occur in rivers and estuaries, while mature animals tend to occur more often in coastal and offshore waters up to 25 m depth (Giles *et al*., 2006; Stevens *et al*., 2005). In northern Australia, this species appears to be confined to freshwater drainages and the upper reaches of estuaries, occasionally being found offshore. It is likely to occur within the carbonate bank and terrace system of the Sahul Shelf KEF. The nearest freshwater sawfish foraging BIA is at King Sound, located over 450 km away from the OA. Given the species preferred estuarine habitat, and the location of the foraging BIA, the presence of the species within the OA is expected to be low. The species may be present in the coastal region of the EMBA.

Species	EPBC Act Status/ Migratory Status	Description of Species and Potential to Occur within the OA and EMBA
Green sawfish *Pristis zijsron*	V M	Green sawfish are distributed in coastal waters from Queensland across northern Australia to Shark Bay in WA, with some records being offshore in relatively deep water (Stevens *et al.*, 2005). Adult green sawfish appear to preference shallow inshore waters (Stevens *et al.*, 2005). The carbonate bank and terrace system of the Sahul Shelf KEF is known to support green sawfish (Donovan *et al.*, 2008). A portion of this KEF overlaps with the eastern portion of the OA. The closest foraging BIA for green sawfish in the area is located along the eastern shore of Camden Sound, over 385 km away from the OA and outside of the EMBA. Given green sawfish are known to occur in the JBG. The species may be encountered in low numbers in the OA and may be present in higher numbers in the coastal region of the EMBA.
Narrow sawfish *Anoxypristis cuspidata*	N/A M	The exact distribution of the narrow sawfish is uncertain, but it is likely that its distributed from Australia to Japan and South Korea. (IUCN, 2017). The narrow sawfish occurs from inshore and estuarine areas to offshore habitat of up to at least 40 m depth (Peverell, 2005). Given the relatively shallow-water distribution of this species, it is unlikely to be present in the OA. The species may be present in higher numbers in the coastal region of the EMBA.
Dwarf sawfish *Pristis clavata*	V M	The dwarf sawfish usually inhabits shallow coastal waters and estuarine habitats. Its distribution is thought to extend north from Cairns, across northern Australian waters to the Pilbara coast in WA (DoEE, 2022). The closest foraging BIA for dwarf sawfish in the area is located along the eastern shore of Camden Sound, over 300 km away from the OA and outside of the EMBA. Given the species preferred coastal habitat, and the location of the foraging BIA, the presence of the species within the OA is expected to be low. The species may be present in the coastal region of the EMBA.

Species	EPBC Act Status/ Migratory Status	Description of Species and Potential to Occur within the OA and EMBA
Whale Shark *Rhincodon typus*	V M	The Whale shark are the largest known living fish species, reaching up to 12 m in length, although more commonly measuring 4 – 10 m (Colman, 1997). It is estimated that whale sharks may live for over 100 years (Taylor, 1994). Whale Sharks is an oceanic and coastal, tropical to warm-temperate pelagic species that is generally encountered close to or at the surface but can make dives to around 1000 m in search of prey (DAWE, 2022a; Compagno, 1984). In Australia, the Whale Shark is most commonly seen in waters off northern WA, NT and Queensland (Compagno, 1984; Last and Stevens, 1994). There is a recovery plan in place that identifies actions to ensure this species long term viability and survival (DEH, 2005a). Whale shark foraging is noted to occur in the region, from Ningaloo Reef to waters in the Timor Sea (Sleeman *et al*., 2010; Wilson *et al*., 2006; Reynolds *et al*., 2017). A BIA is designated for whale shark foraging, which is located within the OA and EMBA (**Figure 18**). The foraging BIA represents waters where solitary whale sharks may forage during the migration from Ningaloo, which occurs primarily in spring (September to November). According to the DoEE's Conservation Advice on whale sharks, the species is known to aggregate at Christmas Island (approximately 2,400 km away) between December and January and at Ningaloo Reef (approximately 1,800 km away) between March and July to feed on krill and baitfish associated with coral spawning events (DoEE, 2022). The whale shark migration between Christmas Island and Ningaloo Reef is expected to occur in deep waters away from the OA between January and March (Colman, 1997). The population participating in the Ningaloo aggregation is estimated to comprise between 300 and 500 individuals, although the total population size in the region is unknown (Meekan *et al*., 2006). Due to the species widespread distribution and highly migratory nature, individuals are likely to be present in both the OA and EMBA.
Shortfin mako shark *Lsurus oxyrinchu*	N/A M	The shortfin mako is a large pelagic and fast mackerel shark, reaching up to 4 m in length and exhibiting speed bursts of 18.8 ms^{-1}. They are considered to be the fastest swimming shark species (Last and Stevens, 2009). Shortfin mako are highly migratory and occur globally in tropical and temperate waters above 16°C. It is widespread in Australian waters having been recorded in offshore waters all around the continent's coastline (Last and Stevens, 2009). Given the species distribution in deep offshore waters, the presence of the species within the OA and EMBA is expected to be low.

Species	EPBC Act Status/ Migratory Status	Description of Species and Potential to Occur within the OA and EMBA
Longfin mako shark *Lsurus paucus*	N/A M	The longfin mako inhabits oceanic and pelagic habits and is a widely distributed, but rarely encountered, tropical ocean shark. This species appears to be cosmopolitan in tropical and warm temperate waters; however, at present, records are sporadic, and the complete distribution remains unclear (IUCN, 2017). In Australian waters, longfin mako sharks are found from WA, and north to Port Stephens in New South Wales (Last and Stevens 2009). Whilst assumed to be a deep-water shark, sightings on the ocean surface, and the species' diet, suggest a broader depth range (Rigby *et al*., 2019). Given the species distribution in deep offshore waters, the presence of the species within the OA and EMBA is expected to be low.
Oceanic whitetip shark *Carcharhinus longimanus*	N/A M	The oceanic whitetip shark is a deep-water pelagic species inhabiting tropical to warm-temperate waters (Compagno, 1984). Oceanic whitetip sharks prefer water temperatures above 20°C and can reach depths of >180 m (Castro *et al*., 1999). Within Australian waters, the oceanic whitetip shark is found from WA, through parts of the NT and down to Sydney (Last and Stevens 2009). Given the species distribution in deep offshore waters, the presence of the species within the OA and EMBA is expected to be low.
Scalloped Hammerhead *Sphyrna lewini*	Conservation Dependent	The scalloped hammerhead is a migratory, schooling, coastal-pelagic, semi-oceanic species that travel within the EEZ of many coastal nations. These sharks aggregate in huge numbers, making them extremely vulnerable to commercial and illegal fishing. Known in Australian waters from about Geographe Bay, WA, around the tropical north, to Sydney, New South Wales. Elsewhere, widespread in tropical and warm temperate. They can range from the surface to more than 275 m deep, but juveniles are often found close inshore and in enclosed bays and estuaries. The Australian populations are dominated by juveniles and small adult males (Bray and Thompson, 2022). Given the species preferred coastal habitat, the presence of the species within the OA is expected to be low. The species may be present in the coastal region of the EMBA.

Species	EPBC Act Status/ Migratory Status	Description of Species and Potential to Occur within the OA and EMBA
Reef manta ray *Manta alfredi*	N/A M	The reef manta ray has a circumtropical and subtropical distribution, existing in the Pacific, Atlantic and Indian Oceans. Within this broad range, populations appear to be sparsely distributed and highly fragmented (Marshall *et al*., 2018b). The reef manta ray is found around most of Australia's coast (DoEE, 2022). The reef manta is often resident in coastal areas (Marshall *et al*., 2018b) and its movement patterns differs from site-specific to seasonal migrations of several hundred kilometres (Couturier *et al*., 2011). Given the species is generally associated with nearshore environments, the presence of the species within the OA is expected to be limited. The species may be present in higher numbers within the coastal region of the EMBA.
Giant manta ray *Manta birostris*	N/A M	The giant manta ray has a circum-tropical and semi-temperate distribution throughout the world's major oceans. Within this broad range, populations appear to be sparsely distributed and highly fragmented (Marshall *et al*., 2018). The giant manta ray appears to be a seasonal visitor to coastal or offshore sites and are capable of large-scale movements of >1,000 km (Kashiwagi *et al*., 2011). Whilst largely solitary, giant mantas can aggregate in large numbers to feed, mate or clean. The giant manta ray has a widespread distribution along the coast of Australia and is also known to seasonally migrate between aggregation sites (Marshall *et al*., 2018b). The year-round population of giant manta rays present at Ningaloo Reef from May through to September. Given the species wide-distribution, the presence of the species within the OA is expected to be low. The species may be present in higher numbers in the coastal region of the EMBA.

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

4.5.4 Cephalopods

All cephalopods consist of a mantle, head, and eight arms (and two long tentacles in the case of some squid). This class of animals includes cuttlefish, squid, octopus and nautilus. Cephalopods are highly significant ecologically within the marine environment, both as top-level predators and as prey for numerous vertebrates, including fish, seals, cetaceans and seabirds. Australian waters contain the highest diversity of cephalopods found anywhere in the world and, according to the Atlas of Living Australia (ALA, 2022), 22 species of cephalopods have been recorded within EMBA according to Atlas of Living Australia field guide, download generated 3 March 2022 (see results in **Appendix C**). The records vary from a few sightings up to approximately 50 records. Cephalopods, particularly squid, are an important food source for many fish, bird, elasmobranch and marine mammal species that inhabit the OA.

More than 30 cuttlefish species are known from Australian waters. Cuttlefish live in a range of habitats including reefs, sand, mud and among seagrass and seaweed. They have a lifespan of one to two years and are productive breeders. According to records in ALA field guide nine different cuttle fish species has been observed within EMBA (seven of them within OA). Cuttlefish occupy shallow depths up to approximately 1,000 m (ALA, 2022).

Twelve squid species have been recorded in the EMBA according to ALA field guide, nine of them within the OA. Squid have rapid growth rates and most live for up to only one year, dying shortly after spawning.

Octopuses mainly live on the seafloor and are the largest predators on reefs, feeding on crustaceans and shellfish (Te Ara, 2018). Only one octopus species (Banded Stringarm Octopus) is listed in the ALA field guide as having been recorded within the EMBA, not the OA. This species, and potentially other octopus species, could be present within the OA but are most likely to be affiliated with reefs and coastal waters.

There are six living species of Nautilus in Australian waters, none of which have been recorded in the OA or EMBA (ALA field guide). Nautiluses generally inhabit waters of around 300 m in depth rising to approximately 100 m during the night to feed, mate and lay eggs.

No cephalopod species are included in the EPBC Act List of Threatened Fauna.

4.5.5 Marine Reptiles

Many marine reptile species are known to occur in the NWMR and NMR, including marine turtles, sea snakes and saltwater crocodiles. Of the seven marine turtle species globally, six occur regularly in the NWMR and NMR and all are listed as vulnerable or endangered by the EPBC Act (DSEWPC, 2012; DSEWPC, 2012a). These regions also collectively support most of the 35 sea snake species that occur in Australia; with two of the sea snake species occurring here being listed as critically endangered. In particular, the Timor Sea is regarded as a sea snake biodiversity hotspot (Guinea and Whiting, 2005; Minton and Heatwole, 1975; Smith, 1926).

Whilst there is no emergent land within the OA to support nesting marine reptiles, many species forage within the OA, and both foraging and breeding behaviours occur within the EMBA. The closest known turtle nesting site occurs at Ashmore Reef (located approximately 106 km west of the OA). Ashmore Reef also provides important habitat to at least 14 species of sea snake (Cogger, 2000), and high levels of endemism are reported for this location (Lukoschek *et al*., 2013).

Results from the EPBC Act Protected Matters Database (3 March 2022) revealed that there are two threatened, and six threatened and migratory marine reptile species that may be present within the OA, in addition to one threatened and nine migratory species within the wider EMBA.

There are several BIAs for marine reptile species in the region, including within the OA, along the coastline and offshore islands adjacent to the OA, and within or close to the EMBA (**Figure 19**). These include:

- A small Flatback turtle foraging BIA overlaps with the OA.
- Flatback turtle nesting, inter-nesting[5] and inter-nesting buffer BIAs, with the nearest located 240 km southeast of the OA.
- Loggerhead turtle foraging BIA located approximately 9 km east of the OA.
- Green turtle foraging, mating, nesting and inter-nesting buffer BIAs, with the nearest located approximately 87 km west of the OA.
- Hawksbill turtle foraging, nesting and inter-nesting buffer BIAs, with the nearest located 107 km west of the OA.
- Olive Ridley turtle foraging BIA located approximately 9 km east of the OA.

While no ‘critical habitat’ as defined under Section 207A of the EPBC Act (Register of Critical Habitat) has been identified and listed for marine turtles, the Turtle Recovery Plan (Commonwealth of Australia, 2017b) identifies the areas shown in **Figure 20** as critical habitat and the associated seasonality for these locations is listed in **Table 17**. While the OA does not overlap with any identified critical turtle habitat, the EMBA overlaps with critical green turtle habitat at Ashmore Island and near Kalumburu, and flatback turtle habitat in the JBG.

A description of the distribution, preferred habitat and life stages of the identified threatened marine reptile species is provided in **Table 18,** including commentary on their likely presence in the OA and EMBA. **Table 19** lists those non-threatened marine reptile species that may also occur in the region.

[5] inter-nesting areas are where females live between laying successive clutches in the same season.

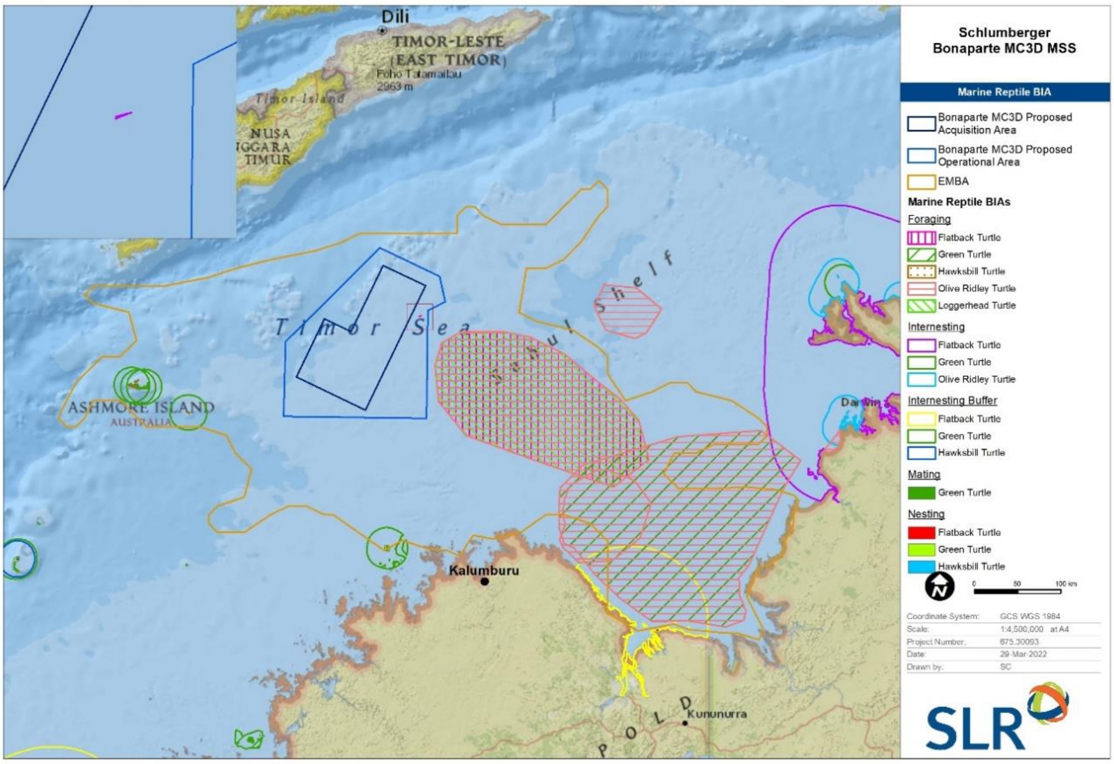


Figure 19 Biologically Important Areas for marine reptiles in the EMBA

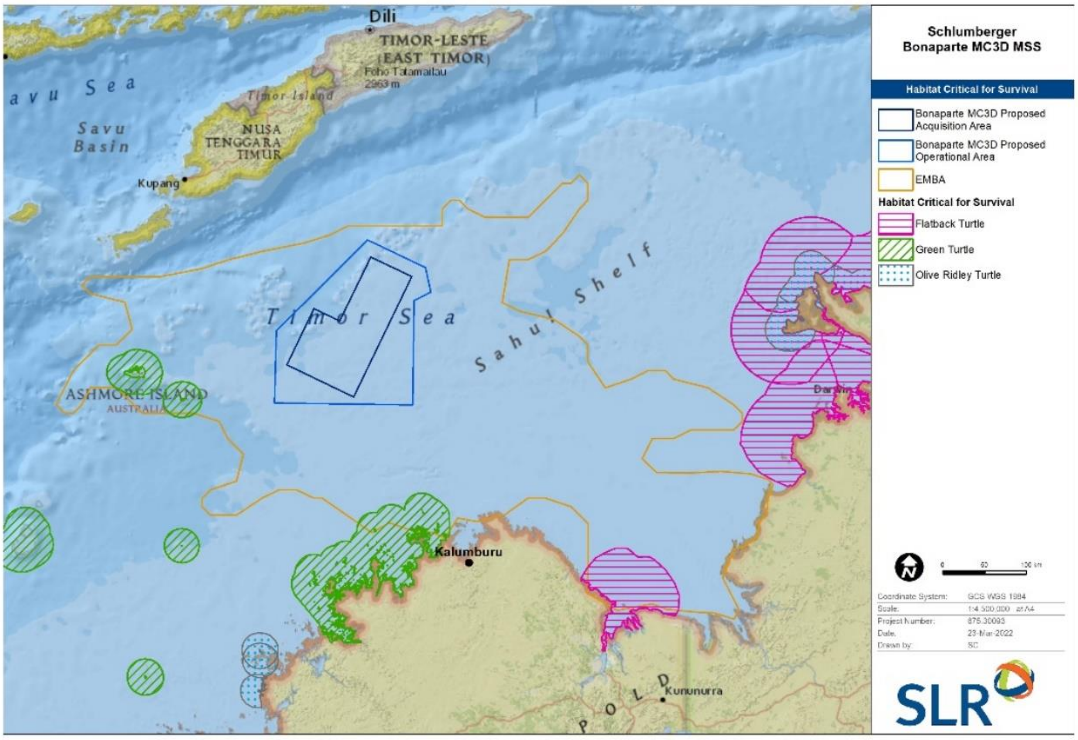


Figure 20 Marine Turtle 'Critical Habitat' as Identified by the Recovery Plan for Marine Turtles in Australia

Table 17 Relevant Nesting and Interesting Areas identified as Marine Turtle 'Critical Habitat'

	Genetic Stock	Nesting Location	Inter-nesting buffer	Season
Green Turtle	North West Shelf	Adele Island, Maret Island, Cassini Island, Lacepede Islands, Barrow Island, Montebello Islands (all with sandy beaches), Serrurier Island, Dampier Archipelago, Thevenard Island, Northwest Cape, Ningaloo coast.	20 km	Nov-Mar
	Ashmore Reef	Ashmore Reef and Cartier Reef.	20 km	Year round, peak Dec-Jan
	Scott-Browse	Scott Reef (Sandy Islet) and Browse Island.	20 km	Nov-Mar
Flatback Turtle	Arafura Sea	Field Island, Crab Island, Bare Sand Island, Tiwi Islands, Quail Island, Hawkesbury Point, Cobourg Peninsula, Wessel Islands, Gove Peninsula, Groote Eylandt Archipelago, Sir Edward Pellew Islands, Wellesley Islands, Deliverance Island, mainland beaches from Jardine River to Edward River, Crocodile Island Group.	60 km	Year round, peak Jun-Sep
	Cape Domett	Cape Domett, Lacrosse Island.	60 km	Year round, peak Jul-Sep
	Southwest Kimberley	Eighty Mile Beach, Eco Beach, Lacepede Islands.	60 km	Oct-Mar, peak Dec-Jan
	Unknown genetic stock Kimberley, WA	Maret Islands, Montilivet Islands, Cassini Island, Coronation Islands (includes Lamarck Island), Napier-Broome Bay Islands (West Governor Island, Sir Graham Moore Island – near Kalumbaru), Champagny, Darcy and Augustus Islands (Camden Sound).	60 km	May-Jul
Olive Ridley	Unknown genetic stock Kimberley, WA	Prior Point, Vulcan Island, Darcy Island, Llangi, Cape Leveque.	20 km	May-Jul

Table 18 EPBC Act List of Threatened and/or Migratory Marine Reptiles Potentially Occurring in the OA and/or EMBA

Common Name(s) Scientific Name	EPBC Act Protection Status	Distribution, Habitat and Life Stages	Records in OA/EMBA	Presence Within the OA and EMBA
Leaf-scaled sea snake *Aipysurus foliosquama*	CE	• Endemic to the NWMR being only found on reefs associated with the Sahul Shelf. Ashmore Reef and Hibernia Reef were population strongholds in the 1970s-1990s (Guinea, 1995; Guinea and Whiting, 2005; Minton and Heatwole, 1975); however, no sightings have been made here since 2001 (Guinea, 2007; Lukoschek, *et al.*, 2013). • This species occurs on the reef flats of shallow reefs (< 10 m), can be seen in tidal pools at low tide (Ehmann, 1992; McCosker, 1975; Guinea and Whiting, 2005). • Like all sea snakes, the leaf-scaled sea snake is long lived and slow growing, all reproduction stages occur at sea where live young are born after 6-7 months of gestation (DEWHA, 2008b).	OA & EMBA	Species MAY occur in OA and EMBA
Short-nosed sea snake *Aipysurus apraefrontalis*	CE	• Endemic to WA from Exmouth to Sahul Shelf, particularly Ashmore and Hibernia Reefs (DoE, 2022a). Whilst common in surveys during the 1990s, no sightings have occurred at Ashmore Reef since 1998 (Lokoschek *et al*., 2013). • Restricted to shallow reef flats (< 10 m) on the outer reef edge (Cogger, 2000; Guinea, 1993 and 1995). • Like all sea snakes, the leaf-scaled sea snake is long lived and slow growing, all reproduction stages occur at sea where live young are born after 6-7 months of gestation (DEWHA 2008b).	OA & EMBA	Species LIKELY to occur in OA Species KNOWN to occur in EMBA
Olive Ridley Turtle, Pacific Ridley Turtle *Lepidochelys olivacea*	E, M	• This is most numerous marine turtle species in the world, but the least common in the NWMR (DSEWPC, 2012). In Australia, nesting primarily occurs in NT where nest densities are low but widespread (Chatto and Baker, 2008). Breeding does not routinely occur in WA, but hatchlings have been found near Cape Leveque (200 km north of Broome) in WA (NAILSMA, 2008). Papua New Guinea and Indonesia also support low density nesting (Spring, 1982; Limpus, 1997), but the Australian breeding population may be isolated (DoE, 2022b). The breeding population in NT is estimated to be 1,000-5,000 females (Taylor *et al*., 2006). • Sexual maturity occurs between 10 – 18 years of age (Zug *et al*., 2006). Nesting occurs on sandy beaches (from Mar to Oct) before hatchlings enter a pelagic phase using offshore currents (Musick and Limpus, 1997). Movements during this phase are not well understood. Foraging is typically associated with shallow benthic habitat in water depths of 11 – 40 m (Robbins, 2002), but pelagic foraging in depths >100 m has been recorded (Whiting *et al*., 2005). Feeding occurs around the pinnacles of the Bonaparte Depression (Donovan *et al*., 2008).	OA & EMBA	Species KNOWN to occur in OA and EMBA Foraging, feeding or related behaviour known to occur within OA and EMBA

Common Name(s) Scientific Name	EPBC Act Protection Status	Distribution, Habitat and Life Stages	Records in OA/EMBA	Presence Within the OA and EMBA
Loggerhead Turtle *Caretta caretta*	E, M	• Australia supports 2-4% of the global population (DoE, 2022c) and WA supports largest population in Australia (Limpus, 2008). In WA nesting routinely occurs from Shark Bay to North West Cape, but a single nest has been recorded from Ashmore Reef (Guinea, 1995) and small numbers of nests occur as far north as the Dampier Archipelago (WA DEC, 2009). Estimates from the 1990s suggest 1000-2000 breeding females in WA (Baldwin *et al.*, 2003). • Foraging areas are widely distributed in waters around Australia (SPRAT, 2022). WA population forages from Shark Bay (WA) to Arnhem Land (NT) and across to the Indonesian Java Sea (Baldwin *et al*., 2003). The carbonate banks of JBG and the pinnacles of the Bonaparte Depression are used as feeding grounds (Donovan *et al*., 2008). • Nest on sandy beaches, before hatchlings disperse and spend c. 15 years at sea (Bjorndal *et al*., 2000) where they forage in top 5 m of water column (Spotila, 2004). Breeding adults then develop site fidelity to both benthic foraging (out to depths of 55 m, Plotkin *et al*., 1993) and nesting locations (Limpus, 2008). Nesting females are restricted to an 'inter-nesting' area within 10 km of the rookery during breeding period (Tucker *et al*., 1995). Breed from November to March with a peak in late December/early January (Limpus 1985).	OA & EMBA	Species KNOWN to occur in OA and EMBA Foraging, feeding or related behaviour known to occur within OA and EMBA
Leatherback Turtle, Leathery Turtle, Luth *Dermochelys coriacea*	E, M	• Globally found in tropical, sub-tropical and temperate waters. Only two nesting attempts have been recorded in WA (Limpus, 2009), but low-density nesting is known from QL and NT (Limpus and MacLachlan, 1994). Coarse sandy beaches are preferred for nesting (Limpus *et al*., 1984). Year-round nesting occurs in nearby Indonesia Papua New Guinea and Solomon Islands (Benson *et al*., 2011), but mortality rates here are high (Hamann *et al*., 2006). • Forages year round over Australian continental shelf pelagic habitat, but mostly in the south half of Australia (Hamann *et al.*, 2006). A foraging preference for steep bathymetry and converging currents is possible (Houghton *et al*., 2006). Dives to over 1,000 m have been recorded (Houghton *et al*., 2008). • Breeding females can lay up to 5 times over the nesting period (Spotila *et al*., 1996), but only nest every 2-3 years. Hatchlings disperse widely, but juvenile movements unknown (Lutz and Musick, 1996). Adults make large scale migrations to foraging areas in temperate seas (Benson *et al*., 2007).	OA & EMBA	Species LIKELY to occur in OA and EMBA Foraging, feeding or related behaviour likely to occur within OA Breeding likely to occur within EMBA

Common Name(s) Scientific Name	EPBC Act Protection Status	Distribution, Habitat and Life Stages	Records in OA/EMBA	Presence Within the OA and EMBA
Flatback Turtle *Natator depressus*	V, M	• Nesting for the entire species is restricted to the northern half of Australia where four breeding populations are recognised – eastern QL, Torres Strait and Gulf of Carpentaria, NT and WA (Limpus, 2007). In NT nesting occurs over the entire coastline. In WA, Cape Dommet and Lacrosse Island (in the JBG) are important nesting areas (Bowlay and Whiting, 2007) in winter (Prince, 1994a). In addition to this and further south, another WA breeding stock is recognised (Exmouth Gulf to Lacapede Islands) where nesting occurs Dec – Mar (DSEWPC, 2012). Slow growing and breed every 1-5 years (Limpus *et al*., 1983). • Foraging distribution in WA is not well known (Prince, 1998), but unlike other turtles flatback turtles lack a post-hatching dispersal phase (Walker and Parmenter, 1990) and instead stay in coastal waters near their breeding beach (DSEWPC, 2012). Adults feed on soft bottom shelf habitat off northern Australia and into Papua New Guinea and Irian Jaya (Zangerl *et al*., 1988) to depths of over 40 m (Robins, 1995). Foraging turtles have been seen in the JBG and Bonaparte Depression (Donovan *et al*., 2008).	OA & EMBA	Species KNOWN to occur in OA and EMBA Foraging, feeding or related behaviour known to occur within OA Breeding known to occur within EMBA
Green Turtle *Chelonia mydas*	V, M	• Found in tropical and subtropical waters globally. WA supports one of the largest populations (c 20,000) in the world (DEH, 2005) and this species is the most common breeding turtle in the NWMR (DSEWPC, 2012). The closest 'critical' nesting and inter-nesting area to the OA are Lacepede Islands (Environment Australia, 2003), but moderate numbers (in the low hundreds) of nests also occur annually at Ashmore Reef and Cartier Islands (Whiting *et al*., 2000) which are closer. In WA three breeding stocks are recognised: Northwest Shelf, Scott Reef and Ashmore stocks (Dethmers *et al*., 2006). The Northwest Shelf breeding stock nests between Nov and Mar, but year-round nesting occurs on Scott Reef, Ashmore Reef and Cartier Islands, peaking in summer (DEH 2005). Small rookeries occur throughout the Bonaparte Archipelago (DSEWPC, 2012). • Hatchlings enter a 5-10 year pelagic phase before settling at shallow benthic foraging habitats, over sea grass beds or algae mats on which they feed (Robins *et al*., 2002). Tagging studies on Lacepede Islands show foraging occurs in the Kimberley region, Arnhem Land, the Gulf of Carpentaria and Indonesia (Prince, 1993; Prince, 1994b). Feeding is known to occur around the pinnacles of the Bonaparte Depression (Dethmer *et al*., 2006), and Ashmore Reef is an important feeding site (DSEWPC, 2012). • This species is late to sexually mature 25-50 years (Chaloupka *et al*., 2001). Breeding females lay up to 5 clutches in a single season and breed every 1-9 years (DoE, 2022d). They remain within 5-10 km of their nesting beach during inter-nesting period (Pendoley, 2005).	OA & EMBA	Species KNOWN to occur in OA and EMBA Foraging, feeding or related behaviour known to occur within OA Breeding known to occur within EMBA

Common Name(s) Scientific Name	EPBC Act Protection Status	Distribution, Habitat and Life Stages	Records in OA/EMBA	Presence Within the OA and EMBA
Hawksbill Turtle *Eretmochelys imbricata*	V, M	• Found in tropical, sub-tropical and temperate waters around the world (DOE, 2022e). Australia supports two genetically distinct populations: 1) on the Northwest Shelf of WA and 2) comprised of Great Barrier Reef, Torres Strait and Arnhem Land. These populations represent two of the five most significant breeding populations globally (see Hoenner *et al*., 2016). • This species is very slow growing, reaching sexual maturity >31 years of age (Limpus, 1992). In WA nesting occurs year-round, with peak nest numbers from Oct to Jan (Limpus, 1995). Females nest every 2-4 years but can produce up to six clutches in a breeding season (Dobbs *et al*., 1999). Major nesting beaches occur on the offshore islands between the Dampier Archipelago (in the north) and Onslow (in the south). Nesting distribution is from North West Cape to Ningaloo (DSEWPC, 2012). • Like most turtles they have an extended pelagic phase for the first 5-10 years they then settle on coral and rocky reefs where they have a wide omnivorous diet (Whiting, 2000). WA feeding grounds are typically 50-450 km from breeding grounds, but they can migrate up to 2400 km between these sites. The area west of Cape Preston and south to Onslow is a key feeding area in WA (Pendoley, 2005), but feeding habitat is assumed throughout the NWMR (DSEWPC, 2012).	OA & EMBA	Species LIKELY to occur in OA Species KNOWN to occur in EMBA Foraging, feeding or related behaviour likely to occur within OA and EMBA
Plains Death Adder *Acanthophis hawkei*	V	• Terrestrial snake species, that occur on the plains of northern Australia (DEPWS, 2021). Can be present in coastal floodplains which is why this species is identified as potentially present in the EMBA. Irrelevant to the Seismic Survey.	EMBA	Species MAY occur in EMBA
Salt-water Crocodile, Estuarine Crocodile *Crocodylus porosus*	M	• This species occurs from King Sound (near Broome) and north through NT to QL (DoE, 2022f), inhabiting mostly tidal rivers, coastal floodplains, billabongs and swamps; however, they do also occur in coastal and offshore waters at times (Webb *et al*., 1987). In WA, river systems of the Kimberley support crocodiles, with concentrations in the Cambridge Gulf, Prince Regent River and Roe River (DoE, 2022). • Nesting occurs from Nov-May, typically in freshwater swamps without tidal influence (Webb *et al*., 1987). Hatchlings and juveniles remain close to their nests for the first year of life (Webb and Messel, 1978). Limited data exists regarding movements of adults, but relocated individuals have been recorded moving up to 280 km (Walsh and Whitehead, 1993). • Opportunistic predators, crocodiles < 180 cm eat smaller prey (mostly crabs, insects, lizards, snakes and fish), larger crocodiles are capable of eating larger mammals as well (Webb and Manolis, 1989).	EMBA	Species LIKELY to occur in EMBA

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

Table 19 EPBC Act List of Non-Threatened Marine Reptiles Potentially Occurring in the OA and/or EMBA

Common Name(s), Scientific Name	Records in OA/EMBA	Presence Within the OA and EMBA
Spine-bellied sea snake, *Lapemis curtus*	OA & EMBA	Species MAY occur in OA and EMBA
Olive sea snake, *Aipysurus laevis*	OA & EMBA	Species MAY occur in OA and EMBA
Stokes' sea snake, *Astrotia stokesii*	OA & EMBA	Species MAY occur in OA and EMBA
Spectacled sea snake, *Disteira kingii*	OA & EMBA	Species MAY occur in OA and EMBA
Olive-headed sea snake, *Disteira major*	OA & EMBA	Species MAY occur in OA and EMBA
Turtle-headed sea snake, *Emydocephalus annulatus*	OA & EMBA	Species MAY occur in OA and EMBA
Beaked sea snake, *Enhydrina schistosa*	OA & EMBA	Species MAY occur in OA and EMBA
Yellow-bellied sea snake, *Pelamis platurus*	OA & EMBA	Species MAY occur in OA and EMBA
Spine-tailed sea snake, *Aipysurus eydouxii*	OA & EMBA	Species MAY occur in OA and EMBA
Dubois' sea snake, *Aipysurus duboisii*	OA & EMBA	Species MAY occur in OA and EMBA
Horned sea snake, *Acalyptophis peronii*	OA & EMBA	Species MAY occur in OA and EMBA
Elegant sea snake, *Hydrophis elegans*	OA & EMBA	Species MAY occur in OA and EMBA
Black-headed sea snake, *Hydrophis atriceps*	OA & EMBA	Species MAY occur in OA and EMBA
Spotted sea snake, Ornate Reef sea snake, *Chitulia ornata*	OA & EMBA	Species MAY occur in OA and EMBA
Black-headed sea snake, Slender-necked sea snake, *Leioselasma coggeri*	OA & EMBA	Species MAY occur in OA and EMBA
Dusky sea snake, *Aipysurus fuscus*	EMBA	Species KNOWN to occur in EMBA
Freshwater Crocodile, Johnston's Crocodile, Johnstone's Crocodile, *Crocodylus johnstoni*	EMBA	Species MAY occur in EMBA
Plain sea snake, *Chitulia inornata*	EMBA	Species MAY occur in EMBA
Large-headed sea snake, Pacific sea snake, *Leioselasma pacifica*	EMBA	Species MAY occur in EMBA
Black-ringed sea snake, *Hydrelaps darwiniensis*	EMBA	Species MAY occur in EMBA
Northern Mangrove sea snake, *Parahydrophis mertoni*	EMBA	Species MAY occur in EMBA
Small-headed sea snake, *Hydrophis macdowelli*	EMBA	Species MAY occur in EMBA

4.5.6 Marine Mammals

A search of the EPBC Act Protected Matters Database, revealed 23 species of marine mammal as having a potential presence within the OA, with five additional species also having a potential presence within the EMBA. These species are listed in **Table 20** along with the 'presence ranking' (as assigned by the Protected Matters Database for both the OA and EMBA), their threat category and migratory status under the EPBC Act and their WA listing as 'threatened or priority fauna' under the Biodiversity Conservation Act 2016 (WA) (**BCA**). Given the pelagic nature of the OA and parts of the EMBA, several of these species are migratory and are characterised by having large oceanic distributions that are influenced by spatial and temporal variances between feeding and breeding grounds.

Table 20 Marine Mammal Species potentially occurring in the OA and EMBA

Scientific name	Common name	Presence ranking in OA	Presence ranking in EMBA	EPBC Act Threatened category	EPBC Act Migratory status	WA Listing - BCA
Balaenoptera musculus	Blue Whale	Known	Known	Endangered	Migratory	EN
Balaenoptera physalus	Fin Whale	Likely	Likely	Vulnerable	Migratory	EN
Balaenoptera borealis	Sei Whale	Likely	Likely	Vulnerable	Migratory	EN
Balaenoptera edeni	Bryde's Whale	May	Likely	-	Migratory	
Megaptera novaeangliae	Humpback Whale	Likely	Known	-	Migratory	CD
Physeter macrocephalus	Sperm Whale	May	May	-	Migratory	VU
Mesoplodon densirostris	Blainville's Beaked Whale, Dense-beaked Whale	-	May	-	-	-
Ziphius cavirostris	Cuvier's Beaked Whale, Goose-beaked Whale	May	May	-	-	-
Orcinus orca	Killer Whale, Orca	May	May	-	Migratory	-
Pseudorca crassidens	False Killer Whale	Likely	Likely	-	-	-
Feresa attenuata	Pygmy Killer Whale	May	May	-	-	-
Globicephala macrorhynchus	Short-finned Pilot Whale	May	May	-	-	-
Peponocephala electra	Melon-headed Whale	May	May	-	-	-
Kogia breviceps	Pygmy Sperm Whale	May	May	-	-	-
Kogia sima	Dwarf Sperm Whale	May	May	-	-	-
Grampus griseus	Risso's Dolphin, Grampus	May	May	-	-	-

Scientific name	Common name	Presence ranking in OA	Presence ranking in EMBA	EPBC Act Threatened category	EPBC Act Migratory status	WA Listing - BCA
Tursiops truncatus s. str.	Bottlenose Dolphin	May	May	-	-	-
Tursiops aduncus	Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin	May	Likely	-	-	-
Tursiops aduncus (Arafura/Timor Sea populations)	Spotted Bottlenose Dolphin (Arafura/Timor Sea populations)	May	Known	-	Migratory	-
Stenella longirostris	Long-snouted Spinner Dolphin	May	May	-	-	P4
Stenella coeruleoalba	Striped Dolphin, Euphrosyne Dolphin	May	May	-	-	-
Stenella attenuata	Spotted Dolphin, Pantropical Spotted Dolphin	May	May	-	-	-
Steno bredanensis	Rough-toothed Dolphin	May	May	-	-	-
Delphinus delphis	Common Dolphin, Short-beaked Common Dolphin	May	May	-	-	-
Lagenodelphis hosei	Fraser's Dolphin, Sarawak Dolphin	-	May	-	-	-
Orcaella heinsohni	Australian Snubfin Dolphin	-	Known	-	Migratory	P4
Sousa sahulensis	Australian Humpback Dolphin	-	Known	-	Migratory	P4
Dugong dugon	Dugong	-	Known	-	Migratory	OS

Key: EN = Endangered species, VU = Vulnerable species, CD = Species of special conservation interest (conservation dependent fauna), P4 = Priority 4: Rare, Near Threatened and other species in need of monitoring, OS = Other specially protected fauna.

Ecological summaries for the species 'known' or 'likely' to be present in and around the OA and EMBA are provided in the following subsections. In addition, while Omura's whale (*Balaenoptera omurai*) is not identified as having a potential presence in the OA or the EMBA by the EPBC Protected Matters Database, occurrence of this small baleen whale has been noted in the vicinity of the OA and EMBA (Cerchio *et al*., 2019 and references therein). Hence this EP assumes that this species could also be present. Omura's whales were only recently described by Wada et al (2003), and a paucity of information currently prohibits detailed conclusions about potential habitat use by this species within the OA and EMBA. However, McPherson *et al*. (2016) conducted acoustic monitoring at the Barossa Field in 2014/15 (300 km north of Darwin, and over 450 km northeast of the OA) and recorded calls which were attributed to this species in all months of the year, except for the period from 1 Nov to 23 Dec. For the Barossa Field, a consistent presence (as characterised by high call rates) was noted from Apr to Sep with a peak in Jun/Jul, particularly in at the deepest monitoring station (c. 240 m). Whales appeared to arrive and depart the Barossa Field from the southwest, indicating that they most likely have a year-round presence in the Timor Sea. Strandings and sightings of this species have been recorded in Western Australia, with observations of this species feeding over deep shoals and reefs with newborn calves present (marine mammalscience.org as cited in McPherson *et al*. 2016).

Likewise, dwarf minke whale (*Balaenoptera acutorostrata* ssp.) calls were commonly detected by McCauley (2011) around Scott Reef from May to September, so a possible presence of this species in the OA and EMBA have been assumed over this period.

No pinniped species are identified by the EPBC Protected Matters Database as having a potential presence within the OA or the EMBA. Although Australian sea lions and New Zealand fur seals do occur in WA their distribution is restricted to the southwest coast (south of Shark Bay and Kalbarri respectively).

There are several BIAs for marine mammals in the vicinity of the OA and EMBA (**Figure 21** and **Figure 22)**, including:

- Australian snubfin dolphin – although the OA does not overlap with any BIAs for this species, the EMBA overlaps with breeding/calving/resting and foraging BIAs in the vicinity of Kalumburu and Scambridge Gulf. The nearest BIA is located approximately 129 km south of the OA.
- Dugong – the EMBA overlaps with the dugong foraging (including high density) and breeding/calving/nursing BIAs located around Ashmore Reef, approximately 155 km west of the OA.
- Humpback whale – while there is no overlap between the humpback whale BIA and the OA or EMBA, a breeding and calving BIA occurs approximately 210 km to the south of the OA.
- Australian humpback dolphin (listed as Indo-Pacific humpback dolphin) – although the OA does not overlap with any BIAs for this species, the EMBA overlaps with foraging (including high density) and significant habitat BIAs in the vicinity of Kalumburu and breeding and foraging BIAs are also located near Darwin Harbour.
- Indian Ocean bottlenose dolphin/spotted bottlenose dolphin (listed as Indo-Pacific/ spotted bottlenose dolphin) – although no overlap occurs with either the OA or EMBA, breeding/calving and foraging BIAs for this species are located in the vicinity of Augustus Island (285 km south of the OA). A breeding BIA for the species is also located near Darwin Harbour.
- Blue whale migration and known distribution BIAs which overlap with the OA. The nearest blue whale feeding BIA is located 294 km southwest of the OA.

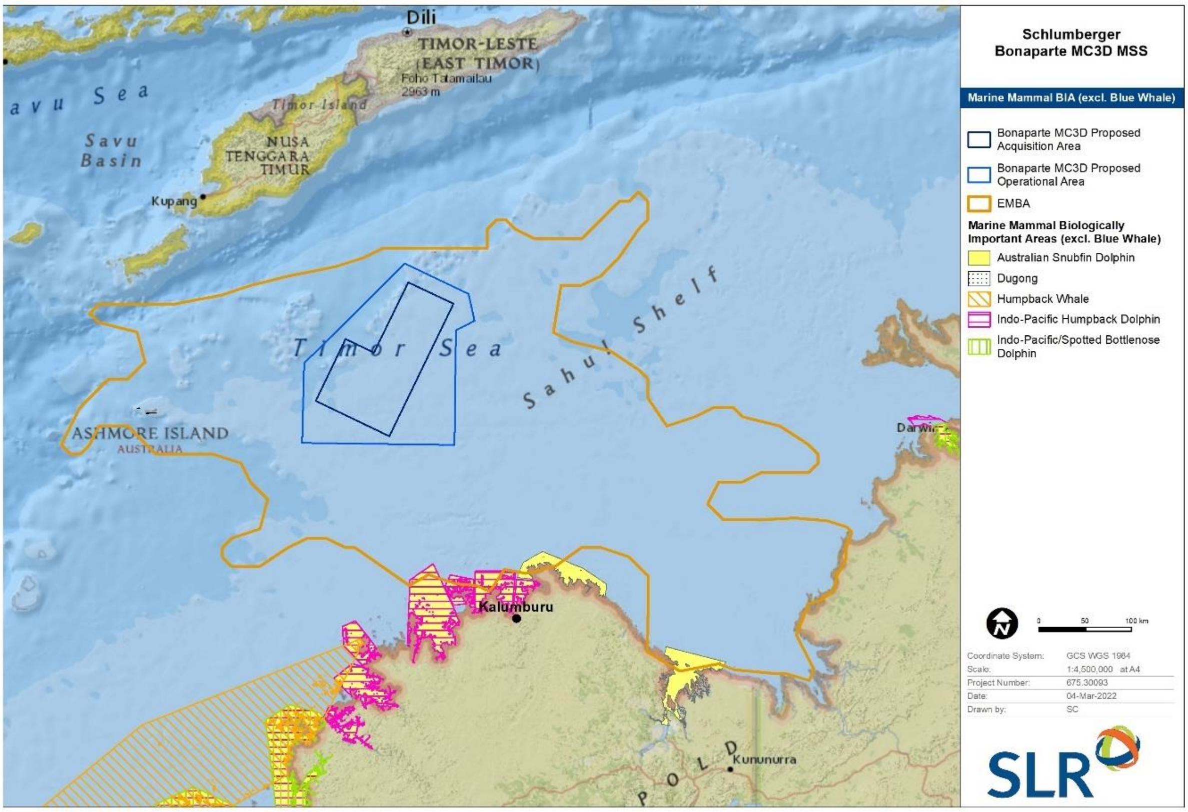


Figure 21 Marine Mammal BIAs in the vicinity of the OA and EMBA (excluding blue whales)

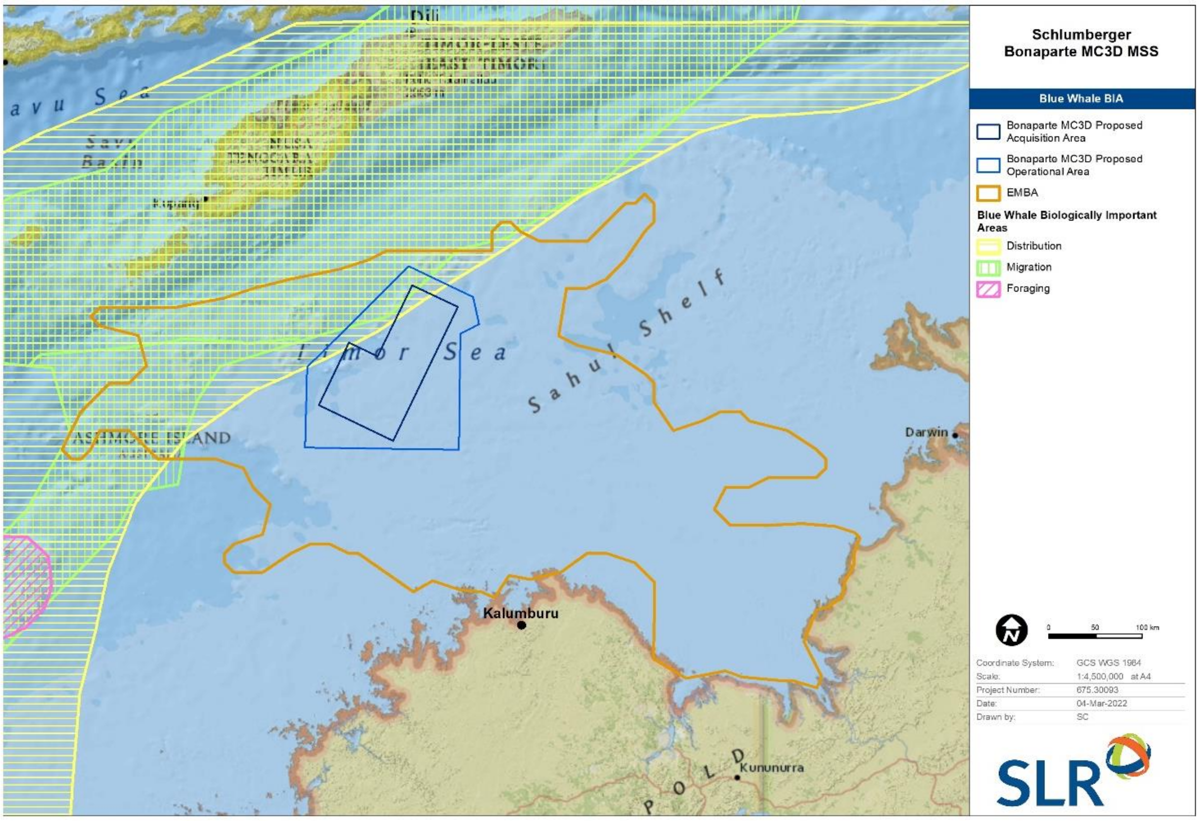


Figure 22 Blue whale BIAs in the vicinity of the OA and EMBA

4.5.6.1 Humpback whales

Humpback whales are currently listed by the IUCN as 'least concern' and this species has recently been removed from the Australian Federal Government's list of threatened species on account of the strong recovery trends for this species in Australian waters since full protection was afforded to them in 1965 (Australian Government, 2022). Within WA, this species is listed as 'conservation dependant' under the BCA (Wildlife Conservation (Specially Protected Fauna) Notice 2018, schedule 6).

Humpback whales undertake the longest migration of any mammal (Jackson *et al.*, 2014). They are seasonal migrants that move between low latitude winter breeding grounds and mid- to high-latitude productive summer feeding grounds (Pomilla and Rosenbaum, 2005; Robbins *et al*., 2011). Although humpbacks may utilise deep oceanic waters during migrations, they are typically a coastal species when breeding and feeding (Smith *et al.,* 2012).

The population of humpback whales that can be found in WA is referred to by the International Whaling Commission as Breeding Stock D (from here on referred to as humpback whales) and migrates annually from Antarctic feeding grounds in summer to winter breeding and calving grounds. Most breeding activity occurs on the east coast of Australia, but calving takes place in the coastal Kimberley Region from Camden Sound in the north to Broome in the south (15-18°S) (210 km south of the OA); however, the presence of neonates further south indicates that calving does occur as far south as North West Cape (Irvine *et al*., 2017). Low densities of whales were found north of Camden Sound which is thought to represent the northern distributional limit of humpback whales during the breeding season (Thums *et al*., 2018). The breeding season is relatively well defined for the Kimberley region and extends from late Jun to early Oct (How *et al.*, 2020). Peak numbers occur in early Aug (How *et al*., 2020) to mid Aug (Thums *et al*., 2018).

Northbound whales leave Antarctica in Mar/Apr and migrate along the WA coastline between Jun and Aug and southbound whales occur along the NW WA coast from Aug to Nov (MMPATF, 2022). The migration corridor along NW WA is typically coastal with whales staying mostly in waters less than 200 m deep; however, some deviation into deeper water is occasionally observed by southbound whales off the Ningaloo coast (e.g. Gales *et al*., 2010). Abundance for this population was thought to be more than 30,000 individuals in 2008 and was in a phase of exponential increase (Salgado-Kent *et al*., 2012).

Both male and female humpbacks produce communication calls, but only males emit the long, loud, and complex 'songs' associated with breeding activities. Dunlop *et al*. (2007) recorded social vocalisations of migrating east Australian humpbacks and recorded frequencies ranging from <30 Hz to 2.5 kHz over 34 different vocalisation types. The source level of singing humpback whales ranges from 123 – 183 dB re 1 µPa @ 1 m (Dunlop *et al.,* 2013). Surface-generated social sounds (e.g. breaches, pectoral slaps, and tail slaps) are also generated by humpback whales and are thought to have a communicative function (Dunlop *et al.,* 2010). These surface-generated sounds have been reported to be in the range of 133 – 171 dB re 1 µPa @1 m (Dunlop *et al.,* 2013).

The EPBC Act Protected Matters Database considers that humpback whales are known to occur in the EMBA and are likely to occur in the OA. There is no overlap between the humpback whale BIA and the OA or EMBA as the nearest BIA occurs approximately 210 km south of OA.

4.5.6.2 Blue whales

There are two subspecies of blue whale recognised in the Southern Hemisphere; the pygmy blue whale (*B. musculus brevicauda*) and the Antarctic blue whale (*B. musculus intermedia*). These two subspecies are difficult to distinguish without the use of genetic techniques, but differ in morphology, distribution, and vocal behaviour. Following an analysis of acoustic detections, and stranding, sighting and historical catch records, Branch *et al.*, (2007) concluded that the majority of blue whales in the Australian region are probably pygmy blue whales, but that a few Antarctic blue whales may migrate to Australia in the austral winter, but Antarctic blue whales tend to have a more southern distribution than pygmy blue whales (Commonwealth of Australia, 2015).

Pygmy blue whales are currently listed by both the IUCN and the EPBC Act as Endangered. In WA they are listed as 'fauna that is rare or is likely to become extinct' in the Wildlife Conservation (Specifically Protected Fauna) Notice 2010, and under state policy they are ranked as endangered based on the IUCN criteria. The Southeast Indian Ocean pygmy blue whale population (also known as Indo-Australian pygmy blue whale population) inhabits waters from Indonesia along the coast of WA, and beyond into South Australia and the Southern Ocean (from here on referred to as pygmy blue whales). As with most baleen whales they undertake an annual migration from higher latitude feeding grounds to lower latitude breeding grounds. Pygmy blue whales feed on krill and depend on areas of high krill density to meet their high calorific requirements. Generally speaking, pygmy blue whales are present at feeding grounds from November to May (Commonwealth of Australia, 2015); however, a finer scale analysis of migration timing is provided later in this subsection.

Using data from both satellite tagging studies (2009-2021, a total of 22 tagged whales) and acoustic monitoring studies (2006-2019), the three most important feeding grounds in WA for this population have recently been confirmed by Thums *et al*. (2021) as being 1) the Perth Canyon and vicinity, 2) the shelf edge off Geraldton, and 3) the shelf edge from Ningaloo Reef to Rowley Shoals. This population also utilises feeding grounds at the Bonney Upwelling and other upwelling features off SA, Vic and Tas (Gill, 2002; McCauley *et al*., 2018; Möller *et al*., 2020) and south of Australian waters along the subtropical convergence zone (Garcia-Rojas *et al*., 2018). Acoustic detections from Scott Reef (c. 300 km southwest of the OA) have been consistently made (McCauley, 2011) and it has been suggested that this, coupled with high krill densities (Sutton *et al*., 2019), could indicate that some feeding may also occur here. While feeding at Scott Reef cannot be dismissed, Thums *et al*. (2021) suggests that this site (if indeed it does support feeding) is of lower relative importance. Despite this, Scott Reef potentially represents the nearest feeding location of pygmy blue whales to the OA. It is also noteworthy that foraging does occur along the migratory route, Double *et al*. (2014) and Möller *et al*. (2020) also suggest that foraging could also occur at the Indonesian breeding grounds as productive upwellings occur here from July to September each year which coincides with pygmy blue whale presence (Double *et al*., 2014).

While a total population abundance estimate is unavailable for the Southeast Indian Ocean pygmy blue whale, photo-identification mark-recapture estimates of the number of whales using the Perth Canyon foraging habitat are between 532 and 1,754 individuals (Jenner *et al*., 2008), and similar estimates of 662 to 1,559 were made following an acoustic assessment of southbound migrating blue whales off Exmouth (McCauley and Jenner, 2010). The total population size is assumed to be much higher though as these assessments only account for one of the known important feeding locations.

Sexual maturity of pygmy blue whales is reached at approximately 10 years of age, and adult females calve every two to three years (Commonwealth of Australia, 2015). Evidence suggests that the breeding ground for this population occurs in Indonesian waters, including Banda Sea, Molucca Sea, Timor Sea and Savu Sea (Gales *et al*., 2010; Thums *et al*., 2021).

Understanding migration timing and migration route is central to understanding temporal and spatial effects of anthropogenic activities on pygmy blue whales. It is noteworthy that there is substantial individual variation in both (Thums *et al*., 2021). For this reason, it is difficult to provide absolute time periods during which whales will certainly pass through or nearby the OA, but **Table 21** summarises multiple lines of evidence to suggest the months when whales could be in the vicinity of the OA.

Table 21 Migration timing of Pygmy Blue Whales in the vicinity of the OA

Month	Northwest WA - Between 12.4°S and 23.6°S - Satellite tag data - 13 whales (N), 2 whales (S) - Source: Thums *et al.* (2021)	Indonesia - North of 12.4°S, limit of EEZ - Satellite tag data - 6 whales (N), 2 whales (S) - Source: Thums *et al.* (2021)	Scott Reef - Between 13.45°S to 14.25°S - Acoustic monitoring data - 12 noise loggers - Source: McCauley, 2011	Assumed Presence of Pygmy Blue Whales in OA - See text for more context
Apr (start of northward migration period)	Migrating north, earliest date 12 Apr		Calls detected from early-Apr	Presence of northbound whales from late Apr
May	Migrating north	Migrating north, earliest date 15 May	Calls detected	Presence of northbound whales
Jun	Migrating north	Migrating north	Calls detected	Presence of northbound whales
Jul	Migrating north, latest date 12 Jul	Migrating north	Calls detected	Presence of northbound whales
Aug		Migrating north	Calls detected until mid-Aug	Presence of northbound whales
Sep (start of southward migration period)	Migrating south, earliest date 23 Sep	Migrating south		Presence of southbound whales from late Sep
Oct	Migrating south	Migrating south, latest date 11 Oct	Calls detected from early Oct	Presence of southbound whales
Nov	Migrating south, latest date 3 Nov		Calls detected	Presence of southbound whales
Dec			Calls detected	Presence of southbound whales
Jan			Calls detected until mid-Jan	Presence of southbound whales
Feb				
Mar				

For the northbound migration, the conclusions presented in column 5 of are underpinned by the data presented by Thums *et al*. (2021) regarding the occupancy rates of whales during migration where the time whales spent in northwest WA (12.4°S to 23.6°S) was: 19 ± 6 days on the northern migration (n = 13). On this basis, theoretically:

- Individual whales embarking on their northern migration early in the season, for example say 12 April, could be expected to pass into Indonesian waters (12.4°S, i.e. close to the OA), anytime from c. 25 April to 7 May; and
- Individual whales embarking on their northern migration late in the season, for example say 12 July, could be expected to pass into Indonesian waters (12.4°S, i.e. close to the OA), anytime from c. 25 July to 6 August.

Satellite tagging data and acoustic data (see **Table 21**) align well with regard to the extent of the northbound migration period; indicating that in the vicinity of the OA whales will be passing in a northbound direction from April to August.

There is however some uncertainty about the extent of the southbound migration period as tagging data suggests that, in the vicinity of the OA, whales will be travelling south from September to November, but acoustic data collected by McCauley (2011) from Scott Reef suggests that the southern migration period may extend until January. Of note here is that only two of the tagged whales documented by Thums *et al*. (2021) continued to transmit data during the southbound migration, so the sample size here is highly restrictive, and as highlighted by the authors, further research is needed regarding the southbound migration. For this reason, this EP takes a precautionary approach and assumes that southbound whales could be present in and around the OA until January.

There is considerable variability in the characteristics of the northward migratory corridor with latitude, where along the southern part of WA as far north as North-West Cape – Rowley Shoals, the corridor occurs relatively close to the Australian coast (100 ± 1.7 km) (Double *et al*., 2014) and is relatively narrow (Thums *et al*., 2021). North of Rowley Shoals, the migratory corridor widens substantially and becomes highly dispersed over an area of up to c. 700 km (Thums *et al*., 2021). In general, the migratory route of pygmy blue whales off WA makes extensive use of continental slope habitat (as opposed to shelf habitat which is more typical of pygmy blue whale movements off SA) (Thums *et al*., 2021). This highly dispersed nature of the migratory corridor in the vicinity of the OA means that whale density at this latitude is low, and although tag durations reported by Thums *et al*. (2021), were insufficient to document all tagged whales through to the Banda Sea breeding ground, it appears that at least half of the tagged whales were on a trajectory to pass along the west coast of Timor (see Figure 2 of Thums *et al*., 2021) before their tags stopped transmitting. Further to this, McCauley *et al*. (2011) reported that only 6-40% of the whales that pass Exmouth also pass Scott Reef (c. 300 km southwest of the OA) and no tagged whales travelled inshore of Scott Reef (Thums *et al*., 2021). This provides further evidence that a high proportion of northbound whales disperse widely as they progress north and therefore, whale density within the OA is expected to be low.

Some evidence of foraging or breeding or resting (characterised by lower rates of directional movement) was detected by Thums *et al*. (2021) along the east coast of Timor, but in general, this area is more commonly characterised by migratory behaviours. The most important migratory path at this latitude is however along the west coast of Timor (Thums *et al*., 2021) through the Savu Sea.

Thums *et al*., (2021) provide an assessment that compares the placement and extent of the existing pygmy blue whale BIAs (see **Figure 22**) with the locational data from tagged whales and acoustic detections. They concluded that there is generally good alignment between the migration BIA and the collected data. They did note that the migration BIA encompasses not only migratory behaviours, but also the presumed feeding/breeding/resting area in the Banda Sea, stating that further research is required to quantify the extent of area used by whales for different behaviours in Indonesian waters.

Blue whales vocalise at a low frequency (average of 0.01 – 0.110 kHz) (McDonald *et al.*, 2001; Miller *et al.*, 2014), meaning that their calls travel hundreds of kilometres underwater. Vocalisations of pygmy blue whales off Cape Leeuwin (WA) have been characterised as songs of either two or three repeating tonal sounds with harmonics (Gavrilov *et al.,* 2011). The most intense tonal sounds were recorded to have a source level of 179 ±2 dB re 1 µPa @ 1 m. Weaker short-duration calls of impulsive down-swept sounds were estimated to have source levels of 168 – 179 dB re 1 µPa @ 1 m (Gavrilov *et al.,* 2011).

The EPBC Act protected Matters Database considers that blue whales are known to occur in the OA and EMBA, and both the OA and EMBA overlap with distribution and migration BIAs for this species. The closest foraging BIA is located around Scott Reef to the southwest of the OA and EMBA (**Figure 22**).

4.5.6.3 Fin whale

Fin whales are currently listed by the IUCN and the EPBC Act as 'vulnerable'. Within WA, this species is listed as 'endangered' under the BCA. In general, fin whales are found in offshore waters throughout the world (NOAA, 2018). Like other baleen whales, they head to high latitudes (between 50°S and 65°S) to feed over the summer months (Miyashita *et al*., 1995) and move to warmer lower latitude waters during winter to breed. Their migration paths are oceanic, and do not obviously follow coastlines (Bannister *et al.,* 1996). The migratory distribution of fin whales around Australia was investigated by Aulich *et al*. (2019) using passive acoustic monitoring and the results of this study for WA are summarised below.

Five monitoring stations were located along the WA coast at (from north to south) Scott Reef, Dampier, Montebello Islands, Onslow, Perth Canyon and Cape Leeuwin. Despite a three-year monitoring period at Scott Reef (the closest monitoring station to the OA), no fin whale vocalisations were detected at this location, neither were there any recorded off Onslow (two-year deployment). Calls were however detected from the Dampier, Perth Canyon and Cape Leeuwin stations. Perth Canyon represented the WA site with the greatest number of detections with a total of c. 177,000 fin whale pulses detected between 2009-2016. Across years, whales had a seasonal presence here from May to October. Fin whales were only recorded in two of the four survey years at Dampier where detections were made from August to October. The authors hypothesised that the lower rate of detection for Dampier could indicate either that whales at this latitude are spread across a wider offshore area; hence density and therefore detection rates are substantially lower or that most whales do not reach waters this far north. The lower detection rates for the Montebello Island and Onslow sites were more likely to reflect a smaller detection range based on shallower deployment sites.

Despite fin whales being listed as 'likely' to occur in the OA on the EPBC Protected Matters Database, the lack of acoustic detections north of Dampier suggest that if they do occur further north they will be at very low densities.

Fin whale communication vocalisations have been described as short (<1 second) down-swept tones, between 28 and 15 Hz at source levels of 189 ± 4 dB re 1 µPa @1 m (Širović *et al*., 2007).

The EPBC Act Protected Matters Database considers that fin whales are likely to occur in the OA and EMBA.

4.5.6.4 False killer whale

False killer whales are currently listed by the IUCN as ‘near threatened’ on account of their low natural densities, declining population trends and widespread impacts from fisheries bycatch. False killer whales are not listed as a threatened or migratory species by the EPBC Act, and within WA, this species is not listed as ‘threatened or priority fauna’ under the BCA.

Distributional information for this species at sea occurrence is scant for Australian waters, but strandings data suggests that false killer whales are widely distributed (Bannister *et al*., 1996; Chatto and Warneke 2000; Nicol 1987). Seasonal latitudinal changes and inshore/offshore movements may occur in response to the presence of warm oceanic currents and prey availability, such movements have been described for this species in western North Pacific and the northeastern Pacific (Culik, 2005; Ross, 2006).

Satellite tracking of four false killer whales was undertaken in the Arafura and Timor Seas in 2014 and indicated that although tagged individuals travelled large distances (over 7,500 km in c 100 days), the median distance from land was 24 km (range 100 m to 188 km) and water depth range was 0.3 to 118 m (Palmer *et al*., 2017). Locational positions from tracked whales extended from northwest of Darwin to Cape Wessel (Palmer *et al*., 2017). It is unknown if Australia waters support separate inshore and offshore populations as has been documented for other locations (e.g. in Hawaii: Baird *et al*., 2008), but this possibility may explain why the apparent distribution of tagged animals off the NT coast did not conform to the typical habitat preference for this species which is for deep oceanic waters (Stacey and Baird, 1991).

Despite false killer whales being listed as ‘likely’ to occur in the OA on the EPBC Protected Matters Database, this species typically occurs at low natural densities (Baird, 2018).

4.5.6.5 Sei whale

Sei whales are currently listed by the IUCN as ‘endangered’ and as ‘vulnerable’ by the EPBC Act. Within WA, this species is listed as ‘endangered’ under the BCA. Sei whales are thought to undertake a similar annual migration as other great whale species, although the timing of the sei whale migration is possibly later than the other species (Commonwealth Government, 2005).

Sei whales tend to prefer warmer water temperatures than other baleen whales (Mizroch *et al.*, 1984); their preferred water temperature is between 8 and 18°C (Horwood, 2009). In the south Indian Ocean the summer distribution (Jan-Feb) is thought to occur mostly between 40-55°S (Miyashita *et al*., 1995), but winter distributions at lower latitudes are not well understood. Sei whale occurrence and distribution in Australian waters has been complicated by the appearance similarities between sei and Bryde’s whales; with many early records of sei whales not thought to be Bryde’s whales which are more common in warmer waters (DoE, 2022g). In general this species is infrequently sighted in Australian waters, but records from WA do exist (Commonwealth, 2005).

Sei whale vocalisations have been recorded as low-frequency down-sweep calls that sweep from 82 to 34 Hz over 1.4 seconds, most often produced as a single call but occasionally as pairs or triplicates (Baumgartner *et al*., 2008). As well as low-frequency tonal and swept calls, McDonald (2006) also recorded broadband sounds described as ‘growls’ or ‘wooshes’. The maximum source level of tonal calls recorded by McDonald (2006) was 156 ±3.6 dB re 1 µPa @ 1 m.

The EPBC Act Protected Matters Database considers that sei whales are likely to occur in the OA and EMBA.

4.5.6.6 Bryde's whale

Bryde's whales are currently listed by the IUCN as of 'least concern' and as 'migratory' by the EPBC Act. Within WA, this species is not listed as threatened or priority fauna under the BCA.

Year-round acoustic detections of Bryde's whales near Scott Reef were detected by McCauley (2011). This report also noted that Bryde's whale calls have also been detected from locations north of Darwin to off Exmouth with no apparent seasonality. In general, the distribution of Bryde's whales is typically restricted to tropical and warm temperate waters with a latitudinal range of between 40°N and 40°S (Kato, 2002). A point of difference between Bryde's whales and other baleen whales is that they do not migrate (Kato, 2002).

Oleson *et al*. (2003) analysed Bryde's whale calls from the Eastern Tropical Pacific, the Caribbean, and the Northwest Pacific. Whilst they concluded that regional variations in calls were present, Bryde's whales typically produce low frequency 'tonal' and 'swept' calls that are not dissimilar to other baleen whales. Virtually all calls analysed had a fundamental frequency below 60 Hz and were produced in extended sequences (Oleson *et al.*, 2003).

The EPBC Act Protected Matters Database considers that Bryde's whales may occur in the OA and are likely to occur in the EMBA.

4.5.6.7 Indian Ocean Bottlenose Dolphin and Spotted Bottlenose Dolphin

The Indian Ocean bottlenose dolphin is currently listed by the IUCN as 'near threatened' but is not listed by the EPBC Act or the BCA; however, DoE (2022h) recognises that the taxonomic and conservation status of many populations is unknown. The spotted bottlenose dolphin population of the Arafura and Timor Seas is currently considered to be a regional population of the broader taxonomic unit that is referred to as the Indian Ocean bottlenose dolphin (CMS, 2016).

Indian Ocean bottlenose dolphins are restricted to coastal waters of the Indo-Pacific, Indian and Western Pacific Oceans, where they are most commonly found in water depths less than 100 m (Wang, 2018). Within Australian waters, this species is distributed contiguously around the Australian mainland, where they have been confirmed to occur in bays and estuaries, nearshore waters, open coast environments, and shallow offshore waters off eastern, western, and northern Australia (Hale *et al.,* 2000; Möller and Beherehary, 2001).

The vocalisations of Indian Ocean bottlenose dolphins are likely to be similar to those of common bottlenose dolphins which include echolocation clicks in the frequency range of 0.1 to 300 kHz (source levels of 125 to 173 dB re 1 µPa at 1 m), and communication whistles from 0.8 to 24 kHz (source levels of 218-228 dB re 1 µPa at 1 m) (Au *et al*., 1974; Evans, 1987; Richardson *et al*., 1995).

The EPBC Act Protected Matters Database considers that the Indian Ocean bottlenose dolphin may occur in the OA and is likely to occur in the EMBA, and that the regional spotted dolphin population from the Arafura and Timor Seas may occur in the OA and is known to occur in the EMBA. Although no overlap occurs with either the OA or EMBA, breeding/calving and foraging BIAs for this species (*Tursiops aduncus*), listed as Indo-Pacific/Spotted bottlenose dolphins, are located in the vicinity of Augustus Island. A breeding BIA for the species is also located near Darwin Harbour.

4.5.6.8 Australian Snubfin Dolphin

Australian snubfin dolphins are currently listed by the IUCN as 'vulnerable' and as 'migratory' by the EPBC Act. Within WA, this species is listed as 'Priority 4' under the BCA which relates to 'rare, near threatened and other species in need of monitoring'.

The distribution of this species is primarily shallow coastal waters (< 20 m deep) around the northern half of Australia between Broome and Brisbane River (Parra *et al*., 2002). Occurrence tends to be particularly associated with estuaries, river mouths and seagrass beds, but records of this species have been made out to 23 km offshore and along the northern Sahul Shelf (Parra, 2006; Parra and Corkeron, 2001; Parra *et al*., 2002; DoE 2022i). It is possible that Australian snubfin dolphins use shallow waters of the Sahul Shelf to transit between Australian coastal waters and eastern Indonesia and Papua New Guinea (DoE, 2022i), indeed a record of this species exists from Papua New Guinea (Beasley *et al*., 2002).

In WA, important areas for this species occur at Beagle and Pender Bays on the Dampier Peninsula, and Yampi Sound, and between Kuri Bay and Cape Londonderry (DEWHA, 2008b), although detailed population assessments for this species in WA have not been conducted to date. Evidence from this species in Queensland suggest that alongshore home-ranges for this species are large (Parra, 2006) and that average pod size is 5 individuals range 1-15) (Parra, 2005).

The EPBC Act Protected Matters Database considers that Australian snubfin dolphins are known to occur in the EMBA. Although the OA does not overlap with any BIAs for this species, the EMBA overlaps with breeding/calving/resting and foraging BIAs in the vicinity of Kalumburu and Scambridge Gulf.

4.5.6.9 Australian Humpback Dolphin

Australian humpback dolphins are currently listed by the IUCN as 'vulnerable' and as 'migratory' by the EPBC Act. Within WA, this species is listed as 'Priority 4' under the BCA which relates to 'rare, near threatened and other species in need of monitoring'.

This species occurs in tropical and subtropical waters along the northern Australian coast, including across the Sahul Shelf where they range between Australian waters and waters around the island of New Guinea (Jefferson and Rosenbaum, 2014), however uncertainties about the distribution around New Guinea and throughout the Arafura Sea remain due to lack of surveys in this area (Parra and Cagnazzi, 2016). While some movement between jurisdictions may occur, the majority of sightings data in Australian waters indicates that this species occupies coastal waters (< 20 km from shore) or sheltered offshore locations (close to islands or reefs) most of the time (Parra and Cagnazzi, 2016). Indeed, sightings in WA occurred in both clear water and turbid water habitats within 5 km of the coast, from 1 – 40 m water depth (see Parra and Cagnazzi, 2016). This species typically occurs in small groups and low levels of dispersal between populations has been hypothesised based on genetic studies (Parra and Cagnazzi, 2016).

The EPBC Act Protected Matters database considers that Australian humpback dolphins are known to occur in the EMBA. Although the OA does not overlap with any BIAs for this species, the EMBA overlaps with foraging BIAs in the vicinity of Kalumburu and breeding and foraging BIAs for Australian humpback dolphins (*Sousa sahulensis*), listed as Indo-Pacific humpback dolphins, are also located near Darwin Harbour (**Figure 21**).

4.5.6.10 Dugong

Dugongs are currently listed by the IUCN as 'vulnerable' and as 'migratory' by the EPBC Act. Within WA, this species is listed as 'other specially protected fauna' under the BCA which relates to 'fauna otherwise in need of special protection to ensure their conservation'. Dugongs have a patchy, but large distribution across the South Pacific, occurring in Papua New Guinea, Solomon Islands, Vanuatu, New Caledonia, Palau and Australia (Gillespie, 2005). Given their reliance on seagrass habitats for food, their distribution is closely linked to the presence of seagrass meadows in tropical and subtropical waters. The highest densities of dugongs occur in large shallow bays, wide mangrove channels or in the lee of nearshore islands (Marsh *et al*., 2011), although they also use some offshore habitat over shallow, protected areas of the continental shelf (DoE, 2022j). In WA, several areas support dugong populations; however, the Kimberley Coast, including Roebuck Bay (Brown *et al*., 2014) and Ashmore Reef are of relevance to the EMBA. In general dugongs spend most of their time in water depths of less than 3 m (Chilvers *et al*., 2004).

Patchy seagrass habitat means that individual dugongs move between significant seagrass meadows (Sheppard *et al*., 2006), but the movement pattern and extent of individuals tends to vary substantially. The largest distance that an individual has been recorded travelling (between foraging habitats) is 560 km (Sheppard *et al*., 2006). Dugongs are a long-lived slow breeding species that are subject to a wide range of threats across their distribution (Woinarski *et al*., 2014).

The EPBC Act Protected Matters Database considers that dugongs are known to occur (including breeding) in the EMBA. The EMBA overlaps with the dugong foraging and breeding/calving/nursing BIAs located around Ashmore Reef. The dugong population at Ashmore Reef is estimated at c. 100 individuals (all age classes represented) and is possibly genetically distinct from other Australian populations (Whiting and Guinea, 2005). Habitat used by these dugongs here is considered unusual in its oceanic nature compared to populations around the Australian mainland, and a dugong sighting 130 km east of Ashmore Reef suggests that dugongs may also utilise other shallow areas of the Sahul Shelf (Whiting and Guinea, 2005). There is no overlap between the dugong BIAs and the OA.

4.5.7 Seabirds and Migratory Shorebirds

There are over 100 species of seabirds that occur naturally or regularly visit Australia during the course of their lifecycle. Australia's coastal and oceanic habitats, particularly offshore islands and surrounding waters are critically important areas for seabirds during the breeding and non-breeding season as places to breed, rest and feed. For long-distance migratory species, these habitats also provide resources so birds can build enough energy reserves to travel the long distance to complete their annual migration.

The DoEE has prepared a draft of a wildlife conservation plan for seabirds (DoEE, 2019). The Plan aims to provide a strategic national framework for the research and management of listed marine and migratory seabirds and to outline national activities to support the conservation of 76 seabird species and their habitat in Australia and beyond.

Many migratory shorebirds and seabird species are known to occur in the NWMR and NMR and 34 bird species are considered to be ecologically significant for the marine parks; 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 vulnerable.

A number of seabirds and BIAs have been identified as potentially present within the OA and/or EMBA. A description of the distribution, migration movements, preferred habitat and life stages of the identified marine bird species is provided in **Appendix D**. The offshore distribution of seabirds is patchy, with birds congregating in areas where food is abundant (Reid *et al*., 2002). A number of the seabirds identified as potentially present do not breed in close proximity to the OA, as there are no islands within the OA to support breeding colonies, and seabirds breeding season will also determine the presence of seabirds. Therefore, not all the species identified in the tables below may be present during the Seismic Survey and, where possible, an indication of seasonality has been provided.

The closest known breeding sites occur at Ashmore Island and along the coast, east of the OA, see **Figure 23**, which support seabird and shorebird colonies of 10,000–15,000 birds. Extensive areas of shorebird and waterbird feeding habitat are associated with the mangroves and mudflats in this region (DEWHA, 2008b). Additionally, the Cartier Island and Ashmore Reef, within the EMBA, support breeding colonies of seabirds and migratory shorebirds. Given coastal habitats support large migratory populations, seabirds may fly over the OA during migrations.

Results from the EPBC Act Protected Matters Database (3 March 2022) revealed that there are one threatened, three threatened and migratory, and eight migratory seabird species that may be present within the OA, in addition to nine threatened, three threatened and migratory, and 29 migratory seabird species within the wider EMBA.

Within the EMBA another eight seabirds, that is not listed as threatened or migratory, has been registered: Black Noddy (*Anous minutus*), Rainbow Bee-eater (*Merops ornatus*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Black-eared Cuckoo (*Chalcites osculans*), Cattle Egret (*Bubulcus ibis*), Silver Gull (*Chroicocephalus novaehollandiae*), Lesser Crested Tern (*Thalasseus bengalensis*) and Magpie Goose (*Anseranas semipalmata*).

The following BIAs for marine bird species are located adjacent to the OA, within or close to the EMBA (**Figure 23**):

- Lesser crested tern breeding BIAs with the nearest located approximately 87 km southeast of the OA;
- Greater crested tern breeding BIA, located 87 km southeast of the OA;
- Roseate tern breeding BIAs, with the nearest located approximately 125 km southeast of the OA;

- Lesser frigatebird breeding and foraging BIAs, with the nearest located approximately 17 km south of the OA;
- Greater frigatebird breeding and foraging BIAs, with the nearest located 50 km west of the OA;
- Wedge-tailed shearwater breeding BIAs, with the nearest located 56 km of the OA;
- White-tailed tropicbird breeding BIA, located 60 km west of the OA;
- Red-footed booby breeding and foraging BIA, located 50 km west of the OA;
- Brown booby breeding and foraging BIA, located 114 km west of the OA;
- Little tern breeding BIAs, with the nearest located approximately 156 km south of the OA; and
- Little tern resting BIA (Ashmore Reef) located approximately 146 km west of the OA.

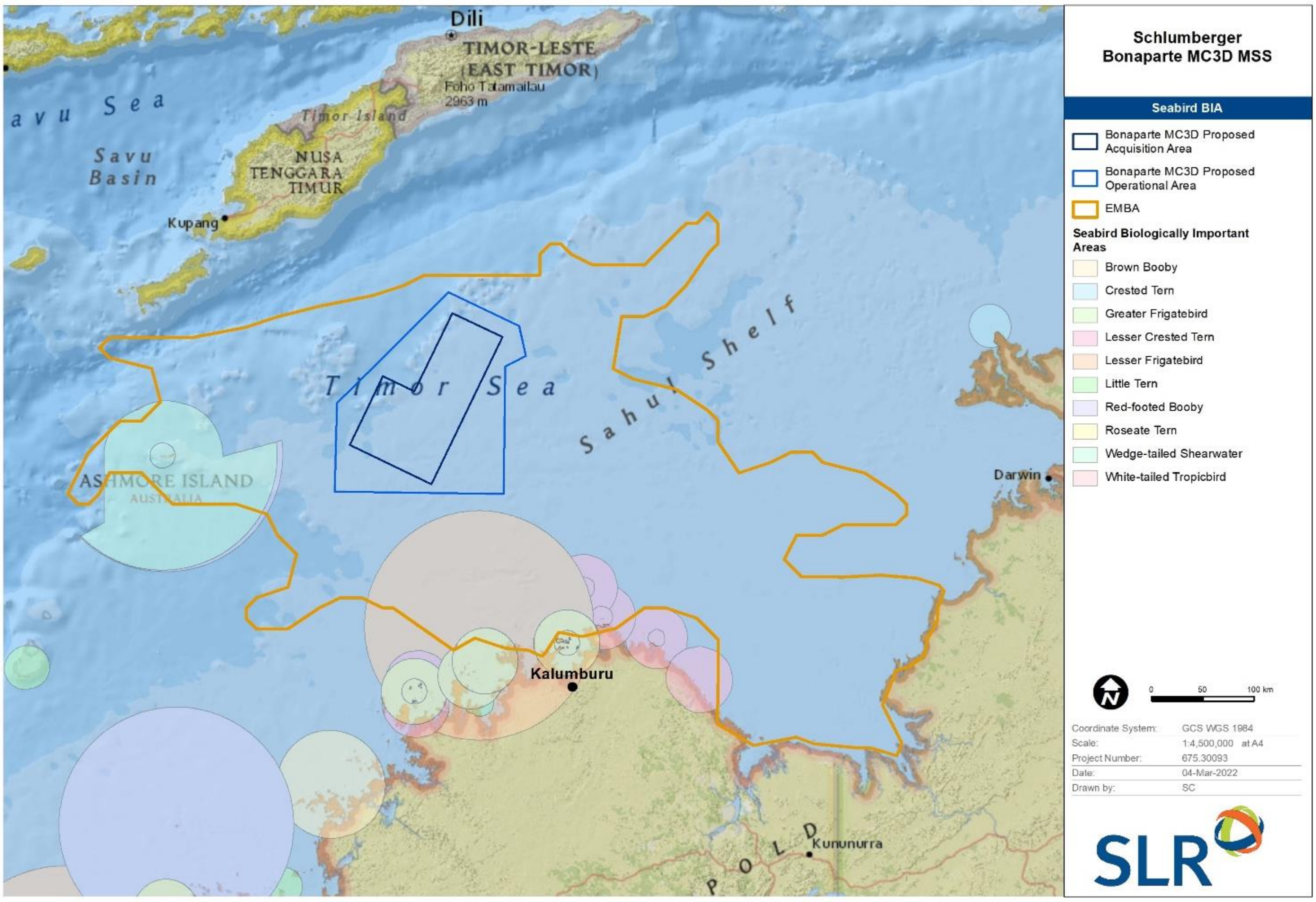


Figure 23 Biologically Important Areas for Seabirds and Migratory Shorebirds in the EMBA

4.5.8 Conservation Management Plans

Based on the characterisation of the biological environment provided in **Section 4.5**, a summary of the EPBC Act Conservation Management Plans, Recovery Plans and Conservation Advice that relate to species with the potential to occur within the OA are described in **Table 22**, below. In addition, any relevant measure contained within the conservation advice and recovery plans has been considered as part of the assessment of impacts and risks that may occur as a result of the Seismic Survey (**Section 7 – Section 9**).

Table 22 EPBC Act Conservation Management Plans, Recovery Plans and Conservation Advice relevant to the Seismic Survey

Species	Relevant Plan/Conservation Advice	Key threats within Plan/Advice of relevance to MSS	Plan/Advice actions relevant to this EP
Fish, Sharks and Rays			
Whale shark	Conservation Advice adopted 1 October 2015	Boat strike	Minimise transit time of large vessels in areas close to marine features likely to correlate with whale shark aggregations (Note these areas are not expected within OA).
Marine Reptiles			
Flatback Turtle	2017 Recovery Plan for Marine Turtles in Australia	Marine debris – Entanglement and Ingestion	Support the implementation of the EPBC Act in accordance with the *Threat Abatement Plan for the impacts of marine debris on vertebrate marine life* (Commonwealth of Australia 2018).
		Chemical (e.g., from vessels) and terrestrial discharge	Ensure spill risk strategies and response programs adequately include management for marine turtles and their habitats, particularly in reference to 'slow to recover habitats', (e.g., nesting habitat, seagrass meadows or coral reefs).
		Light pollution	No management actions of relevance to the Seismic Survey due to lack of habitat *critical* to marine turtles and turtle nesting are located in the vicinity of the OA. However, in accordance with the National Light Pollution Guidelines for Wildlife (Commonwealth of Australia 2020), *important* internesting habitat for listed species was identified within the OA and important foraging habitat was reported within 20 km of the OA. Subsequently, the potential impacts of artificial light generated throughout the Seismic Survey on marine turtles is further assessed in **Section 7.5.2.3**.
		Vessel disturbance	No management actions specific to vessel disturbance identified in Recovery Plan.
		Noise disturbance	No management actions specific to vessel disturbance identified in Recovery Plan.
Hawksbill Turtle	2017 Recovery Plan for Marine Turtles in Australia	See above for threats	See above for relevant actions.
Olive Ridley Turtle	2017 Recovery Plan for Marine Turtles in Australia	See above for threats	See above for relevant actions.

Species	Relevant Plan/Conservation Advice	Key threats within Plan/Advice of relevance to MSS	Plan/Advice actions relevant to this EP
Green Turtle	2017 Recovery Plan for Marine Turtles in Australia	Marine debris – Entanglement and Ingestion	Support the implementation of the EPBC Act in accordance with the *Threat Abatement Plan for the impacts of marine debris on vertebrate marine life* (Commonwealth of Australia 2018).
		Chemical (e.g., from vessels) and terrestrial discharge	Ensure spill risk strategies and response programs adequately include management for marine turtles and their habitats, particularly in reference to 'slow to recover habitats', (e.g. nesting habitat, seagrass meadows or coral reefs).
		Light pollution	No management actions of relevance to the Seismic Survey were identified due to lack of habitat *critical* to marine turtles and turtle nesting present in the vicinity of the OA. Further, no *important* habitat was reported within 20 km of OA. Nevertheless, a precautionary approach was taken and the potential impacts of artificial light, generated throughout the Seismic Survey, on marine turtles is further assessed in **Section 7.5.2.3.**
		Vessel disturbance	No management actions specific to vessel disturbance identified in Recovery Plan.
		Noise disturbance	No management actions specific to vessel disturbance identified in Recovery Plan.
Hawksbill Turtle	2017 Recovery Plan for Marine Turtles in Australia.	See above for threats	See above for relevant actions.
Leaf-scaled Sea Snake	Conservation Advice approved 15 February 2011	Not delineated	Not delineated. More research is required to fully understand the threats and ecological requirements for the species in order to determine the most appropriate management strategies. Thereafter, a Recovery Plan will be considered.
Short-nose Sea Snake	Conservation Advice approved 15 February 2011	Not delineated	Not delineated. More research is required to fully understand the threats and ecological requirements for the species in order to determine the most appropriate management strategies. Thereafter, a Recovery Plan will be considered.

Species	Relevant Plan/Conservation Advice	Key threats within Plan/Advice of relevance to MSS	Plan/Advice actions relevant to this EP
Marine Mammals			
Humpback whale	Conservation Advice approved 1 October 2015	Noise interference	All seismic surveys must be undertaken consistently with the EPBC Act Policy Statement 2.1 – Interactions 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; For actions involving acoustic impacts (e.g. pile driving, explosives) on humpback whale calving, resting, feeding areas, or confined migratory pathways site specific acoustic modelling should be undertaken (including cumulative noise impacts); Should acoustic impacts on humpback calving, resting, foraging areas, or confined migratory pathways be identified a noise management plan should be developed. This can include: • The use of Shut-down and Caution Zones; • Pre and post activity observations; • The use of MMOs and/or PAM; and • Implementation of an adaptive management program following verification of the noise levels produced from the action (i.e. if the noise levels created exceeded original expectations).
		Vessel disturbance and strike	• Ensure all vessel strike incidents are reported in the National Vessel Strike Database; and • Ensure the risk of vessel strike on humpback whales is considered when assessing actions that increase vessel traffic in areas where humpback whales occur and, if required appropriate mitigation measures are implemented to reduce the risk of vessel strike

Species	Relevant Plan/Conservation Advice	Key threats within Plan/Advice of relevance to MSS	Plan/Advice actions relevant to this EP
Blue whale	2015 – 2025 Conservation Management Plan for the Blue Whale	Noise interference – seismic and shipping	• Assess the effect of anthropogenic noise on blue whale behaviour; • Anthropogenic noise in BIAs will be managed such that any blue whale continues to utilise the area without injury, and is not displaced from a foraging area; and • EPBC Act Policy Statement 2.1. – Interaction between offshore seismic exploration and whales is applied to all seismic surveys.
		Vessel disturbance – vessel collisions	• Ensure all vessel strike incidents are reported in the National Ship Strike Database; and • 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, appropriate mitigation measures are implemented.
		Marine debris	No management actions specific to marine debris have been identified within the blue whale Conservation Management Plan.
Fin whale	Conservation Advice approved 1 October 2015	Anthropogenic noise and acoustic disturbance	• Once the spatial and temporal distribution (including BIAs) of fin whales if further defined, an assessment of the impacts of increasing anthropogenic noise should be undertaken on fin whales; and • If required, additional management measures should be developed and implemented to ensure the ongoing recovery of fin whales.
		Vessel strike	Ensure all vessel strike incidents are reported in the National Vessel Strike Database.

Species	Relevant Plan/Conservation Advice	Key threats within Plan/Advice of relevance to MSS	Plan/Advice actions relevant to this EP
Sei whale	Conservation Advice approved 1 October 2015	Vessel disturbance and strike	• Ensure all vessel strike incidents are reported in the National Vessel Strike Database; and • Ensure the risk of vessel strike on humpback whales is considered when assessing actions that increase vessel traffic in areas where humpback whales occur and, if required appropriate mitigation measures are implemented to reduce the risk of vessel strike.
		Vessel strike	Ensure all vessel strike incidents are reported in the National Vessel Strike Database.
Seabirds and Migratory Shorebirds			
Seabirds (*general*)[6]	Draft Wildlife Conservation Plan for Seabirds 2019	Prey depletion	No management actions specific to prey depletion identified in the Conservation Plan.
		Anthropogenic disturbance	• Identify important habitats for all seabirds during critical life stages; and • Manage the effects of anthropogenic disturbance to seabird breeding and roosting areas.
		Transport	Identify important habitats for all seabirds during critical life stages
		Pollution – marine debris, light pollution, acute pollution, heavy metals	• Enhance contingency plans to prevent and/or respond to environmental emergencies that have an impact on seabirds and their habitats; and • Identify important habitats for all seabirds during critical life stages.

[6] Species covered under the wildlife conservation plan include those listed within Table 1 of the '*Draft Wildlife Conservation Plan for Seabirds'* (Commonwealth of Australia 2019), including but not limited to White-tailed tropicbird (*Phaethon lepturus*), Wedge-tailed shearwater (*Ardenna pacifica*), Lesser Frigatebird (*Fregata ariel*), Greater Frigatebird (*Fregata minor*), Brown Booby (*Sula leucogaster*), Red-footed booby (*Sula sula*), Little Tern (*Sternula albifrons*), Roseate Tern (*Sterna dougallii*), Crested Tern (*Thalasseus bergii*) and Lesser Crested Tern (*Thalasseus bengalensis*). As this document is still in draft and not in effect, it has been used as a guideline only.

4.6 Cultural and Heritage Values

In the NWMR and NMR, which comprise the OA and EMBA, cultural and heritage features such as sites of aboriginal significance and built European heritage are important. Most of these features are located along or in close proximity to the shoreline and coastal margins and fall within the State's jurisdiction.

The cultural and heritage properties of the OA and surrounding EMBA are considered below; however, as described above these are predominantly terrestrial and constrained to the coastal margins.

4.6.1 Aboriginal Heritage

Indigenous Australian people have a strong continuing connection with Land and Sea Country that extends back some 50,000 years. Across Australia, Indigenous people have been sustainably using and managing their sea Country throughout this period. Sea country is valued for Indigenous cultural identify, health and wellbeing. A search of the Department of Aboriginal Affairs Aboriginal Heritage Inquiry System[7] was undertaken to assess the potential for Aboriginal sites or artefacts of significance to occur within the waters of the OA. The search concluded that the OA does not overlap with any areas of known, registered Indigenous Heritage value, which are largely constrained to the limit of State Coastal Waters approximately 127 km to the south. To this end, Aboriginal Heritage sites are present along the coastline within the southern boundary of the EMBA in proximity to Kalumburu and Cambridge Gulf. Given the EMBA reflects a coarse spatial footprint of impacts associated with an unplanned event (i.e., shoreline accumulation of hydrocarbons, in the event of an oil spill), and the low likelihood of occurrence, these sites are not predicted to be impacted.

4.6.1.1 Native Title

Native Title is the recognition that Aboriginal and Torres Strait Islander people have rights and interested to land and waters according to their traditional law and customs, as set out in Australian Law, Native title is governed by the *Native Title Act 1993* (Cth). In accordance with the *Native Title Act 1993 ,* non-exclusive Native Title can exist offshore within the limits of Australia's territorial sea (12 NM), meaning that native titleholders will not have the right to exclude others from accessing the sea or seabed in the waters where native title exists.

A search of the National Native Title Tribunal Register did not identify any Native Title areas or any pending titles within the OA. However, two Native Title determinations have been made over (coastal) sea country within the southern portion of EMBA, south of the OA, including the Uunguu Part A (Wanjina-Wunggurr (Native Title) Aboriginal Corporation RNTBC on behalf of the members of the Wanjina Wunggurr community), and Balanggarra (Combined) (Balanggarra Aboriginal Corporation RNTBC on behalf of the members of the Balanggarra community) (**Figure 24**). These determinations, recognised in law, are non-exclusive, however, preserve continuing rights to access sea country to hunt, fish, gather and use the resources of the waters for personal, domestic, communal, cultural and spiritual needs.

[7] Database accessed on 21 April 2022, via https://espatial.dplh.wa.gov.au/AHIS/index.html?viewer=AHIS

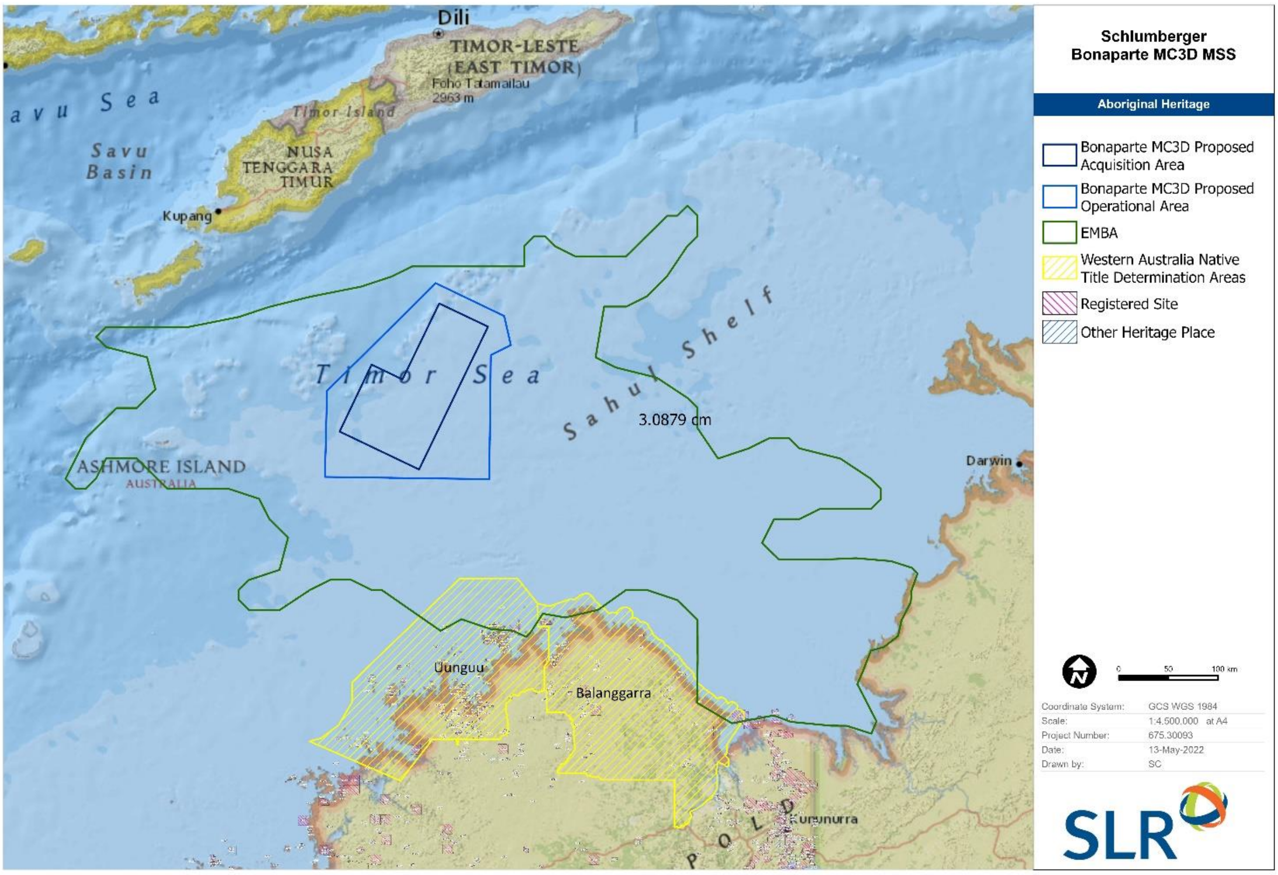


Figure 24 Cultural Heritage

4.6.1.2 Traditional Use

Traditional Use of nearshore and marine waters in the vicinity of the OA and EMBA typically constitutes fishing, hunting and trade activity (DSEWPC, 2012a). The Ashmore Islands are thought to have been visited by Indonesian fishers from the islands of Rote, Sulawesi, and Ceram since the early eighteenth century, evidence of this is found at gravesites within the Ashmore Reef Marine Park (DSEWPC, 2012a). The Ashmore Islands were used both for fishing and as a staging point for voyages to the southern reefs off Australia's coast. Visits from traditional Indonesian fisherman continue today under the MoU 74 (see **Section 4.4.1.2**), with the MoU box shown in **Figure 28**. Therefore, Indonesian traditional fishers may be present within the EMBA, but are not expected to be present within the OA (further described in **Section 4.7.3**).

Australian Indigenous peoples use and actively manage the coastal and marine environments of the region as a resource and to maintain cultural identity, health and wellbeing, including within conservation areas such as Commonwealth, Australian and State Marine Parks. It is recognised that spiritual corridors extend from terrestrial areas into nearshore and offshore waters, that a number of marine animals are totems for Indigenous people, and that songlines pass through marine parks (DSEWPC, 2012a). Fishing, hunting, trade and the maintenance of culture and heritage through ritual, stories and traditional knowledge continue to be important uses of land and sea country (DSEWPC, 2012a).

The North Kimberley Marine Park located approximately 101 km south of the OA (**Figure 14**), contains many places of cultural and spiritual importance to traditional owners. Hunting, subsistence fishing and shell collecting are recognised as occurring in the Kimberley region (DNP, 2018a; DPAW, 2016b; Smyth, 2007).

As identified in **Section 4.6.1.1**, the land and sea country of the Wanjina Wunggurr people extends from the Bonaparte Archipelago to Kalumburu. The Wanjina Wunggurr people are strongly connected to sea country within this area, undertaking pearling, fishing and trade with Makassan. Many of the offshore warrurru (reefs) were visited by the Wanjina Wunggurr using rafts and canoes to take traditional sea voyages using travel routes extending from Lammarck Island to East Holothuria Reef (Wunambal Gaambera Aboriginal Coroporation, 2016). The continuing importance of traditional use within region is reflected in the establishment of the Uunguu Indigenous Protected Area (Commonwealth of Australia, 2021).

The land and sea country of the Balanggarra people extends from Napier-Broome Bay to Cambridge Gulf and Wyndham in the JBG. In the past, the Balanggarra people speared fish along the rocky shoreline and in shallow waters. Saltwater fish, turtles, dugong, mud crabs and cockles continue to be important food sources for the Balanggarra people today (DPAW, 2016b). Fishing and hunting are still practiced today (DPAW, 2016b).

The largest settlement is the Aboriginal community of Kalumburu (DPAW, 2016b). Kalumburu is located on the western side of Cape Londonderry, 200 km southwest from the OA. There are no settlements on the western coast of the JBG until the Cambridge Gulf where the Oombulgurri community is located, approximately 130 km southeast of the OA.

4.6.2 European and Marine Heritage

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

A search of the Australasian Underwater Cultural Heritage Database confirms that there are no protected shipwrecks or sunken aircraft located within the OA. However, the Ann Millicent shipwreck (with shipwreck ID 3670), a sailing vessel wrecked in year 1888, is located immediately beyond the OA, 109 km to the west (**Figure Figure 25**). Water depths at the wreck site are less than 80 m.

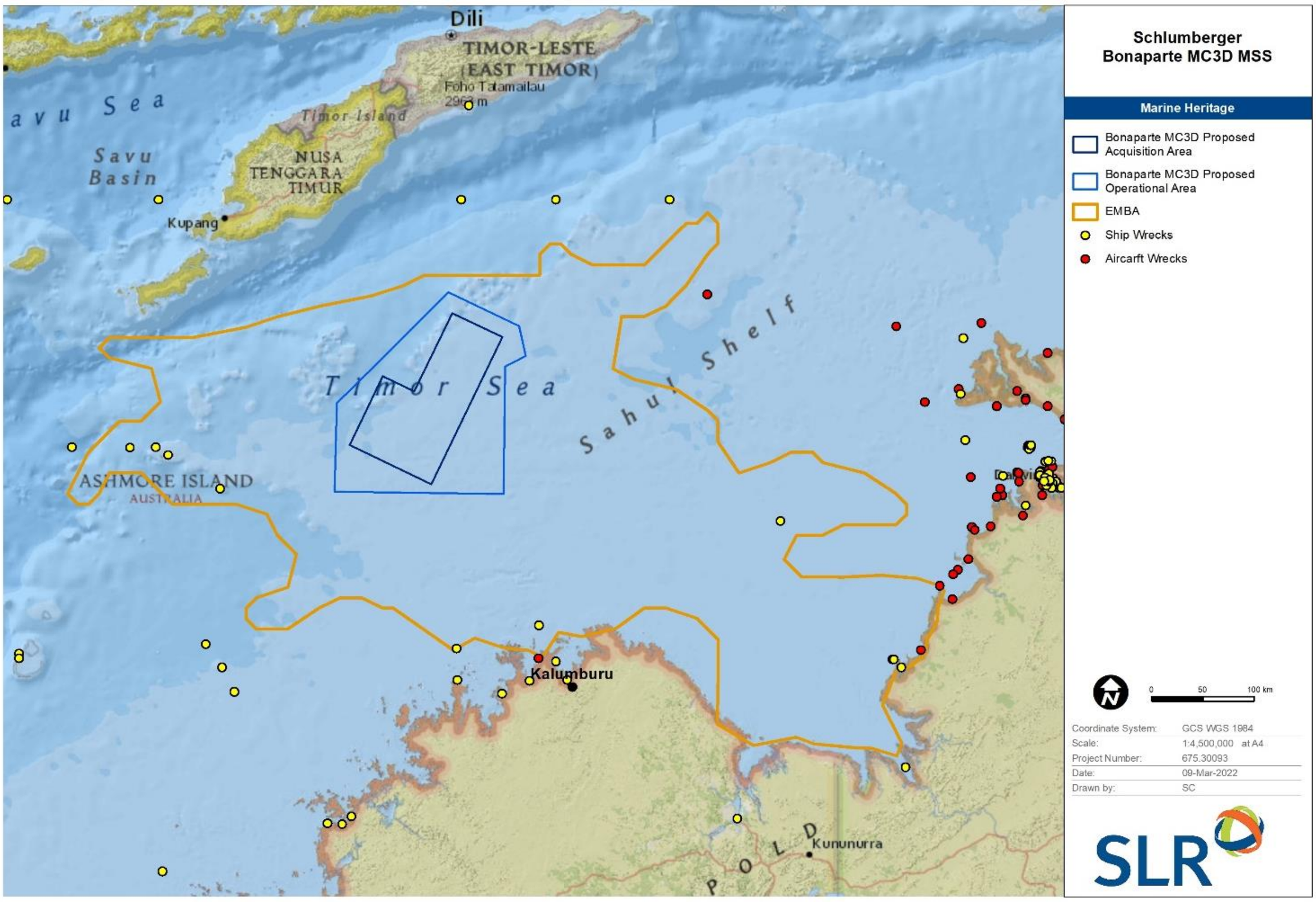


Figure 25 Places of Marine Heritage including Shipwrecks and Aircraft wrecks

4.7 Socio-Economic Environment

4.7.1 Coastal Settlements

Coastal settlements only occur along the southeastern extent of the EMBA, from Port Warrender across northwest WA to Wadeye within the Northern Territory extent of the JBG. Overall, these coastal areas are sparsely developed with population centres ranging from smaller indigenous community settlements of less than 50 people to small towns such as Kununurra comprising a population of 5,308 (Australian Bureau of Statistics, 2016).

Kununurra has an important horticultural industry, reflected in the high employment rates associated with the Agriculture, Forestry and Fishing industry. It's role as a transport hub in northern Australia is also evident, with Transport and Services identified as an important economic base for the region (Clifton *et al.*, 2007). Outside of this, government administration and government supported industries such as education, defence and health are important employment sectors.

The following list includes those settlements adjacent to the EMBA which have a direct association with the marine environment through commercial and/or recreational activities and their corresponding population values[8]:

- Kalumburu (population; 412);
- Kununurra (population; 5,308);
- Wyndham (population; 780);
- Wadeye (population; 2,280);
- Thamarrurr (population; 3,764); and
- Baines (population; 249).

Where limited information was available on the extent, population, and socio-economic environment for community settlements, including indigenous community settlements, the precautionary principle has been applied and assumed a direct association with the marine environment. To this end, potential impacts to these coastal settlements has been evaluated and managed through engagement with the nominated State Government and the Representative Aboriginal Torres Strait Islander Body, in this case the Kimberley Land Council Aboriginal Corporation and the Northern Land Council (see **Section 5**).

[8] As denoted in the Australian Bureau of Statistics 2016 Census data, in lieu of 2021 Census data (to be released July 2022).

4.7.2 Tourism and Recreation

4.7.2.1 Whale Watching

Migrating humpback whales attract visitors to the Kimberley coastline from approximately July to September. The coastline encompassing Roebuck Bay, Broome, and the adjacent coastal waters are the staging point for departing whale watching cruise vessels and Australian Snubfin Dolphin viewing. Of note, is that Broome represents the most northerly location along the WA coastline where whale watching tourism providers operate, with most whale watching activity concentrated within the southwest region. Therefore, no commercial or tourism-based whale watching activity is known or expected to occur within the OA or the EMBA.

No whale watching tourism services appear to occur centric to pygmy blue whales.

This is consistent with what is known about humpback and pygmy blue whale distribution, migration and habitat use which show that humpback whale's activity is largely constrained to the coastal waters extending from the south up to the Bonaparte Archipelago and pygmy blue whale activity which appears to migrate to the offshore waters immediately beyond the Dampier Archipelago on route to the warmer waters of Indonesia and Timor Leste.

Due to these limitations, it is also considered unlikely that recreational whale watching activity is occurring within the OA or the EMBA.

4.7.2.2 Cruise, Sailing and Boating Activity

Similar to that described for recreational diving and snorkelling activity, vessel-based tourism within the NWMR is predominantly concentrated around natural features such as reefs, islands and cay, particularly, Rowley Shoals, Adele Island, Scott Reef and Ashmore Reef. Activities are characterised by luxury, multi-day cruises originating from Broome, travelling north, and incorporating a range of marine and terrestrial based activities undertaken at key staging points. Tourism in the region typically peaks during the dry season, from May to October. However, cruises are scheduled year-round.

No key staging or stop-over points were identified within the OA. However, a review of current itineraries for Cruise Operators such as Coral Expeditions and Diversity Charters indicated they routinely visit West Island at Ashmore Reef, a small Recreational Use Zone (IUCN IV) within the broader AMP which otherwise comprises Sanctuary Zone (IUCN Ia). Consequently, vessels may transit through the OA between key activity locations.

Having regard to the potential overlap in vessel tracks for tourism vessels and the proposed Seismic Survey Vessel, SLB has consulted with industry representative bodies including Marine Tourism WA and Kimberley Marine Tourism Association. The outcome of stakeholder consultation activities is described in **Section 5.**

A number of luxury cruise operators have previously been identified as accessing the Kimberley coastal waters comprising the EMBA, including Kimberley Quest, Silversea and True North which operate from late throughout February to November to avoid the wet season (Santos, 2021). Some Kimberley cruises extend to the coastal waters of the JBG, situated over 350 km from the OA and located within the EMBA. Here, activities are predominantly land-based or take place in rivers, estuaries or within a few kilometres from the coast. As describe above, cruise itineraries do not include the offshore waters of the OA, although operators may occasionally transit through the OA between key activity locations (Santos, 2021).

No sailing or other recreational boating activity was identified to occur within the OA, with the exception of recreational fishing activity. Recreational fishing activity is described in **Section 4.7.2.4.**

4.7.2.3 Diving, snorkelling and wildlife watching

Recreational diving and/or snorkelling within the northwest marine region of the OA generally occurs in water depths less than 30 m, concentrating around natural features such as reefs, islands and cay, particularly around Rowley Shoals, Adele Island, Scott Reef, Ashmore Reef, and around structures such as shipwrecks (DNP, 2018a; WA DPIRD, 2021).

Given its relative proximity to higher value recreational dive sites, such as Ashmore Reef, and the prevailing water depths (approximately 95% of that OA consists of water depths greater than 60 m), recreational diving and/or snorkelling is not anticipated to occur within the OA. However, it is a permitted activity within the adjacent Oceanic Shoals Marine Park, the marine waters where the Ann Millicent shipwreck is grounded (see **Section 4.6.2**) and on the West Island of Ashmore Reef, all of which are located within the EMBA.

In all cases, dive sites within the EMBA are typically only accessible via boat. A search of mainstream dive and charter tour offerings within the broader region identified two itineraries which included diving and snorkelling activity at West Island, Ashmore Reef. Based on the information available, tours ranged from September to December which is distinct from the peak cruise season ranging from May to October each year.

Bird watching activity is also known to occur at Ashmore Reef concurrent with the cruise and dive itinerates identified above (Kimberley Bird Watching, 2018). Whilst historical itineraries indicate specific trips occurred throughout the key seabird and shorebird breeding period from October through to March, no proposed voyages were identified across this time period.

4.7.2.4 Recreational Fishing

Recreational fishing is a popular activity in Western Australia, providing important social and economic benefits to the State's population. The participation rate of Western Australian residents is generally above the national average, with an estimated 25.4% of the population aged 15 years or older participating in fishing in the 2017/2018 monitoring period, which constitutes the most recent, published Statewide survey of boat-based recreational fishing in Western Australia (Ryan et al., 2019). Recreational Boat Fishing Licenses (RBFL) are lodged through the WA Department of Transport (WA DoT) and issued/regulated through WA DPIRD. There are four Fishing Bioregions, including the South Coast, West Coast, Gascoyne, and the North Coast. For the purposes of assessment, each bioregion can be further characterised into zones, whereby the Nort Coast bioregion comprises the Kimberley and Pilbara zones. The OA is located within the North Coast bioregion, which extends from Longitude 114 50 East to the WA – NT border and overlaps the Kimberley zone. The Kimberley zone extends from Pardoo, in the south, to the WA-NT border.

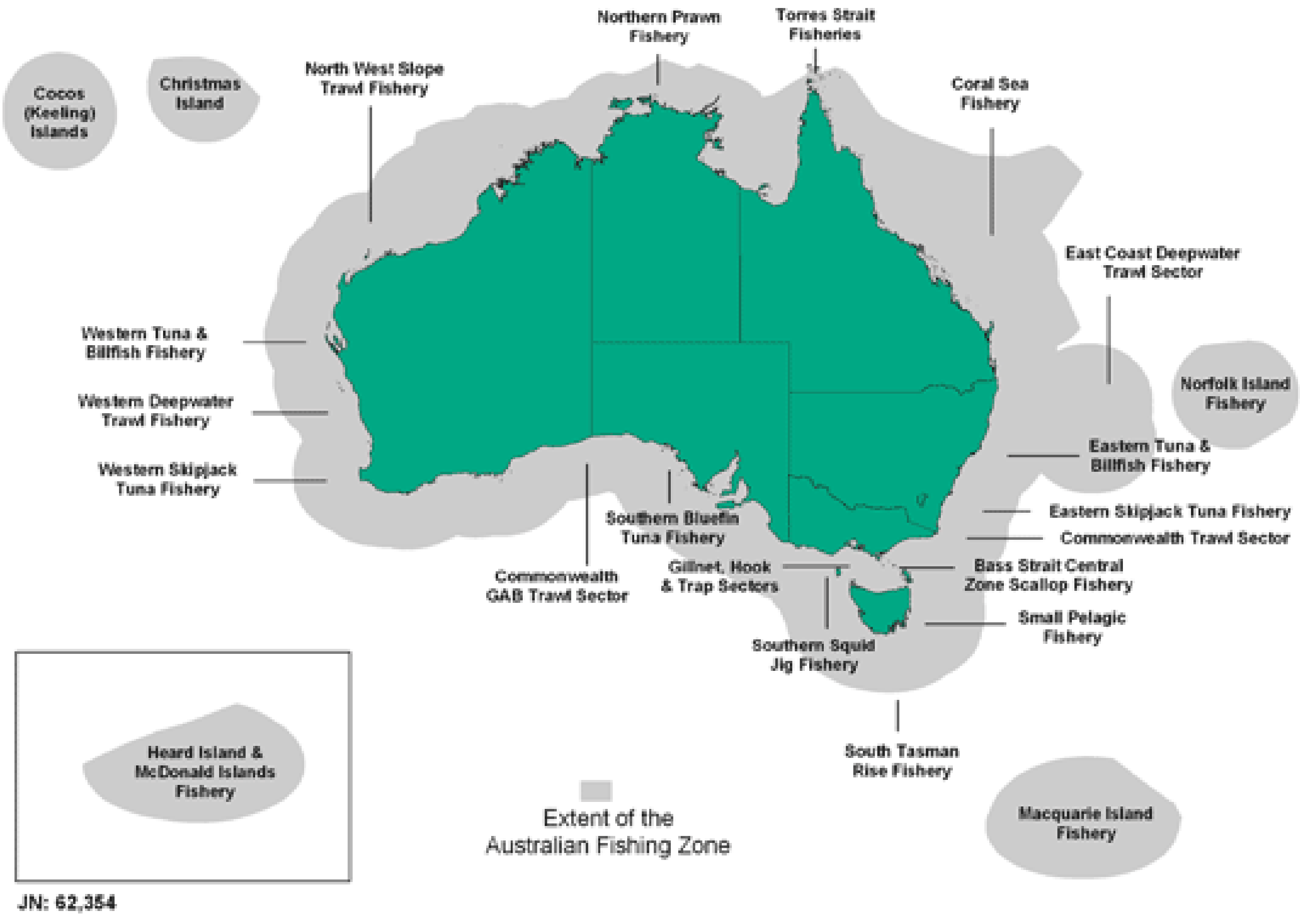
Within the Kimberley portion of the Nort Coast Bioregion, 55% of recreational license holders fished 15 days or more with 93% of activity reported to occur within the North Coast. Of the fishing effort recorded within the North Coast, activity occurred predominantly in nearshore habitat (47%), followed by inshore demersal (33%), estuary (11%), pelagic (4%), offshore demersal (2%) and freshwater (2%) (Ryan et al., 2019).

Twenty species accounted for 75% of the total catch (by numbers) of finfish and invertebrate in the Kimberley zone within 2017/2018. The top finfish species caught (kept and released) were Stripey Snapper (11% of the zone total catch), Grass Emporer (10%), Barramundi (7%) and Saddletail Snapper (5%). A further 14 species were caught at rates between 2 and 5%. The most common invertebrate species were Mud Crab (6%) and Blue Swimmer Crab (2%)(Ryan et al., 2019).

Given only 6% of the of all recreational fishing activity within the Nort Coast is reported to occur within the pelagic or offshore demersal environment, little to no recreational fishing activity is anticipated within the OA. However, recreational fishing is known to occur within the nearshore, inshore and estuarine environments comprising the EMBA.

4.7.3 Commercial Fisheries

Australia's fisheries are those that occur within the Australian EEZ (waters out to 200 NM from coastal baselines). Boundaries within Australia's fisheries have been established in order to simplify jurisdiction (Department of Agriculture and Water Resources (**DoAWR**), 2002). Inshore waters out to 3 NM represent State waters, with jurisdiction of these waters vested in the adjacent State or Territory (Geoscience Australia, 2018b). The Commonwealth has jurisdiction over fisheries occurring in Commonwealth waters; those between 3 NM and 200 NM from the coastline (DoAWR, 2002). Commonwealth waters are covered by the Australian Fishing Zone (**Figure 26**) (DoAWR, 2018) and are managed through the Australian Fisheries Management Authority (**AFMA**). Where a fishery falls within multiple jurisdictions, an Offshore Constitutional Settlement arrangement is generally developed, whereby sole responsibility is passed to one jurisdiction. Alternatively, a Joint Authority may be formed, allowing for the co-management of the fishery through the legislation of one jurisdiction (DoAWR, 2002).



Source: DoAWR, 2018

Figure 26 Australian Fishing Zone and Location of Commonwealth Fisheries

The offshore waters of WA and the NT are rich in marine resources and include the fishing grounds of a variety of commercial fisheries. The OA encompasses some Commonwealth, WA, and NT managed commercial fisheries and these are discussed in the following sections.

4.7.3.1 Commonwealth Managed Fisheries – The Regulator

AFMA is the Government agency responsible for the management and sustainable use of Australia's Commonwealth fisheries (those from 3 NM out to the extent of the Australian Fishing Zone). AFMA was established under the Fisheries Administration Act 1991, and it is under this Act, as well as the Fisheries Management Act 1991, that AFMA is invested with its objectives, functions and powers.

AFMA looks after Commonwealth fisheries through:

- Research and science which provides the information to manage fisheries, such as the setting of quota levels;
- Management and regulation that develops and makes the rules for fisheries (e.g. quota and gear restrictions, and issuing of permits); and
- Monitoring and enforcement of rules and regulations.

The aim of AFMA is to keep fish species, and the marine environment as a whole, in good health for the future. In order to achieve this, they work together with Australian State agencies, international counterparts, industry, scientists, and recreational and environmental fishery stakeholders (AFMA, 2018b).

AFMA ensures that impacts on commercial fisheries from petroleum activities, including MSSs, are considered by providing comment directly to the Department of Industry, Innovation and Science on annual acreage releases, and by providing comment to petroleum companies on proposals that may have significant impacts on fisheries. AFMA expects petroleum operators to consult directly with fishing operators about proposed petroleum activities. Note that in some fisheries there are no associations (AFMA, 2018c).

Consultation with commercial fishers that may be affected by the Seismic Survey has been guided by AFMA recommendations and expectations. See **Section 5** and **Appendix F** for details on consultation with AFMA and the commercial fishing sector.

Commonwealth-managed fisheries with management boundaries that overlap with the OA and EMBA include:

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

These fisheries are further described below.

4.7.3.1.1 Northern Prawn Fishery

The NPF extends from JBG across the top end to the Gulf of Carpentaria (**Figure 27**) with banana prawns and tiger prawns being the main targeted species.

White banana prawn (*Penaeus merguiensis*) is mainly caught during the day on the eastern side of the Gulf of Carpentaria, whereas redleg banana prawn (*P. indicus*) is caught during both day and night, mainly in JBG. Tiger prawns (*P. esculentus and P. semisulcatus*) are primarily taken at night (daytime trawling has been prohibited during the tiger prawn season). Most catches come from the southern and western Gulf of Carpentaria, and along the Arnhem Land coast (ABARES, 2021).

The NPF uses otter trawl gear to target a range of tropical prawn species. Most vessels have transitioned from using two trawl nets to using four trawl nets, a configuration that is considered more efficient (ABARES, 2021). Fishing effort and participation were reduced from a peak in 1980 to the current levels of around 8,000 days of effort and 52 vessels. Total catch in 2020 was 4,767 t, comprising 4,653 t of prawns and 114 t of byproduct species (predominantly squid, bugs and scampi). Annual catches tend to be quite variable from year to year, mostly because of natural variability associated with the target species, especially banana prawns (ABARES, 2021).

The fishery has two seasons: a predominantly banana prawn season that runs from 1 April to 15 June and a longer tiger prawn season that runs from 1 August to 30 November.

Figure 27 shows the main areas of fishing activity in the within the NPF between 2015-2020, based on fishing intensity data provided by the Australian Bureau of Agriculture and Resource Economics and Sciences (**ABARES**). No fishing occurs within the OA as it is located outside the NPF boundaries, however the eastern part of the EMBA extends into the JBG part of the NPF; however, the level of effort in this area is relatively minor compared to other parts of the NPF.

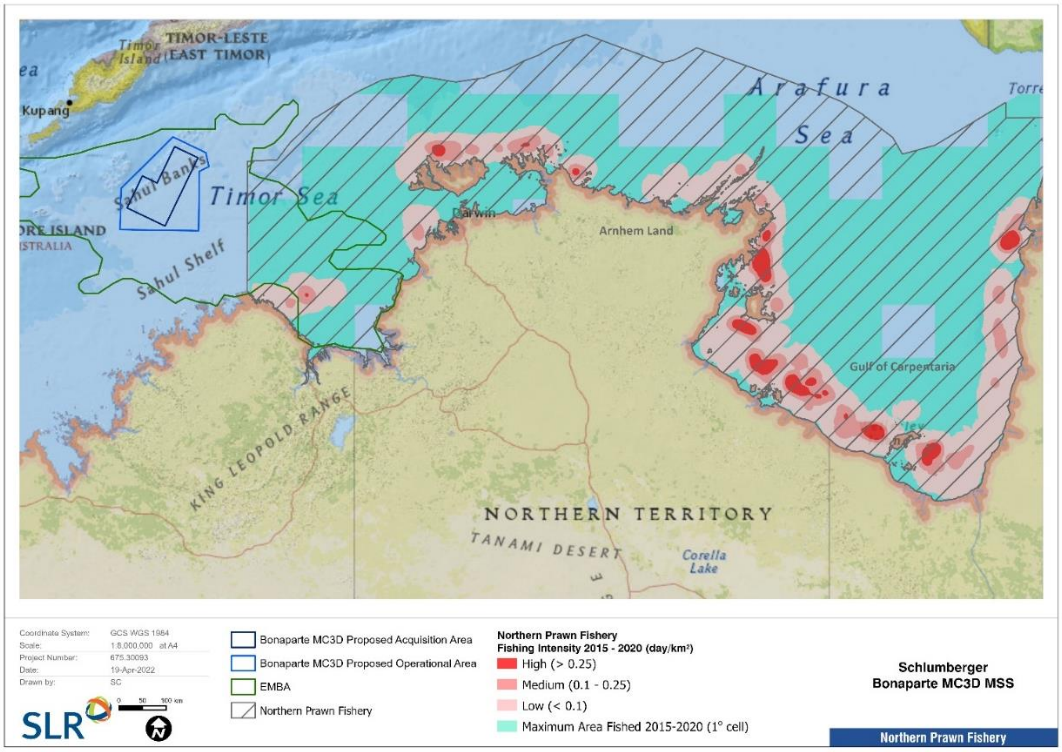


Figure 27 Fishing Effort within the Northern Prawn Fishery (2015-2020)

4.7.3.1.2 North West Slope Trawl Fishery

The NWSTF operates off north-western Australia from 114°E to 125°E, roughly between the 200 m isobath and the outer boundary of the Australian Fishing Zone. A large area of the Australia–Indonesia MOU box (an area off north-western Western Australia where Indonesian fishers may operate using only traditional methods) falls within the NWSTF (ABARES, 2021).

The NWSTF is divided into two regions, the western Pilbara and eastern Kimberly as shown in **Figure 28**. Since the late 1990s, the NWSTF has predominantly been a scampi fishery using demersal trawl gear, however a quantity of prawns is harvested each season, and squids are becoming an increasingly significant component of the catch (ABARES, 2021).

Fishing effort in the NWSTF is often linked to fishing in the NPF (discussed in **Section 4.7.3.1.1**) in that when boats cease to operate in the NPF, some move to the NWSTF (ABARES, 2021).

Figure 28 shows the areas of fishing activity in the within the NWSTF during 2019-20, based on fishing intensity data provided by the ABARES. No fishing occurs within the OA as it is located outside the NWSTF boundaries, however the western part of the EMBA extends part of the NWSTF, however no fishing occurred within the EMBA during 2019-20 as most of the fishing occurred further south (offshore from Broome).

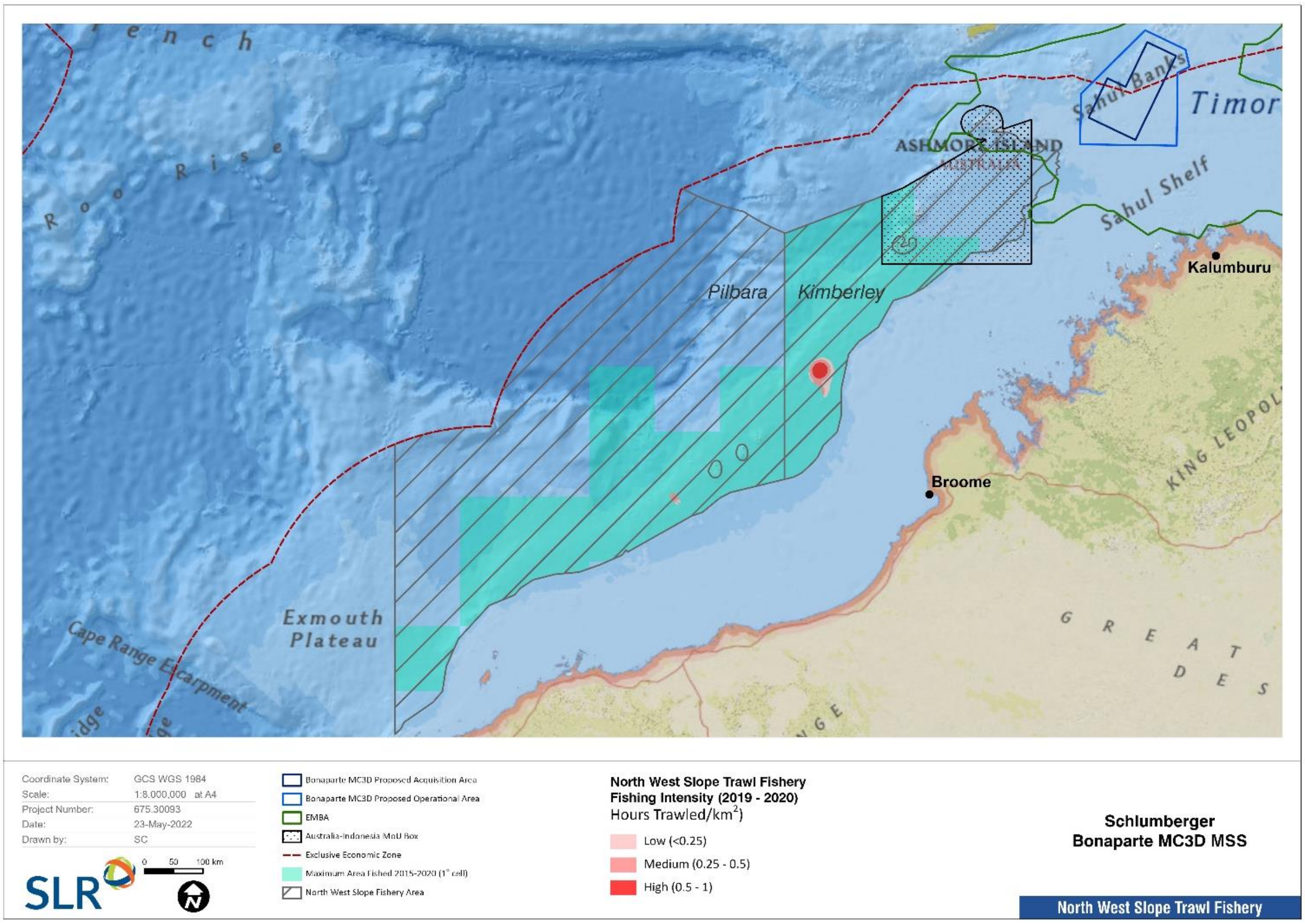


Figure 28 Fishing Effort within the North West Slope Trawl Fishery (2019-2020)

4.7.3.1.3 Western Tuna and Billfish Fishery

The WTBF operates in Australia's Exclusive Economic Zone and high seas of the Indian Ocean. In recent years, fishing effort has concentrated off south-west Western Australia (over 2,000 km from the OA), with occasional activity off South Australia (ABARES, 2021), meaning there is no overlap of either the OA or EMBA with recent fishing effort within the WTBF.

4.7.3.1.4 Western Skipjack Tuna Fishery

Two stocks of skipjack tuna (*Katsuwonus pelamis*) are thought to exist in Australian waters: one on the east coast that is part of a broader stock in the Pacific Ocean and one on the west coast that is part of a larger stock in the Indian Ocean. The two stocks are targeted by separate fisheries: the Eastern Skipjack Tuna Fishery and the WSTF. These are collectively termed the Skipjack Tuna Fishery, but the two stocks are assessed separately (ABARES, 2021).

Globally, catch of skipjack tuna increased steadily since the 1970s, and skipjack tuna has become one of the most commercially important tuna species in both the Indian and Pacific oceans. Catch in the Skipjack Tuna Fishery increased for a short period from 2005 to 2008, peaking at 817 t in 2007–08. The catch was supplied almost exclusively to the cannery in Port Lincoln. However, the cannery closed in 2010, and there has been no catch in the Skipjack Tuna Fishery since the 2008–09 fishing season (ABARES, 2021).

4.7.3.1.5 Southern Bluefin Tuna Fishery

The SBTF spans the Australian Fishing Zone. Southern bluefin tuna (*Thunnus maccoyii*) is targeted by fishing fleets within the Australia's EEZ. Young fish (1–4 years of age) move from the spawning ground in the north-east Indian Ocean into the Australian EEZ and southwards along the Western Australian coast (ABARES, 2021).

Since 1992, most of the Australian catch has been taken by purse seine, targeting juvenile southern bluefin tuna (2–5 years of age) in the Great Australian Bight with no fishing effort within the OA or EMBA. This catch is transferred to aquaculture farming operations off the coast of Port Lincoln in South Australia, where the fish are grown to a larger size to achieve higher market prices. Australian domestic longliners operating along the east coast also catch southern bluefin tuna, and there is some recreational fishing for the species (ABARES, 2021).

There is no overlap with fishing effort within the SBTF and the OA or EMBA.

4.7.3.2 Western Australian Managed Fisheries

WA State commercial fisheries are managed by the Western Australian Department of Primary Industries and Regional Development (**DPIRD**) under the Fish Resources Management Act 1994, Fisheries Resources Management Regulations 1995, relevant gazetted notices and licence conditions and applicable Fishery Management Plans.

The following WA managed fisheries have management boundaries that overlap with the OA and EMBA:

- Northern Demersal Scalefish Managed Fishery (**NDSMF**);
- Mackerel Managed Fishery (**MMF**);
- Specimen Shell Managed Fishery;
- Western Australia Joint Authority Northern Shark Fishery;
- Western Australian Sea Cucumber Fishery (**SCF**);

- Marine Aquarium Fish Managed Fishery (**MAFMF**);
- Abalone Managed Fishery;
- Kimberly Prawn Managed Fishery (**KPMF**);
- Kimberly Gillnet and Barramundi Managed Fishery (**KGBMF**);
- West Coast Deep Sea Crustacean Managed Fishery;
- Pearl Oyster Managed Fishery; and
- Kimberly Crab Managed Fishery (**KCMF**).

Schlumberger requested fish catch and effort data from WA DPIRD (FishCube data) for the above fisheries. Data were assessed for 60 x 60 NM and for 10 x 10 NM Catch and Effort System (**CAES**) blocks for the most recent six years (2015 to 2020). DPIRD does not release catch and effort data for CAES blocks where less than three vessels fished during the period of interest (i.e. less than three vessels per year or less than three vessels over the complete 6-year period). Where this applies, the Vessel Count is marked 'Less than 3', while Weight and Fishing Day Count are marked as 'N/A'. CAES blocks where the results are provided in this way confirm that fishing effort did occur within the block during that period, but the associated catch and effort values are not available.

Of the above fisheries, those which had any records of fishing effort within the OA were the NDSMF and MMF and the KPMF had more than three fishing day counts recorded fishing effort within the EMBA (but outside the OA). These three fisheries are discussed in greater detail in the following sections. In addition, fishing charters operate close to and offshore of the Kimberley Coast and this activity is also discussed in the following sections.

The four other fisheries, namely the SCF, KCMF, MAFMF, and KGBMF, had very minor fishing effort[9] recorded in the past five years within the southern part of the EMBA (adjacent to the Kimberley Coast) and are therefore not discussed further.

4.7.3.2.1 Northern Demersal Scalefish Management Fishery

The NDSMF is divided into two subregions, namely the Pilbara and Kimberly subregions. The Kimberley subregion of the NDSMF is relevant to this EP and operates off the WA coast east of 120° E longitude and is divided into two areas, Area 1 being the inshore sector and Area 2 being the offshore sector, the latter being split into three zones (Zones A, B, and C). The permitted methods in Area 2 of the NDSMF include handline, dropline, and fish traps, but since 2002 it has essentially been a trap-based fishery which uses gear time access and spatial zones as the primary management measures (Newman *et al*., 2020). The main species landed by this fishery in the Kimberley subregion are goldband snapper, saddletail snapper, and red emperor.

Since 2008, annual catches within the Kimberley subregion of the NDSMF have exceeded 1,000 t (Newman *et al*., 2020). The 2019 catch of 1,507 t was the largest reported catch across the whole fishery. The total catch within the Kimberly subregion of the NDSMF in 2019 constituted 34% of the total catch within the entire NDSMF (the remaining 64% being caught in the Pilbara subregion).

Analysis of FishCube data shows that the area of fishing effort within the Kimberley subregion of the NDSMF is 127,613 km^2 for the period between 2015 and 2020 (refer **Figure 29**). The OA overlaps with 14,526 km^2 (11 %) of this fished area and the Acquisition Area overlaps 6,290 km^2 (5%) as shown in **Figure 29**.

[9] The SCF had three 10x10 NM boxes, all with <3 vessel counts; the KCMF had on 60x60 NM box with a <3 vessel count; the KGBMF had four 60x60 NM boxes, three of which with <3 vessel counts and one with an unknown vessel count; and the MAFMF had four 10x10 NM boxes, all with <3 vessel counts.

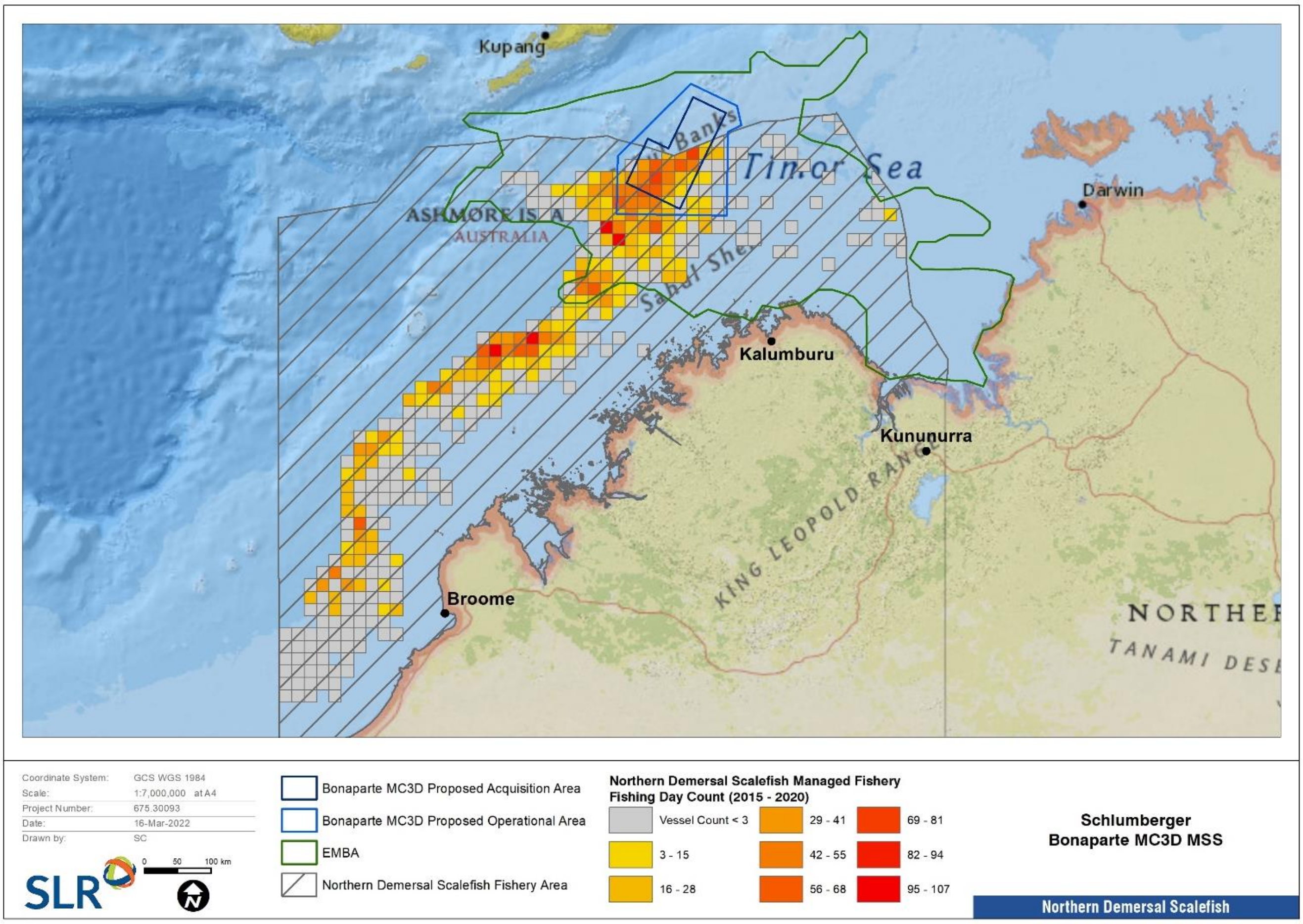


Figure 29 Fishing Effort within the Northern Demersal Scalefish Managed Fishery (2015-2020)

4.7.3.2.2 Mackerel Managed Fishery

The MMF is divided into three areas with the OA being located within Area 1 – Kimberley (121°E to WA – NT border). The primary target species of the MMF is Spanish mackerel (*Scomberomorus commerson*), which is fished commercially between Geraldton and the NT border.

Licence holders may only fish for mackerel by trolling or hand-line. There are currently only 14 licences in the Kimberley management area. A total of 15 vessels operated across the entire MMF during the 2019/20 season (Lewis *et al*., 2021).

Analysis of FishCube data shows that the area of fishing effort within the Kimberley subregion of the NDSMF is 44,010 km^2 for the period between 2016 and 2020 (refer **Figure 30**). The OA overlaps with 538 km^2 (1 %) of this fished area as shown in **Figure 30** and no fishing occurred within the Acquisition Area.

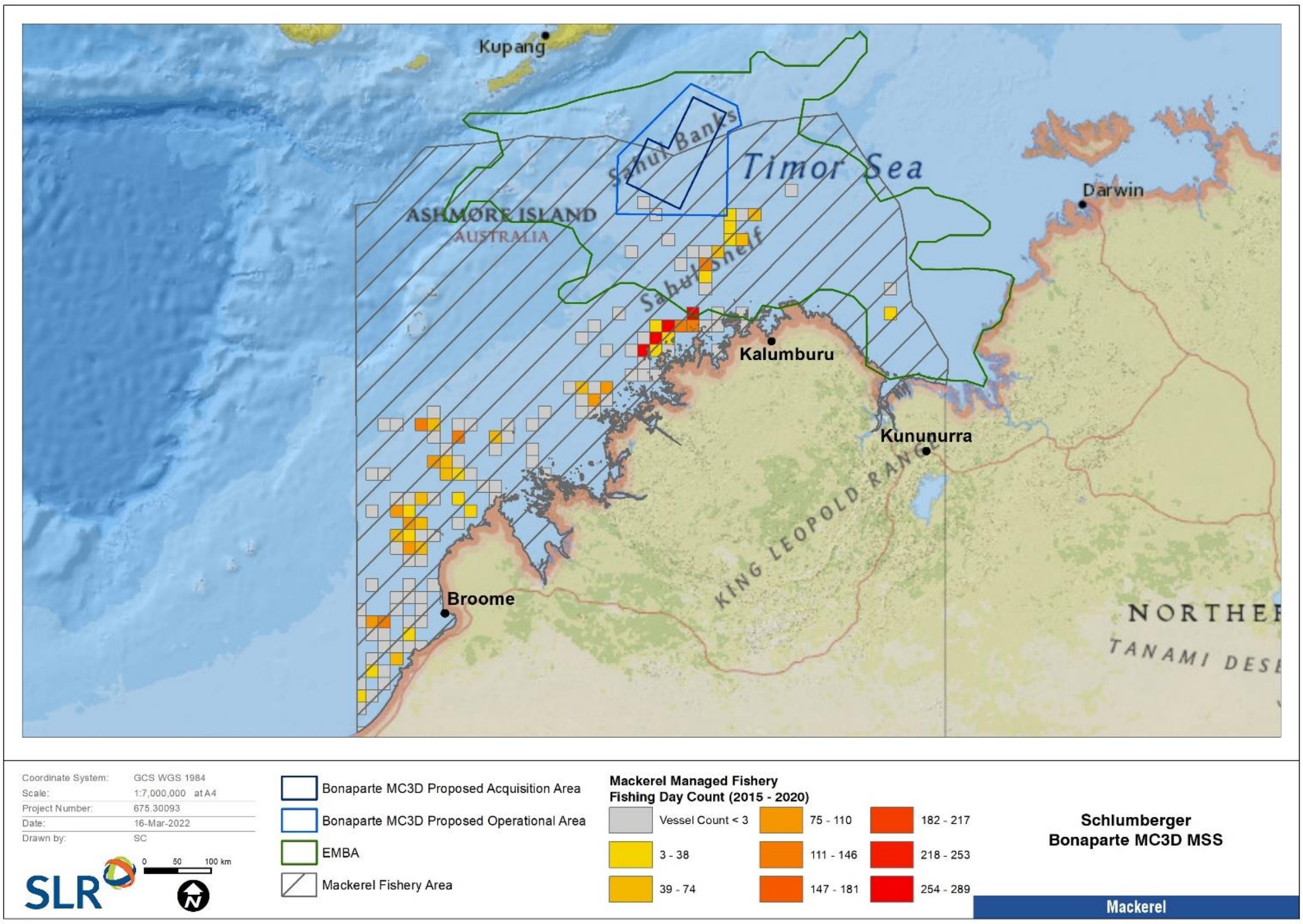


Figure 30 Fishing Effort within the Mackerel Managed Fishery (2015-2020)

4.7.3.2.3 Kimberley Prawn Managed Fishery

The KPMF is one of four managed prawn fisheries managed by the WA government and extends from Collier Bay in the west to Napier Broome Bay. The total prawn landings in 2019 for the KPMF were 100 t which was the lowest catch on record. The catch was primarily banana prawns (97 t), with 2 t of brown tiger prawns and 1 t of blue endeavour prawns also taken. There are two fishing periods for the season (April to mid-June, then from August to the end of November) with around 90% of the total landings taken in the first fishing period.

Analysis of FishCube data shows that the area of fishing effort within KPMF is concentrated close to the coast, however some fishing occurs within the EMBA, but none within the OA or Acquisition Area (refer **Figure 31**).

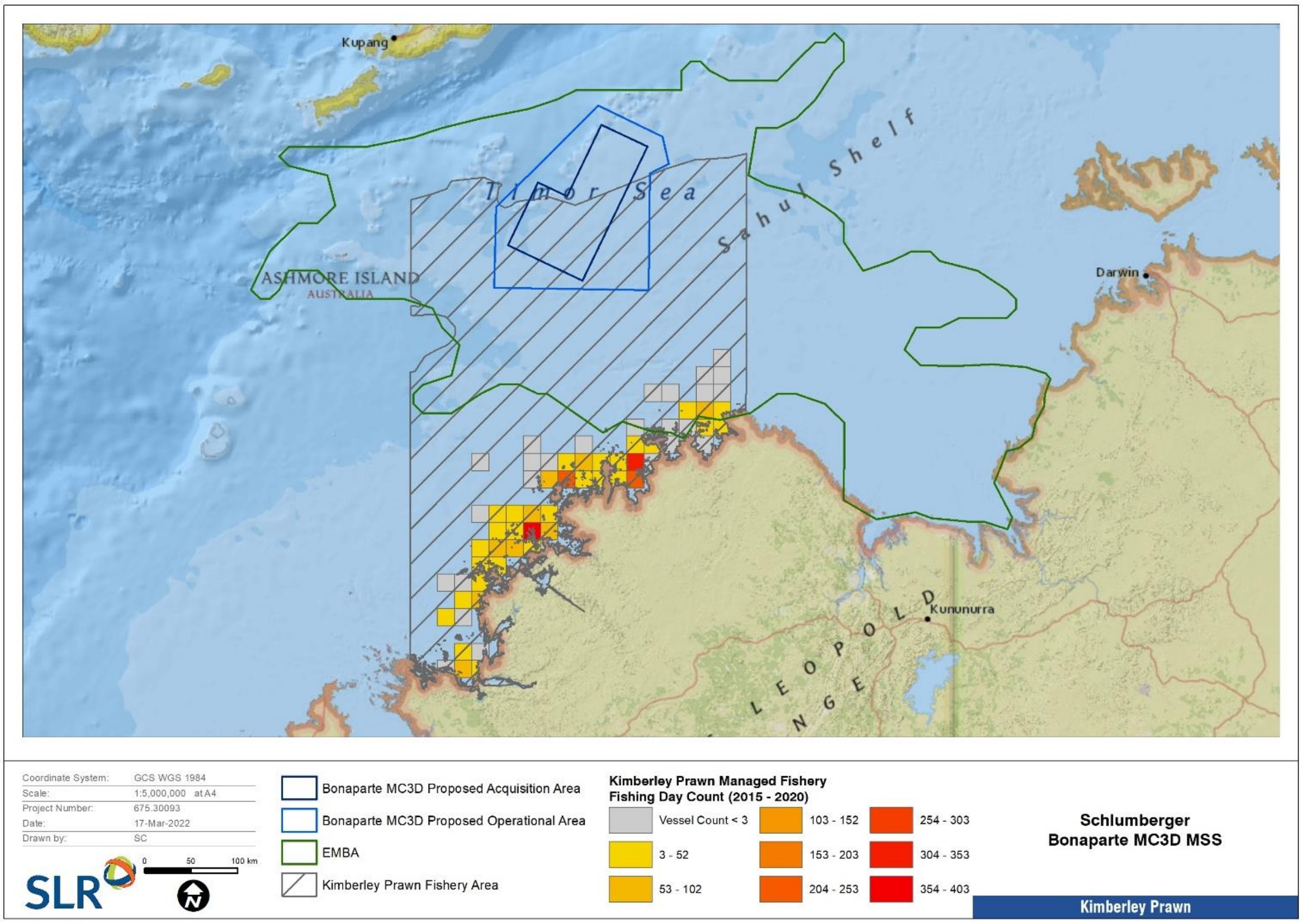


Figure 31 Fishing Effort within the Kimberley Prawn Managed Fishery (2015-2020)

4.7.3.2.4 Charter Fishing

The fishing charter industry in WA offers boat-based fishing tours of half day, full day and extended live aboard charters of two to 10 days duration (Howard *et al*., 2021). The industry operates tours along most of the WA coast, including the tours in the metropolitan area, regional tourist areas and a range of tours to very remote locations. Tours are offered all year round from a range of ports. The fishing charter industry in WA is regulated by the DPIRD. To operate as a Fishing Charter business, an operator is required to have a Fishing Tour Operator Licence covering the specific zone in which they operate tours. There are four Fishing Bioregions or zones, namely the South Coast, the West Coast, gascoyne, and the North Coast (Pilbara/Kimberley). Each zone has different fishing regulations for possession limits per person. The charter fleet primarily consists primarily of vessels between five and 25 metres. The OA is located within the North Coast zone, which extends from Longitude 114 50 East to the WA – NT border.

The top species caught /kept In the North Coast zone in 2019 with shares of total take are Golden Snapper (14%), Rankin Cod (11%), Spangled Emperor (7%) and Mangrove Jack (6%), however there are a variety of fish caught/kept in with seven species rating 3-5% (Howard *et al*., 2021).

Figure 32 presents the charter fishing trip counts between 2016 and 2020. Most of the trips are close to the Kimberley Coast, however there are occasional trips further offshore. There are no recorded trips within the OA or Acquisition Area; however, some occur with the EMBA.

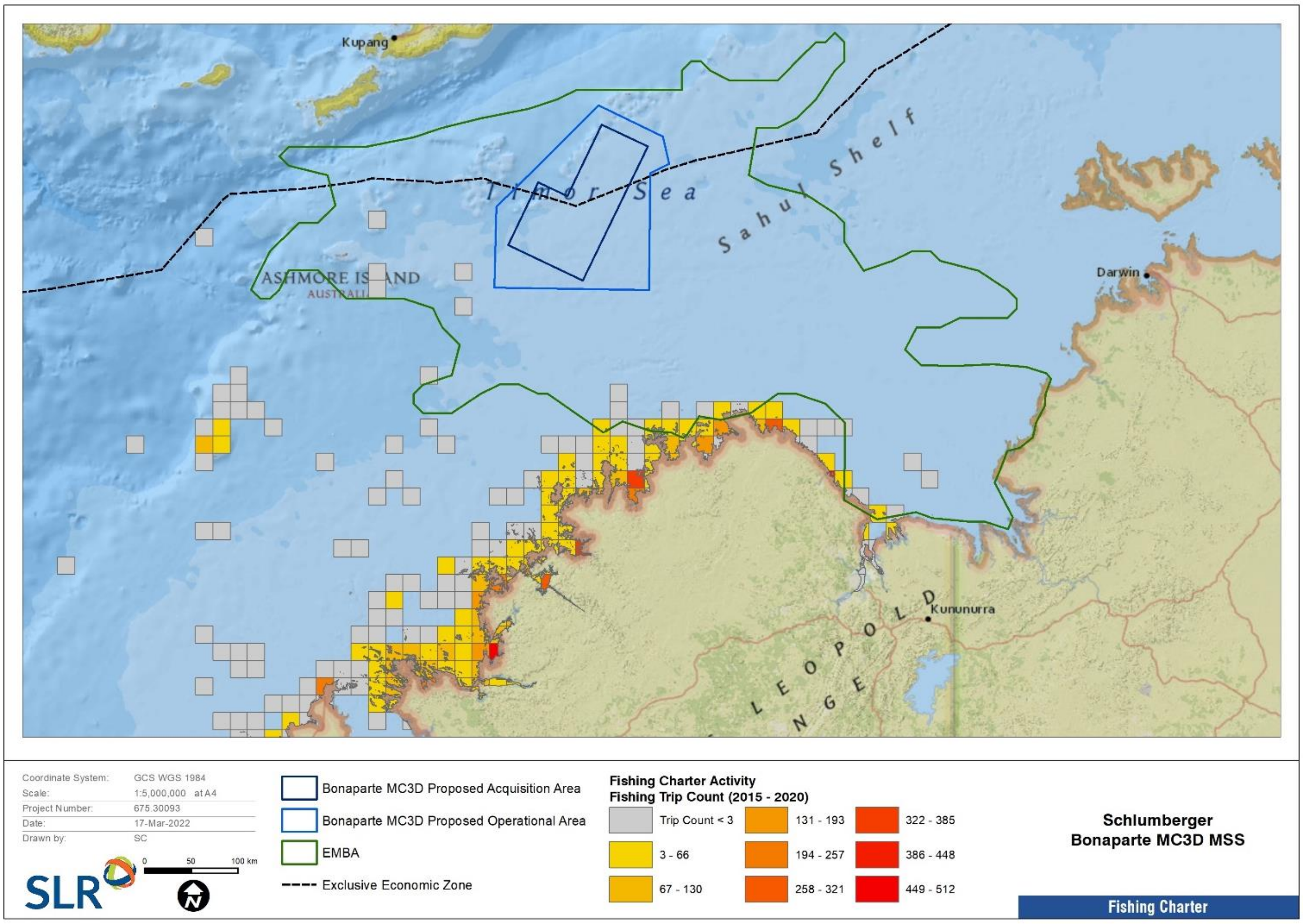


Figure 32 Western Australia Charter Fishing Trip Counts (2015-2020)

4.7.3.3 Northern Territory Managed Fisheries

NT State commercial fisheries are managed by the Northern Territory Department of Industry, Tourism and Trade (**DITT**), formerly known as the Department of Primary Industry and Resources (**DPIR**). Wild harvest fisheries are managed under the Fisheries Act 1988 and the Fisheries Regulations 1992.

Schlumberger requested fish catch and effort data from NT DITT for the fisheries it manages. Data were available in 60 x 60 NM CAES blocks for the most recent six years (2015 to 2020).

None of the NT managed fisheries overlap with the OA as it is not located within NT waters, however the following NT managed fisheries had some fishing effort between 2015-2020 within the southeast of the EMBA (as shown in **Figure 33**):

- Timor Reef Fishery;
- Small Pelagic Development Fishery (West Segment);
- Jigging Fishery;
- Demersal Fishery;
- Spanish Mackerel Fishery;
- Offshore Net and Line Fishery;

- Barramundi Fishery;
- Coast Line Fishery;
- Mud Crab Fishery;
- Special Permit Fishery;
- Aquarium Fishery;
- Pearl Oyster Managed Fishery; and
- Fishing Tour Operator.

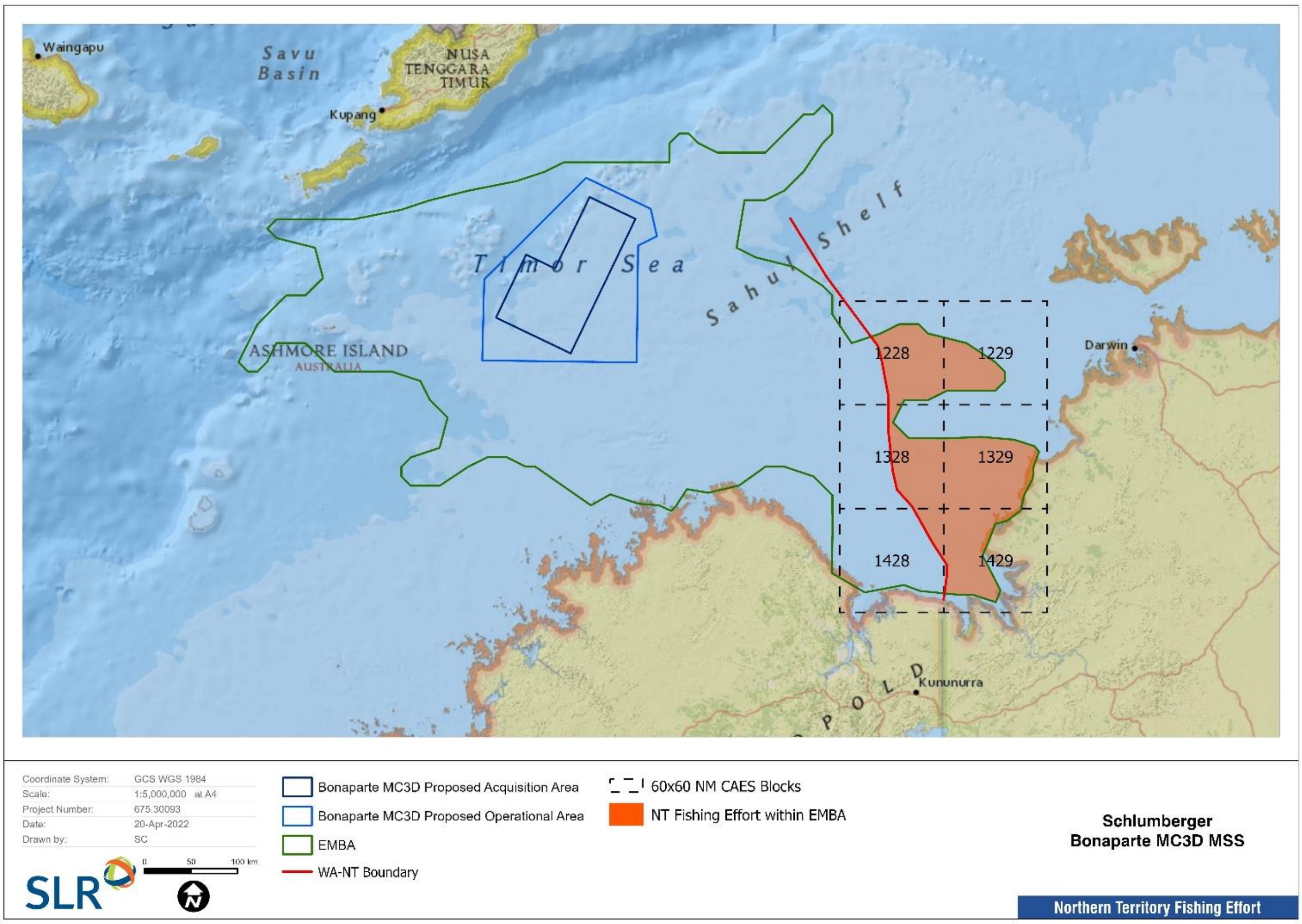


Figure 33 Northern Territory Fishing Effort within the EMBA

Catch information was unable to be provided by DITT for those blocks which had less than five licenses operating in them due to confidentiality reasons, however effort data was provided which gives an indication of the relative importance of any particular 60 x 60 NM CAES block to the fishery. **Table 23** presents a summary of the fishing effort within the six CAES blocks shown in **Figure 33** between 2015-2020 within the NT managed fisheries. It should be noted that some of this effort may not actually have taken place within the EMBA area because the 60 x 60 NM CAES blocks extend beyond the EMBA boundary (as shown in **Figure 33**). The greatest effort and catch totals within the EMBA were for the Demersal Fishery, Spanish Mackerel Fishery, Offshore Net and Line Fishery, and Barramundi Fishery. In addition, fishing tour operators fished extensively within the EMBA.

Table 23 Northern Territory Fisheries Fishing Effort within the EMBA (2015-2020)

Fishery	Fishing Effort	Total Catch*
Demersal Fishery	5,314 hours	>3,569,409 kg
Spanish Mackerel Fishery	15,822 hours	>427,536 kg
Offshore Net and Line Fishery	3,784 hours	>772,806 kg
Barramundi Fishery	1,131 days	382,792 kg
Mud Crab Fishery	638 days	>11,406 kg
Coastal Line Fishery	573 hours	>8,222 kg
Fishing Tour Operators	58,918 hours over 86,263 days	N/A
Aquarium Fish	277 hours	Confidential
Small Pelagic Development Fishery	108 hours	Confidential
Special Permit	70 hours	Confidential
Timor Reef Fishery	15 hours	Confidential
Jigging Fishery	6 hours	Confidential
Pearl Oyster Fishery	0.6 hours	Confidential

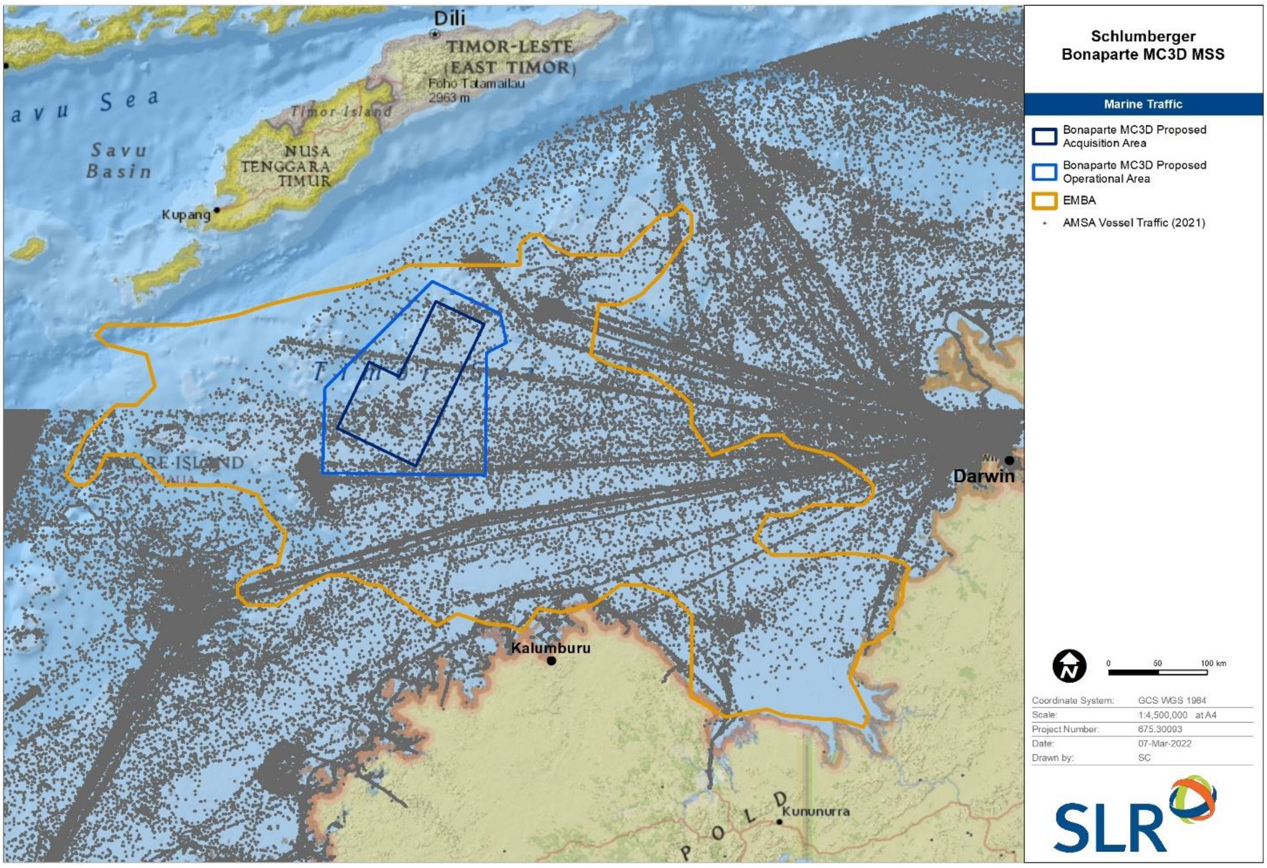
* Where ">" is stated it means that some catch data was not available for a particular CAES block but fishing occurred in that block, meaning the total catch will be greater than that stated.

4.7.4 Shipping

The North-west offshore region facilitates high shipping activity associated mining and oil and gas activities. The closest major port to the OA is Darwin Port, located over 650 km east of the OA. Kimberley Ports Authority operates two ports within the broader region, the Port of Derby to the southwest and the Port of Wyndham to the southeast. The Port of Wyndham is situated inland of the EMBA, on the West Arm of the Cambridge Gulf. Shipping activities within 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 facilitates;
- Construction vessels/barges/dredges;
- Offshore survey vessels; and
- Cruise ships

Vessel traffic in waters overlapping and in the vicinity of the OA between January 2021 and December 2021 is presented in **Figure 34** (AMSA, 2021). The data provides a conservative prediction of the likely traffic volumes that may be expected during the proposed Seismic Survey indicating the southern boundary of OA overlaps with high traffic shipping route.



Note: The above map only shows the vessel tracks from the vessels that have AIS onboard, vessels which don't have AIS will not be shown.

Figure 34 Marine Traffic Density in 2021

4.7.5 Oil and Gas Activities

The Bonaparte Basin is an established hydrocarbon province with a number of commercial operations identified within the OA and the EMBA. Petroleum titleholders with titles within the OA are listed in **Table 24** and shown in **Figure 35**.

Table 24 Offshore Petroleum Titles Details

Title Number	Title Type	Title Holder
WA-523-P	Exploration Permit	Carnarvon Energy Limited
AC/P66	Exploration Permit	INPEX Browse E&P Pty Limited
AC/RL12	Retention Lease	PTTEP Australasia (Ashmore Cartier) Pty Limited
AC/P61	Exploration Permit	Finder No 1 Pty Limited, Fugro Exploration Pty Limited
AC/RL6	Retention Lease	PTTEP Australia Timor Sea Pty Limited
AC/P69	Exploration Permit	Neptune Energy Bonaparte Pty Limited, Santos Offshore Pty Limited, SapuraOMV Upstream (Western Australia) Pty Limited
AC/RL10	Retention Lease	Bengal Energy Limited, PTTEP Australia Timor Sea Pty Limited
AC/RL7	Retention Lease	PTTEP Australasia (Ashmore Cartier) Pty Limited
AC/RL4	Retention Lease	PTTEP Australia Timor Sea Pty Limited

Title Number	Title Type	Title Holder
AC/P54	Exploration Permit	PTTEP Australasia (Ashmore Cartier) Pty Limited
AC/L3	Production Lease	PTTEP Australasia (Ashmore Cartier) Pty Limited
AC/P63	Exploration Permit	Carnarvon Energy Limited
AC/P50	Exploration Permit	Santos Offshore Pty Limited, SapuraOMV Upstream (Western Australia) Pty Limited
AC/P67	Exploration Permit	Neptune Energy Bonaparte Pty Limited, Santos Offshore Pty Limited, SapuraOMV Upstream (Western Australia) Pty Limited

In addition to those permits listed above, there are three production operations in close vicinity to the OA, those being the Montara Venture, Liberdade and the Northern Endeavour (**Figure 35**). These operations either utilise Floating Production, Storage and Offloading vessels, or transport the produced hydrocarbons in subsea pipelines to Darwin for processing onshore.

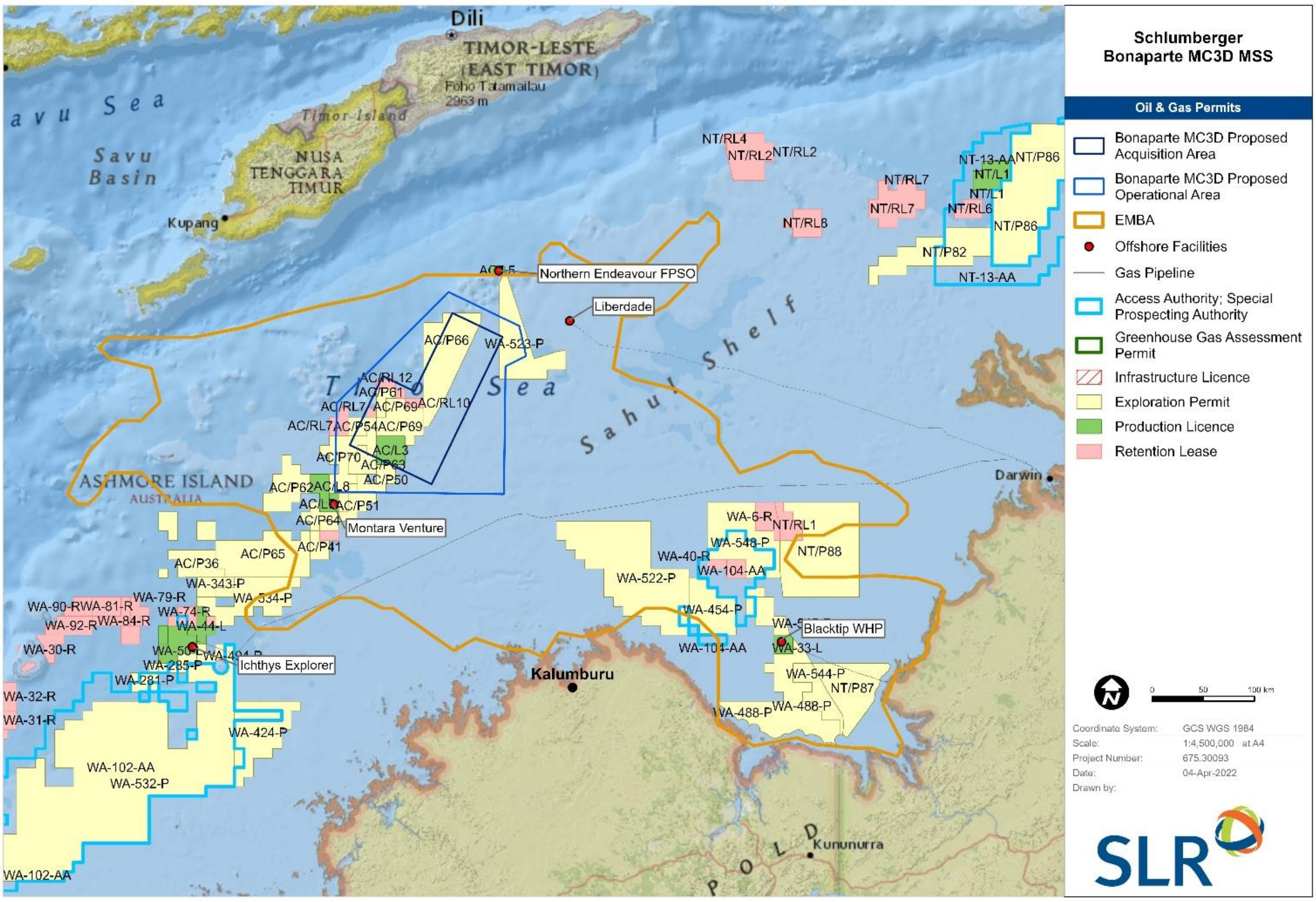


Figure 35 Offshore Petroleum Titles in the vicinity of the OA

4.7.6 Defence Activities

A search of the Department of Defence's unexploded ordinance register (**UXO**) map confirmed UXO are not known to occur within the OA (DoD, 2022). However, three offshore sites characterised as having potential to contain UXO were identified in proximity to the EMBA, with the closest site located 160 km west of Ashmore Reef (**Figure 36**). In each case, sites represent an area where Depth Charges were deployed in World War II including some which failed to function and release. Further detail is contained in Notice to Mariners NTM/12/Aus 315 and NTM/12/Aus 318.

The closest defence training area to the OA is the North Australian Exercise Area, approximately 215 km to the east of the OA and within the footprint of the EMBA (**Figure 36**). The North Australian Exercise Area is a maritime military zone administered by the Australian defence Force, as well as restricted airspace. The North Australian Exercise Area is used by the Royal Australian Air Force and the Roya Australian Navy for military operations including live weapons and missile firings.

A search of the Department of Defence website and WA Department of Transport Notice to Mariners did not identify any planned Defence activity within the OA or EMBA. However, a precautionary approach was adopted and the Department of Defence will be engaged and notified of the proposed Seismic Survey.

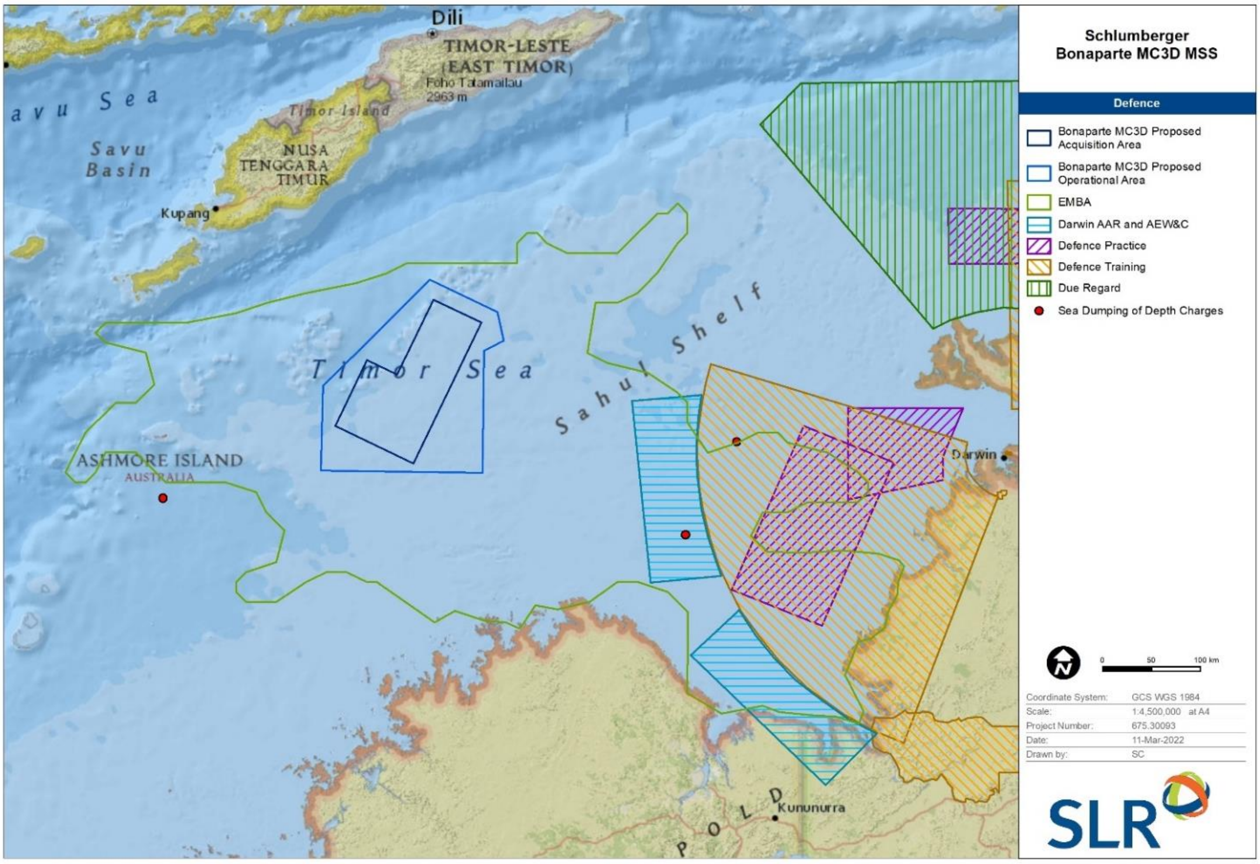


Figure 36 Defence Activities in the Vicinity of the OA and EMBA

4.8 Periods of Peak Sensitivity or Activity within the OA

A summary of distribution, activities and peak periods for significant species and other relevant activities that may occur annually within or close to the OA is provided in **Table 25** below.

Table 25 Timing of Key Activities Relevant to the OA and the Surrounding Area

Activity/Sensitivity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Source
Seismic Survey													
Planned timeframe													
Environmental Receptors and Activities													
Marine mammals													
Pygmy Blue Whale BIA (northern migration)													Thums *et al.*, 2021
Pygmy Blue Whale BIA (southern migration)													Thums *et al.*, 2021; McCauley, 2011
Fish/sharks													
Whale Shark BIA													Reynolds *et al.*, 2017; Sleeman *et al.*, 2010
Marine reptiles (closest site adopted for each species)													
Flatback turtle foraging BIA													Donovan *et al.*, 2008
Loggerhead turtle foraging BIA													Donovan *et al.*, 2008
Olive Ridley turtle foraging BIA													Donovan *et al.*, 2008
Green turtle nesting BIAs													Dethmers *et al.*, 2006; DEH, 2005
Hawksbill turtle nesting BIAs													DSEWPC, 2012; Limpus, 1995
Seabirds and migratory shorebirds (BIAs close to OA, and species that are likely to be present within OA)													
Greater Frigatebird, breeding, foraging BIA													DoEE, 2022
Lesser Frigatebird, breeding, foraging BIA													Birdlife, 2022
Lesser Crested Tern, breeding BIA													DSEWPC, 2012c
Greater Crested Tern, breeding													Chatto, 2001; DSEWPC, 2012c

Activity/Sensitivity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Source
Wedge-tailed shearwater, breeding BIA													DoEE, 2022
Streaked shearwater													DoEE, 2022; Marchant and Higgins 1990
Red-footed Booby, breeding, foraging BIA													DoEE, 2022; Clarke, 2010
White-tailed tropicbird, breeding													DoEE, 2022; Clarke, 2010
Wedge-tailed shearwater, breeding BIA													DoEE, 2022
Streaked shearwater													DoEE, 2022; Marchant and Higgins 1990
Red-footed Booby, breeding, foraging BIA													DoEE, 2022; Clarke, 2010
White-tailed tropicbird, breeding BIA													DoEE, 2022; Clarke, 2010
Commercial indicator species spawning/aggregation													
Spanish mackerel													Lewis, 2020
Goldband snapper													Newman *et al.*, 2008
Saddletail snapper													Newman *et al.*, 2008
Red emperor													Newman *et al.*, 2008
Banana prawns													AFMA, 2022
Brown tiger prawns													AFMA, 2022
Blue endeavour prawns													AFMA, 2022
Commercial fishing													
Northern demersal scalefish fishery													DPIRD, 2022
Marine traffic													
Commercial shipping													AMSA, 2021

Activity/Sensitivity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Source
Tourism – cruise vessels													Santos, 2021
Tourism – diving, snorkelling, wildlife watching													DNP, 2018a; WA DPIRD, 2021
Key	Distribution/activity occurs:												
	Peak period:												

5 Stakeholder Engagement

Stakeholder engagement is an integral component of the project development and planning phase of any potentially impacting activity, and SLB acknowledges that undertaking an effective stakeholder engagement programme is critical to the success of the Seismic Survey. SLB is aware of the requirements regarding appropriate consultation, as defined under the Environment Regulations and has developed an inclusive and ongoing stakeholder engagement process that will extend beyond the completion of the Seismic Survey.

To assist with developing an effective programme that informs and builds capacity in stakeholders, to the extent that they understand the potential risks and impacts associated with the proposed Seismic Survey, SLB has been guided by the relevant regulations and guidelines and the general principles for public participation regarded as underpinning good practice (IAP2, 2016).

5.1 Regulatory Requirements and Guidelines

The stakeholder engagement programme led by SLB is ongoing. It has, and continues to provide a mechanism for information and knowledge exchange between SLB and stakeholders regarding the proposed Seismic Survey. SLB have made available the opportunity for stakeholders to ask specific questions and have transparent and honest communications as seen in **Appendix I**.

In accordance with sub regulation 11A(2) of the Environment Regulations, SLB are required to consult with 'relevant persons' (also referred to herein as stakeholders) who may be affected by the Seismic Survey so that they are given the opportunity to assess the activity being proposed (i.e. the Seismic Survey) and respond accordingly to raise any objections or claims they may have. Issues and concerns raised may relate to environmental, social, economic and other factors. It is expected that any such objections or claims raised are considered by SLB and, wherever practicable, incorporated into the management of the proposed Seismic Survey as a component of this EP.

The parties considered as 'relevant persons' and who have been engaged with as part of the stakeholder engagement programme are defined within **Section 5.3**. For the purpose of this EP, the definition of a relevant persons was interpreted broadly, so that a wide range of groups, organisations, associations and individuals were included within the stakeholder engagement programme and to ensure processes are adequate to support ongoing dialogue throughout the lifespan of the project.

In developing this EP and the corresponding stakeholder engagement programme, SLB has considered the requirements of the following Regulations and Guidelines:

NOPSEMA:

- Guidance Document N-04750-IP1411 Consultation Requirements under the Offshore Petroleum and Greenhouse Gas Storage (Environmental) Regulations 2009;
- Guidance Note N-04750-GN1847 Responding to Public Comment on Environment Plans 2020;
- Guideline N-06800-FL1887 Consultation with Commonwealth agencies with responsibilities in the marine area 2020;
- The publication produced by NOPSEMA titled "Requirements for Consultation and Public Comment on Petroleum Activities in Commonwealth Waters" 2018.

Australian Fisheries Management Authority:

- Petroleum industry consultation with the commercial fishing industry (https://www.afma.gov.au/sustainability-environment/petroleum-industry-consultation), accessed December 2021

Commonwealth Department of Foreign Affairs and Trade:

- Engage with DFAT (https://www.dfat.gov.au/trade/engage-with-dfat), accessed December 2021.

Government of Western Australia, Department of Fisheries:

- Guidance statement for oil and gas industry consultation with the Department of Fisheries 2013.

Government of Western Australia, Department of Transport:

- Offshore Petroleum Industry Guidance Note, Marine Oil Pollution: Response and Consultation Arrangements 2020.

5.2 Stakeholder Engagement Objectives

In support of this EP, SLB identified a set of key objectives for the stakeholder engagement programme. These objectives were developed with the intention to inform and build capacity in stakeholders, to the extent that they understand the potential risks and impacts associated with the proposed Seismic Survey, and to make available the opportunity to raise any objections or claims they may have. Finally, to ensure that wherever practicable concerns raised are incorporated into the management of the proposed Seismic Survey as a component of this EP.

The key stakeholder engagement objectives included:

- Identify all relevant stakeholders;
- Initiate transparent and honest communication with all relevant stakeholders;
- Provide relevant stakeholders with sufficient information to allow them to make an informed assessment of the possible consequences of the activity on their functions or activities;
- Provide adequate opportunity (i.e. reasonable period) for relevant stakeholders to consider the information and provide feedback;
- Provide a mechanism for assessing the merit of any objections or claims received;
- Where applicable, demonstrate where control measures have been incorporated as a result of stakeholder engagement feedback;
- Support ongoing stakeholder identification and engagement as the project continues; and
- Demonstrate to NOPSEMA that completed and ongoing stakeholder engagement is consistent with the requirements of the Environmental Regulations.

5.3 Identification of Stakeholders

A number of different methods were used to identify the stakeholders relevant to the proposed Seismic Survey. In all cases, the analysis of 'relevant persons' gave consideration to the definitions provided within the Environment Regulations 11A, which can be summarised as:

- Department or agency of the Commonwealth to which the activities to be carried out under the EP may be relevant;
- Each Department or agency of a State to which the activities to be carried out under the EP may be relevant;
- A person or organisation whose functions, interests, or activities may be affected by the activities to be carried out under the EP; and
- Any other person or organisation that the Titleholder considers relevant.

At the outset of the planning stage of the Seismic Survey, a 150 km buffer was placed around the OA, or the area which the acoustic source could be discharged. This extent was considered suitable to identify the different State Governments, stakeholders, interest groups, industry bodies, associations, marine parks, protected areas, and tourism operations that could feasibly be impacted by the proposed activity, under reasonable (e.g., planned) conditions and, therefore, should be included within the stakeholder engagement programme. In some instances the stakeholders engaged did extend beyond this distance, where SLB sought to adopt a precautionary approach.

Relevant persons were identified and catalogued based on targeted searches within publicly available databases for the listed groups (e.g., tourism operators), using SLBs local knowledge of key receptors, environment and stakeholders, in accordance with the Government regulations and guidelines and as identified through communications with NOPSEMA.

Due to the nature of the activity (e.g., at sea) and potential pathway for impacts (e.g., displacement), commercial fisheries within and surrounding the OA were identified as key stakeholders. The ability for commercial fishers or licence holders to undertake commercial fishing operations is contingent upon access to marine resources and environmental conditions, so any potential impact on their routine activities could have a potential impact on their livelihoods. For this reason, a high level of resources and importance were allocated to engagement with commercial fishers. Consistent with the expectations of Australian Fisheries Management Authority (**AFMA**), whereby operators should consult directly with fishing operators, SLB intended to manage all consultation activities with the identified fisheries stakeholders; however, given the extensive area covered by the proposed MMS and complex jurisdictional setting (see **Section 2**), SLR were engaged to lead and navigate effective engagement with commercial fisheries, the associated representative bodies and license holders. As a component of this work, SLR also undertook a provisional assessment of fisheries activity within the OA. This assessment allowed SLR and SLB to gain a thorough understanding of the fishing activity in the region, and to accurately identify those licence holders whose fishing activity most likely to be affected by the survey.

A communications database has been developed and maintained to include the identified stakeholders, their associated contact details and the date of all outgoing and incoming correspondence (**Appendix I**). This database will be maintained and updated throughout the Seismic Survey planning and acquisition phases. All correspondence received from stakeholders is also filed on record, as per the information provided in **Appendix F** and **G**. A copy of the Stakeholder Factsheet developed by SLB that was disseminated to all relevant persons, is included in **Appendix H**.

SLB and SLR has made every effort to engage with all relevant stakeholders identified in the preparation of this EP; however, it is noted a number of stakeholders did not respond, despite multiple attempts and there was no other way to get in touch with these stakeholders. It was also made more difficult by only being provided postage details for fishery licence holders, which letters were sent to, but no responses were received at the time of preparation of this EP. It is understood that electronic contact details may be made available in the future, but at this stage they are not, and despite several efforts to find electronic information or phone numbers of the licence holders, this was unsuccessful.

5.4 Stakeholder Engagement Programme

5.4.1 Overview

The list of stakeholders that have been contacted as a component of the stakeholder engagement programme for the Seismic Survey are provided in **Appendix E**. As described in **Section 5.3**, these stakeholders have been characterised using the definitions prescribed under Environment Regulation 11A.

SLB are required to ensure full transparency is maintained during the stakeholder engagement process. This is to allow NOPSEMA to determine whether consultation has been undertaken appropriately and in accordance with the requirements of the Environment Regulations. To this end, a copy of the Information Pack developed by SLB and disseminated to all relevant persons, is included in **Appendix H.**

Environmental Regulations 16(b)(iv) requires SLB to include a copy of the full text of any response that has been submitted by a relevant person, within the final EP. The regulations also require inclusion of the written response by SLB, and any written correspondence received from any other relevant person during the stakeholder engagement programme. The unedited versions of all correspondence with relevant persons that formed part of the stakeholder engagement process are provided in **Appendix F**.

In addition to this, where verbal communications between SLB and stakeholders or relevant persons have occurred, meeting minutes or memos were generated to document the engagement. This documentation of the engagement is consistent with the requirements of the 2011 Explanatory Statement to the Environment Regulations, which states that the summaries included from stakeholder engagement should promote transparency of all levels of consultation undertaken. Where they exist, these minutes and memos have been included within **Appendix G**.

No discernible definition as to what is considered “sufficient time” to support adequate stakeholder feedback is provided in the Environmental Regulations, and it is acknowledged that this is assessed on a case-by-case basis, depending on the stakeholder, and their interest or influence on the proposed activity.

All stakeholders were engaged, at a minimum, on two separate occasions. In most cases, approximately three calendar weeks passed between the initial and follow-up communications. It is considered that multiple attempts to engage and the provision of subsequent updates regarding the survey details and any changes/revisions is characterised as ‘sufficient time’ to support stakeholder feedback. Where no response has been received following the passing of ‘sufficient time’, this has been reflected within the communications database (**Appendix F**).

SLB also notes feedback from the Regulator and peak industry representative bodies regarding the possible influence of 'stakeholder fatigue' on rates of engagement. Given the number and frequency of oil and gas projects proposed and occurring within the broader NWMR, it is understood that many stakeholders have received a high volume of engagement communications resulting in decreased capacity and willingness to engage. With respect to this constraint, SLB will continue to make available the opportunity for stakeholders to engage throughout the life of the project.

The details of completed and projected stakeholder engagement activities are further described in the following sections.

5.4.2 Approach

The stakeholder engagement programme comprises a number of consultation approaches and phase, including:

- General stakeholder engagement, consisting of:
  - Developing an Information pack, including a Stakeholder Factsheet with an overview of the proposed activities and location details (see **Section 5.4.3**);
  - First Round of General Stakeholder Engagement;
  - Second Round of General Stakeholder Engagement, including follow-up;
- Specific stakeholder engagement ;
- Ongoing stakeholder engagement;
- Pre-activity notification; and
- Post-activity notification.

At the outset, general stakeholder engagement material was disseminated to all relevant persons to initiate communications between the proponent and stakeholders, provide an opportunity to establish a meeting and to socialise the proposed Seismic Survey. Using the information gained during the stakeholder identification process and based on feedback received regarding the information pack, key stakeholders were identified for specific engagement. The nature of specific engagement is such that it's tailored to, and therefore highly variable amongst the range of, specific stakeholders. Specific engagement may include increased frequency of communications or more detailed communications regarding the potential impacts to the stakeholder's activities or a change in the mode of communications (e.g., phone vs email).

Of note, is that not all general engagement communications occurred concurrently. As the development of the EP progressed, new sensitivities, receptors and corresponding 'relevant persons' were subsequently identified. Where this occurred, additional stakeholders were contacted as soon as reasonably possible to notify them of the proposed Seismic Survey and, therefore, were communicated 'out of cycle' with the broader general stakeholder engagement programme.

Due to COVID driven constraints placed on face-to-face meetings and non-essential travel, engagement activities were limited to those undertaken using digital means of communications such as email, phone and teleconference. This mode of communication and engagement did not appear to hinder the engagement process as the world has quickly adapted to virtual meetings following the COVID pandemic.

A detailed description of the nature and timing of each engagement activity (such as emails, calls, teleconference meetings or postage of letters) are provided in the subsequent sections (**Sections 5.4.3** to **5.4.6**)

5.4.3 Information Pack

To support the first round of general stakeholder engagement, an Information Pack was developed to describe the proposed Seismic Survey, Location of the OA and introduce SLBs corporate and project level consultation and environmental commitments. The relevant stakeholders identified were contacted via email and provided with the Information Pack in January 2022 (**Appendix F**). This information was subsequently made available to stakeholders as they were identified throughout the development of the EP and as a result of the wider stakeholder engagement process.

The following information was provided to stakeholders within the Information Pack:

- A high-level description of the proposed location of the Seismic Survey;
- Description of the proposed seismic activity;
- SLBs commitment to communication during the Seismic Survey;
- SLBs commitment to environmental performance;
- A request for feedback from stakeholders on the Seismic Survey with full contact details;
- Location map of proposed Acquisition Area and survey lines; and
- Coordinates of OA boundary.

5.4.4 First Round of General Stakeholder Engagement

After the relevant stakeholders were identified, the stakeholder engagement process commenced. This process sought to determine what environmental and social values, sensitivities, access rights, risks and impacts were of most concern to stakeholders in relation to the Seismic Survey and to establish a precedent for mutual sharing of information between all parties

The first round of stakeholder engagement was undertaken in January 2022 and consisted of an introductory email and appended Information Pack. All stakeholders were encouraged to engage, ask questions and invited to provide comment or request additional information if they require.

A detailed record of all feedback received from stakeholders and the responses provided by SLB are provided in **Appendix I**.

Feedback from this first round of stakeholder engagement was incorporated into the survey planning and design phase, as well as the control measures.

The feedback that was received from stakeholders was relatively sparse and focussed on advising on further notification requirements prior to the survey commencing. For example, with respect to surrounding Oil and Gas operators this included implementing a 48-hour operational look ahead plan. Where for selected groups this included recommendations to contact all ancillary stakeholders regarding the Seismic Survey.

Parks Australia provided a list of recommendations to be considered as part of the EP process in their reply, focussing on consideration of the potential impact to protected receptors such as Oceanic Shoals Marine Park located adjacent to the OA, vulnerable species, BIAs, KEFs and areas of significant cultural value. In addition, The Director of National Parks (**DNP**) requested that they be made aware of any oil/gas pollution incidences as soon as possible.

5.4.5 Second Round of General Stakeholder Engagement

The second round of stakeholder engagement was undertaken in February/March 2022. This primarily consisted of disseminating a standardised follow-up email to the stakeholders that had not yet responded. However, a customised email response was also sent to the stakeholders who expressed interest in the proposed Seismic Survey during the first round of engagement, including further high-level information relating to their potentially impacted activities where required.

Similar to the first round of engagement, there were a high proportion of stakeholders who did not respond to communications sent in February/March 2022.

Of note, is that WAFIC replied to the second round of general stakeholder communications, as described in **Section 5.4.6**.

5.4.6 Specific Stakeholder Engagement - Commercial Fishing Industry

The commercial fishing industry are the primary stakeholders with a commercial interest in the maintenance of access to and the condition of the marine environment within and surrounding the OA. There are multiple licence holders that undertake fishing activity within the OA, who may potentially be impacted by the proposed Seismic Survey. A preliminary review of fisheries boundaries showed overlap between the extent of both Commonwealth and State Fisheries and the OA, as described in **Section 4.7.3**. and summarised in **Table 26**.

To inform and focus the specific stakeholder engagement activity, a detailed assessment of catch and effort rates within the OA, for each relevant fishery, was undertaken and is provided in **Section 4.7.3.2**. Of the fisheries assessed, recent records of fishing effort within the OA were reported only for Mackerel Managed Fishery and Northern Demersal Scalefish Managed Fishery.

Of note, is that responses from representatives of Commonwealth Fisheries and State Fisheries were also used to support the findings of the preliminary and detailed assessment of fisheries activities and, ultimately, determine stakeholders which may potentially be impacted by the Seismic Survey.

Table 26 Commercial and State Fisheries Boundaries which overlap with the OA and Estimated Fishing Activity

Jurisdiction	Fishery – Subsector	Estimated fishing activity in OA
Commonwealth Fisheries	Western Skipjack Fishery	No recent effort reported
Commonwealth Fisheries	Southern Bluefin Tuna Fishery	No recent effort reported
Commonwealth Fisheries	Western Tuna and Billfish Fishery	No recent effort reported
Commonwealth Fisheries	Northern Prawn Fishery	No recent effort reported
Commonwealth Fisheries	North-West Slope Trawl Fishery	No recent effort reported
State Managed Fisheries	Joint Authority Northern Shark Fishery	No recent effort reported
State Managed Fisheries	Mackerel Managed Fishery	Limited effort in area
State Managed Fisheries	Northern Demersal Scalefish Fishery	Considerable effort in area
State Managed Fisheries	Specimen Shell Managed Fishery	No recent effort reported[10]
State Managed Fisheries	Western Australian Sea Cucumber Fishery	No recent effort reported

[10] Estimation of effort ascertained based on information provided by the nominated peak representative body, WAFIC.

Jurisdiction	Fishery – Subsector	Estimated fishing activity in OA
State Managed Fisheries	Marine Aquarium Fish Managed Fishery	No recent effort reported[11]
State Managed Fisheries	Abalone Managed Fishery	No recent effort reported
State Managed Fisheries	Kimberley Prawn Managed Fishery	No recent effort reported
State Managed Fisheries	West Coast Deep Sea Crustacean Managed Fishery	No recent effort reported
State Managed Fisheries	Pearl Oyster Managed Fishery	No recent effort reported

5.4.6.1 Western Australian Fishing Industry Council Engagement

As nominated by the WA Government, the Western Australian Fishing Industry Council (**WAFIC**) are the peak industry body representing professional fishing, pearling, and aquaculture enterprises. SLB has been communicating with the WAFIC since the commencement of the stakeholder engagement programme to effectively engage with license holders actively operating within the OA. WAFIC replied in the second-round general stakeholder engagement. Their response consisted of a request for further information regarding the proposed air gun array volume (in^3) and queries regarding the assessment of the peak fishing periods, key spawning times for aquatic species during the survey period and the possibility of an adjustment protocol to compensate fishers if they are displaced from their fishing grounds during the Seismic Survey.

SLB provided the results of the fishery assessment of the OA to WAFIC as well as the additional information that was requested as part of the engagement. Two fisheries were identified as either fishing in or close to the OA and they are discussed in **Sections 5.4.6.2** and **5.4.6.3**. Following the annual summaries of catch data over a five-year period, WAFIC recommended monthly breakdown in catch effort, which was conducted and provided to WAFIC once complete.

WAFIC made it clear that engagement with fishers has changed, whereby in the past, operators went to WAFIC who then engaged with their members on the proposed offshore activity. However, this was taking up a lot of WAFIC's time due to extensive levels of engagement and made a call to no longer facilitate engagement with licence holders and it is up to the applicant to complete the engagement. Due to confidentiality reasons, WAFIC are not able to pass on contact details of licence holders which was found to be difficult in accessing the licence holders directly.

5.4.6.2 Northern Demersal Scalefish Fishery Engagement

SLB has been communicating with the NDSMF since the commencement of the stakeholder engagement programme to effectively engage with the license holders actively operating within the OA.

As described above, general engagement communications were sent to both the Department of Primary Industries and Regional Development and WAFIC in both January and February/March as the Government regulator of State Fisheries and the peak industry representative for corresponding license holders, respectively.

[11] Estimation of effort ascertained based on information provided by the nominated peak representative body, WAFIC.

Thereafter, SLB was advised that WAFIC are the relevant fisheries representative with regard to proposed oil and gas activities. The nature and timing of communications with WAFIC are described in **Section 5.4.6.1**. Due to stakeholder engagement fatigue and resourcing, WAFIC have changed their stance on how they engage with industry and licence holders and as a result, no longer facilitate stakeholder engagement or distribution of information to licence holders. As a result, WAFIC recommend SLB submit a request to DPIRD for the contact information of licence holders active in the northern demersal scalefish fishery.

SLB subsequently submitted a request and obtained the details of the relevant licence holders in the northern demersal scalefish fishery; however, only postage details were provided. Several attempts were made to find phone numbers or emails for the licence holders but that did not prove successful despite many attempts.

As a result, a hard copy letter and accompanying Information Pack was sent directly to individual NDSMF license holders on 22 April 2022. The letter summarised a high-level description of the proposed Seismic Survey, location of the OA, fisheries assessments undertaken to date, SLB's commitments to communication throughout the project. The cover letter sent to licence holders requested the licence holders to make contact and provide their electronic or phone details to commence further engagement.

Unfortunately, WAFIC could not facilitate any further engagement with the licence holders or provision of contact details. No responses from license holders were received nor were any contact details such as email or telephone number provided to follow up again. It is considered that licence holders were provided sufficient information and given sufficient time to assess the information that they were provided, and to make an informed decision as to whether the proposed Seismic Survey would have any impact on their fishing activities. At the time of this report, SLB are still awaiting a response to these letters, and it is assumed that no response means that the licence holders do not have any issues with the propose Seismic Survey. Notwithstanding this, SLB are willing to commence engagement and provide further information or 48-hour lookaheads at any point with these licence holders should they make contact.

5.4.6.3 Mackerel Managed Fishery Engagement (MMF)

At the time of this report, the nature and status of communications for the MMF were consistent with those described for NDSMF, above.

SLB are currently awaiting responses to hard copy letters sent to licence holders on 22 April 2022.

5.4.7 Ongoing General Stakeholder Engagement

SLB will continue to engage with the relevant Commonwealth and State authorities and all other relevant stakeholders for the duration of the Seismic Survey, in accordance with the Environment Regulations 14(9). To achieve this, SLB set the following objective with regard to ongoing consultation, as part of the stakeholder engagement programme (see **Section 5.2**), that being 'support ongoing stakeholder identification and engagement as the project continues'.

The objective was underpinned by the following outcomes, each of which were considered necessary for successful ongoing engagement:

- Continual identification of relevant persons that may be affected by the survey;
- Provision of sufficient information to all relevant persons identified; and
- Continual identification and resolving of any issues that may arise as identified by relevant stakeholders.

Ongoing engagement, as described in the relevant objective and outcomes above, will be achieved by implementing the following actions:

- At least six weeks prior to survey commencement, SLB will perform a desktop review to assess for any new stakeholders in the region. This assessment will include all relevant EP submissions and a review of stakeholders identified by other proponents of seismic operations in any newly accepted EPs;
- In the event that a new stakeholder is identified by SLB, they will be contacted as soon as possible to provide them with sufficient information regarding the Seismic Survey. This will include a description of the identified impacts and associated control measures that are being implemented so that it is clear to see that the risks to this particular stakeholder will be reduced to **ALARP** and **Acceptable Levels**; and
- SLB will distribute Information Sheets at selected locations that target recreational users who are transient to the OA. For example, at retailers that sell recreational fishing gear and local dive shops.

Where the above actions have not resulted in successful notification to stakeholders, SLB will lean on one Support Vessel and one Chase Vessel on the water during the Seismic Survey. These vessels will be in contact with other maritime users during the survey and will be able to identify any vessels on the water that are unaware of the survey operations and ensure that no vessels travel in close proximity to the Seismic Vessel or streamers towed behind the vessel.

Should stakeholders raise any concerns or provide feedback that has not previously been considered within the development of the EP, the potential impacts and risks would be reassessed based on the inclusion of the new information and any literature relevant to the particular issue. If it was determined that a new or increased impact exists, which resulted in a significant modification to the activity, the EP would have to be updated and resubmitted to NOPSEMA in accordance with Regulation 17 of the Environment Regulations.

The following decision support resources would be applied to assess whether any potential change in impacts or risks was significant:

- Classifications of existing impacts and risks within the risk assessment matrix in this EP;
- Legislative requirements, guidelines, standards;
- Relevant literature;
- UAM results;
- Sound thresholds within the EPBC Act; and
- The Temporary Threshold Shift (**TTS**) and Permanent Threshold Shift (**PTS**) for the relevant receptors identified within the OA (**Section 7.2**).
- Professional Judgement

5.4.8 Objections and Responses

A number of responses were received from stakeholders after they had considered the Information Pack provided. The nature of responses was varied; some included requests for further information, to be kept informed and some noted that the proposed survey was not relevant for their interest in the area. At the time of this EP, only one objection to the survey was reported throughout the stakeholder engagement programme. This objection concluded that detailed consideration be given to the protection of BIAs and their corresponding receptors areas of cultural heritage significance. These claims were considered to be adequately addressed through the development of this EP and associated control measures and operational procedures. Likewise, in accordance with the Environment Regulations 16(b)(ii) all submissions have been considered in the assessment of risk and responses have been provided back to all submitters. All concerns raised have been considered within the development of this EP and control measures have been tailored where necessary to reduce the risks to **ALARP** and an **Acceptable Level**.

Control measures in **Section 7** and **8** that will be implemented throughout the Seismic Survey are considered adequate to reduce impacts of the Seismic Survey, and in particular the protection of the BIAs and their corresponding receptors to **ALARP** and an **Acceptable Level**. Where existing control measures did not address any objections or claims made, additional control measures were implemented.

In accordance with the Environment Regulations 16(b)(iii), the claims that have been made by stakeholders are summarised in **Appendix I**, with the response by SLB and the relevant section within the EP where those concerns are addressed. The full correspondence between the relevant persons and SLB is provided in **Appendix F**.

5.4.9 Pre-activity Notification to Stakeholders

Prior to commencing the Seismic Survey, SLB will provide specific details to all relevant stakeholders in relation to confirmed project timing and location. A number of temporal and spatial driven mitigations have been implemented into the survey planning to reduce the impacts on blue whales within the BIA to **ALARP** and an **Acceptable Level**.

SLB has also committed to providing interested stakeholders with 48-hour look-ahead of where the survey vessels will be, so that they can then incorporate the survey plans into their operations. This look-ahead will be updated every 24 hours.

Navigational warnings and Notice to Mariners will also be issued on maritime radio and via email correspondence which provide information about the Seismic Vessel, including the Seismic Vessel being restricted in its ability to manoeuvre due to towing the streamer array.

A summary of the pre-activity notification process by SLB is provided in **Table 27**.

Table 27 Pre-Activity Notifications by SLB

Timing – prior to the Seismic Survey	Stakeholder	Information to be Provided
Approval of EP	Director of National Parks	That the EP has been approved by NOPSEMA via email to MarineParks@environment.gov.au
4 weeks	All relevant stakeholders	• Summary of proposed activity • Summary of vessel and seismic gear • OA coordinates • Date of activity commencement • Duration of activity • SLB contact details
4 weeks	Australian Defence Force	• Operational area coordinates • Date of activity commencement
4 weeks	Australian Hydrographic Office (**AHO**)	Contact AHO at datacentre@hydro.gov.au with details relevant to the operations to promulgate the appropriate Notice to Mariners. Updates should be provided to AHO on progress and, importantly, any changes to the operations.
10 days prior	NOPSEMA	Written notification of the date of intention to commence the Seismic Survey that is included within this EP.
10 days prior	Department of Mines, Industry Regulation and Safety (**DMIRS**)	Provide a pre-start notification confirming the start date of the proposed activity to petroleum.environment@dmirs.wa.gov.au. Consultation with DMIRS resulted in this request, and although no timeframe was provided, a 10-day notification period has been utilised to align with NOPSEMA notification.
At least 24-48 hours prior to operations	AMSA's Joint Rescue Coordination Centre (**JRCC**)	Contact JRCC by email (rccaus@amsa.gov.au) for promulgation of radio-navigation warnings. The JRCC requires: • Vessel details (including name, callsign and Maritime Mobile Service Identity) • Satellite communication details (including INMARSAT-C and satellite telephone numbers) • Area of operation • Requested clearance from other vessels • Date of activity commencement • Duration of activity • SLB contact details • Any other information that may contribute to safety at sea Updates should be provided to JRCC on progress and, importantly, any changes to the operations.

5.4.10 Post-activity Notification to Stakeholders

There are also some post-survey notification requirements that SLB are required to adhere to. These are provided in **Table 28**.

Table 28 Post-Activity Notification Requirements

Timing – post Seismic Survey	Stakeholder	Information to be Provided
Relevant time post-completion	All relevant stakeholders	Notification that the survey is now complete, and the survey vessels are no longer in the area.
Relevant time post completion	AMSA	Summary of any significant or noteworthy interaction with commercial shipping during the Seismic Survey.
10 days post completion	DMIRS	Provide a cessation notification to petroleum.environment@dmirs.wa.gov.au. Consultation with DMIRS resulted in this request, and although no timeframe was provided, a 10-day notification period has been utilised to align with NOPSEMA notification.
10 days post completion	NOPSEMA	Written notification to NOPSEMA advising of the completion of the survey.
As soon as practicable	NOPSEMA	Written notification to NOPSEMA advising that all of the activities and obligations covered under the EP have been completed.

5.4.11 Assessment of Provision of Sufficient Information

Regulation 11A(2) of the Environment Regulations states that:

> *"For the purpose of the consultation, the titleholder must give each relevant person sufficient information to allow the relevant person to make an informed assessment of the possible consequences of the activity on the functions, interests or activities of the relevant person."*

As detailed within **Section 5.4.3** the initial consultation included the provision of an information pack to all relevant stakeholders; consisting of an information sheet and a detailed email. This information pack outlined various aspects of the Seismic Survey including the location of the OA (with GPS coordinates of the corner boundaries), a description of the proposed seismic activity, approximate timing, the adherence of SLB to the relevant legislation. It's considered that this information was sufficient for the stakeholders to make an informed decision on whether their activities would potentially be impacted by the Seismic Survey. This process also made available the opportunity for stakeholders to provide feedback, raise concerns, participate in further engagement and submit any objections to SLB. There were no comments or concerns raised during the stakeholder engagement programme that resulted in any additional control measures being implemented.

NOPSEMAs Guidance Document on consultation requirements (*Consultation requirements under the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009*) states that: "*relevant persons should consider whether the information provided has been sufficient and if not, state the grounds on which additional information should be provided*".

No parties, either via email or phone correspondence stated that the information provided to them was insufficient to allow them to determine the potential impacts and risks associated with the proposed Seismic Survey with regard to their activities. In all cases, where further information was requested, it has been provided.

Despite an extensive approach to the engagement process, only a small proportion of the total stakeholders identified responded with comments or questions regarding the Information Pack, despite a couple of attempts. As a result, it was considered that those stakeholders which did not respond had not concerns over the survey, and SLB focused consultation efforts on those parties which had concerns or comments regarding the proposal such as the commercial fishing industry.

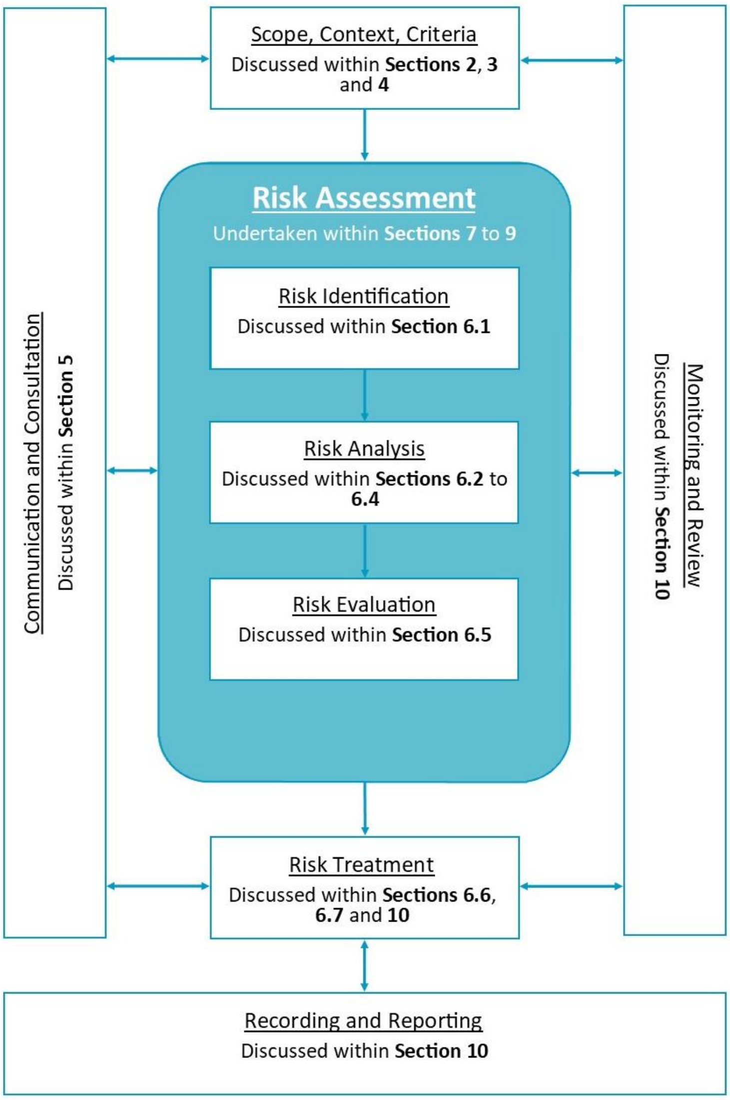
The consultation process with the commercial fishing industry and the industry representatives outlined in **Section 5.4.6** is an ongoing process and will continue for the duration of the Seismic Survey and beyond the life of the project. Engaging with these organisations (i.e., WAFIC) provided SLB with a greater understanding of the potential impacts the Seismic Survey may have on the licence holders and their activities. Mitigation measures will be implemented to alleviate these concerns and to assist with minimising fishing gear in the water within the survey path through the incorporation of 48-hour look-aheads which will be transmitted to fishers. In addition, the use of both a Support Vessel and a Chase Vessel during the survey will provide additional support out on the water.

Based on the discussion and information provided above, SLB considers that the information provided to the relevant stakeholders during the consultation process was sufficient and that stakeholders had sufficient time to consider the information and make an informed decision as to any potential impacts of the survey on their activities, in accordance with the Environment Regulations and relevant guidance.

6 Environmental Impact and Risk Assessment Methodology

Regulation 13(5) and 13(6) of the Environment Regulations requires SLB to include details of all environmental impacts and risks arising from or associated with the proposed activity, along with an evaluation of these impacts and risks. The assessment should give appropriate consideration to the nature and scale of each impact or risk, and whether these are likely to be realised as a result of planned and unplanned operations. Accordingly, this assessment must detail the control measures which will be utilised to reduce the impacts and risks of the activity to **ALARP** and an **Acceptable Level**.

The following impact and risk assessment methodology has utilised the joint Australian & New Zealand International Standard Risk Management – Guidelines, (**AS/NZS ISO 31000:2018**) (ISO, 2018). **Figure 37** shows a modified version of the AS/NZS ISO 31000:2018 risk management process diagram to provide a summary on the framework adopted in the development of this EP. To this end, the corresponding sections which address each aspect of the risk management process have also been highlighted.



Source: modified from ISO, 2018

Figure 37 Risk Management Process Adopted from AS/NZS ISO 31000:2018

6.1 Details of Environmental Impacts or Risks

Regulation 13(5)(a) of the Environment Regulations requires an EP to include details of the environmental impacts and risks which may arise as a result of the activity, to establish a link between the proposed activity and the environment that may be affected.

A robust assessment has been undertaken to identify all activities associated with the proposal which may have an impact on or pose risk to the environment and, by extension, those stakeholders who may use it. The robust assessment was informed by the professional judgement SLR and their extensive experience in delivering impact assessments and regulatory approvals for MSSs within both Australia and New Zealand. The site location and proposed activity have been specified based on SLBs extensive experience undertaking MSSs both globally and, more specifically, in the Asia-Pacific Regions. These inputs have been foundational the quality of the assessment.

The proposed Seismic Survey activities have been split into two sub-categories, planned and unplanned activities. Planned activities are defined as those which constitute part of the MSSs approach and are known to occur, whereas unplanned activities are defined as those which have a risk of occurring but are not anticipated to be realised as part of normal operations. It's important to distinguish that planned activities can give rise to both known and potential environmental impacts, where unplanned activities can only be associated with potential environmental impacts. This is further described in **Section 6.2.**

The following activities have been considered within this assessment:

- Planned activities (**Section 7**), including:
  - Physical presence of the Seismic Vessel and towed equipment (**Section 7.1**);
  - Acoustic disturbance to the marine environment (**Section 7.2**);
  - Routine permissible waste discharges (**Section 7.3**);
  - Atmospheric emissions (**Section 7.4**);
  - Artificial light emissions (**Section 7.5**);
- Unplanned activities (**Section 8**), including:
  - Establishment of invasive marine species (**Section 8.1**);
  - Streamer loss (**Section 8.2**);
  - Vessel collision or sinking, and its associated potential hydrocarbon spill (**Section 8.3**);
  - Hydrocarbon spill response (**Section 8.4**); and
  - Accidental release of hazardous and non-hazardous materials (**Section 8.5**).

In addition to the above sub-categories, the potential cumulative impacts and risks which may arise as a result of the Seismic Survey have been considered within **Section 9**.

6.2 Evaluation of Known and Potential Environmental Impacts or Risks

In accordance with Regulation 13(5)(b) of the Environment Regulations, an EP must include an evaluation of all potential impacts and risks which may arise as a result of the proposed activity, appropriate to the nature and scale of each impact or risk. This evaluation involves the consideration of the cause and source of the impact or risk, the relative consequence and the likelihood of those consequences occurring.

The evaluation of the known and potential environmental impacts or risks has considered previous comparable assessments, a review of scientific studies, stakeholder feedback and the context of the existing environment. This information forms the basis for which the impacts or risks can be assessed, in addition to focusing the development of the control measures for those activities for which the impact or risk is the greatest. The evaluation of the significance of impacts and risks for each of the activities (both planned and unplanned) were undertaken using a variety of methods, including:

- Quantitative analysis, including through numerical analysis or predictive modelling;
- Qualitative analysis of adherence to environmental standards; and
- Proactive and professional judgement, including utilising industry experience

As part of the risk assessment process, the significance of known and potential impacts or risks from each activity is assessed assuming that control measures have been implemented. The resulting residual risk rating assists in determining whether any additional controls are required to reduce the potential impacts or risks from the activities to **ALARP** and **Acceptable Levels**.

6.3 Development of Control Measures

In accordance with Regulation 13(5)(c) of the Environment Regulations, an EP must include a description of the control measures that will be used to reduce the impacts and risks of the activities to **ALARP** and an **Acceptable Level**.

Control measures to be implemented throughout the Seismic Survey have been developed based on industry best practice, legislative requirements and in response to stakeholder concerns and expectations. SLB have also applied learnings gained from previous surveys to develop new and refine existing control measures.

During the development of this EP, the practicability and effectiveness of each control measure has been comprehensively considered and assessed. This included an evaluation of a number of, often competing, factors including availability, reliability, independence, compatibility, benefit and cost of each measure. The outcome of this evaluation determined whether a control measure was considered practicable and/or effective. A clear justification is provided for each determination. Based on this determination, control measures were adopted for implementation or dismissed.

6.4 Environmental Performance of Control Measures

Regulation 13(7)(a–c) of the Environment Regulations requires every EP to:

- Set out the environmental performance outcomes against which the performance of the titleholder (in this case SLB) in protecting the environment is to be measured;
- Set environmental performance standards for the control measures; and
- Include measurement criteria that the titleholder will use to determine whether each environmental performance outcome and environmental performance standard is met.

Environmental performance outcomes (**EPOs**) are a specified measurable level of environmental performance that titleholders are seeking to achieve for the life of the activity. The EPOs developed should support the effective management of aspects of an activity to the extent that any associated environmental impacts and/or risks are of an **Acceptable Level**. Each activity associated with the Seismic Survey will include an environmental performance outcome which relates to all the environmental features that may be impacted or are at risk from the occurrence of the activity.

EPSs relate specifically to the performance of a control measure. They are parameters which control measures are assessed against to ensure they consistently perform to reduce the impact or risk to **ALARP** and to an **Acceptable Level**. These environmental performance standards set levels at which an incident becomes a 'recordable incident' (**Section 10**) and will be utilised as part of performance monitoring of the Seismic Survey.

Measurement criteria define how the environmental performance outcomes and standards will be measured and determine whether the outcomes have been met during the Seismic Survey.

6.5 Residual Risk Assessment

An Environmental Risk Assessment (**ERA**) has been undertaken to identify the relative significance of the potential effects from the Seismic Survey based on a likelihood and consequence approach. AS/NZS ISO 31000:2018 (ISO, 2018) has been used to develop the ERA. In particular, the ERA methodology used in this EP has been adapted from MacDiarmid *et al.,* (2012) which sets out a risk assessment framework for activities in New Zealand's EEZ and extended continental shelf. In addition to MacDiarmid *et al.* (2012), Southall *et al.* (2007) has been utilised to develop consequence levels from underwater noise based on thresholds that predict the physiological effects on marine mammals in New Zealand waters during MSSs. Although this framework was initially developed for activities within New Zealand's jurisdiction, it is considered that it is relevant and appropriate for use to contribute towards the development of the ERA for the proposed activities in Australia. Guidance from Clark *et al.* (2017) has also been used to refine the ERA methodology so that it is specific and relevant to this EP.

To summarise, the main steps undertaken for the ERA process are to:

- Describe the activities;
- Identify the potential sources of impact/risk associated with the activities;
- Identify the relevant receptors and characterise potential impacts/risks (including magnitude, scale, frequency and intensity);
- Assess the potential consequences for each impact/risk across all potential environmental receptors (with operational procedures and proposed control measures in place) – based on the criteria in **Table 29**;

- Assess the likelihood of a consequence occurring for each receptor – based on the criteria in **Table 30**; and
- Assign an overall classification of impact/risk for any residual impacts – based on the criteria in **Table 31**.

Table 29 Criteria for Assessing Potential Consequence Levels

Consequence level	Scale of Effect	Duration of Effect	Effect on Populations & Protected Species and Recovery Period	Effect on Socio-Economic Receptors	Effect on Habitat & Ecosystem Function
0 – Negligible	Highly localised effect (<1 km^2)	Short-term and intermittent/temporary	No predicted adverse effects to populations. Immediate recovery. No protected species impacted.	No disruptions to normal activities. No predicted effects on natural resources or local communities.	Undetectable, affecting <1% of original habitat area. Ecosystem function unaffected.
1 - Minor	Localised effect (1 – 5 km^2)	Short-term, occurring frequently but ceases when activity ceases	Possible adverse effect to populations, but not sufficient to be detectable. Rapid recovery would occur (weeks to months). Some individuals of protected species may be impacted.	Short term disruptions to normal activities (weeks to months). Possible minor adverse effects to natural resources and/or local communities.	Measurable but localised, affecting 1 – 5% of original habitat area. Minor changes to ecosystem function.
2 - Moderate	Medium scale effect (5 - 20 km^2)	Medium-term but ceases when activity ceases	Detectable impacts to populations. Could affect seasonal recruitment but does not threaten long-term viability. Recovery probably measured in months to years. Some population level effects may become apparent for protected species.	Medium-term disruptions to normal activities (months). Moderate adverse effect to natural resource and/or local communities.	Potential impacts more widespread, affecting 5 – 20% of original habitat area. Moderate changes to ecosystem function.
3 - Severe	Large scale effect (20 – 50 km^2)	Long-term but ceases when activity ceases	Impacts to populations are severe and may limit capacity for population increase. Recovery measured in multiple years. Population level impacts are detectable for protected species.	Long-term disruptions to normal activities (years). Severe adverse effect to natural resources and local communities.	Widespread impacts, affecting 20 – 60% of original habitat area. Severe changes to ecosystem function.
4 - Major	Very large scale effect (50 – 100 km^2)	Long-term and continues after activity ceases	Long-term viability of populations is clearly affected. Local extinctions are a real possibility if activity continues. Recovery period of decades. Serious conservation concerns for protected species.	Extensive disruptions to normal activities (years to decades). Highly significant and major adverse effects to natural resources and potentially affecting national communities.	Activity may result in major changes to ecosystem or region, affecting 60 – 90% of original habitat area. Major changes to ecosystem function.
5 - Catastrophic	Regional effect (>100 km^2)	Permanent	Local extinctions are expected in the short-term. Long-term recovery greater than decades and possibly never recovers. Very serious conservation concerns for protected species.	Very extensive disruptions to normal activities (decades). Catastrophic, widespread and potentially irreparable damage to natural resources. Massive negative and potentially irreversible effects on local and national communities, which may not be able to maintain pre-effect livelihood.	Activity will result in critical changes to ecosystem or region, affecting virtually all original habitat. Total collapse of ecosystem.

Table 30 Criteria for Assessing Likelihood of Consequence Occurring

Level/Score	Description	Likelihood of exposure
1	Remote	Highly unlikely but theoretically possible
2	Rare	May occur in exceptional circumstances
3	Unlikely	Uncommon, but has been known to occur elsewhere
4	Possible	Occurred in a minority of similar studies or projects
5	Likely	Likely to occur and has generally occurred in similar projects
6	Certain	Could be expected to occur more than once during project delivery

* Whereby 'likelihood' = the likelihood of a consequence occurring from the various activities

Table 31 Overall Risk of Residual Impacts Matrix

		Consequence Level					
		0 – Negligible	1 – Minor	2 – Moderate	3 – Severe	4 – Major	5 – Catastrophic
Likelihood of Consequence	1 – Remote	Negligible (0)	Low (1)	Low (2)	Low (3)	Low (4)	Low (5)
	2 – Rare	Negligible (0)	Low (2)	Low (4)	Moderate (6)	Moderate (8)	Moderate (10)
	3 – Unlikely	Negligible (0)	Low (3)	Moderate (6)	Moderate (9)	High (12)	High (15)
	4 – Possible	Negligible (0)	Low (4)	Moderate (8)	High (12)	High (16)	Extreme (20)
	5 – Likely	Negligible (0)	Low (5)	Moderate (10)	High (15)	Extreme (20)	Extreme (25)
	6 – Certain	Negligible (0)	Moderate (6)	High (12)	Extreme (18)	Extreme (24)	Extreme (30)

A description of the overall risk rankings contained within **Table 31** from 'Negligible' to 'Extreme' can be found within **Table 32**.

Table 32 Risk Ranking Descriptions

Risk Ranking	Potential Impact	Potential Impact Significance
Extreme (18 – 30)	Extreme Risk – unacceptable for project to continue under existing circumstances. Requires immediate action. Equipment could be destroyed with large environmental impact as a result of a spill or discharge to the environment.	Considered significant
High (12 – 16)	High Risk – where the level of risk is not tolerable and control measures are required to move the risk to lower the risk categories. Medium environmental impact from a spill or discharge to the environment.	Considered significant
Moderate (6 – 10)	Moderate Risk – requires additional control measures where possible or management/communication to maintain risk at less than significant levels. Small environmental impact from a spill or discharge to the environment. Where risk cannot be reduced to 'Low' control measures must be applied to reduce the risk to ALARP. Requires continued tracking and recorded action plans.	Considered significant
Low (1 – 5)	Low Risk – where the level of risk is at a broadly Acceptable Level and generic control measures are already assumed in the design process but require continuous monitoring and improvement. No further development of control measures is practicable and/or the costs of implementing further controls are disproportionate to the environmental benefit.	Not significant
Negligible (0)	Negligible Risk – no intervention or further monitoring is required. No environmental impact.	Not significant

6.6 Demonstration of ALARP

In accordance with Regulation 10A(b) and 13(5)(c) of the Environment Regulations, the EP must demonstrate that the environmental impacts and risks of the activity will be reduced to **ALARP**.

To ensure the impacts and risks from the proposed activities are **ALARP**, a hierarchy of controls has been utilised which follows a tiered system of 'eliminate-substitute-reduce-mitigate' (**Table 33**). The consideration of elimination and substitution are controls generally used for those activities which are higher impacts/risk. Whereas the controls for those activities which are known to have *Negligible* or *Low* impacts/risks are primarily focused on the reduction and/or mitigation aspect of the hierarchy to ensure they are **ALARP**.

Table 33 General Hierarchy of Controls

Control	Example	Effectiveness
Eliminate	Elimination of the risk or impact, such as eliminating the light source to remove impacts from artificial light emissions.	
Substitute	Substitute the method of an activity in favour of a lower impact one, such as substituting Heavy Fuel Oil for MGO to reduce the amount of atmospheric emission.	
Reduce	Reduction of the risk or impact, such as reducing the oil content in discharged water to reduce the potential contamination of the sea.	
Mitigate	Mitigate the potential risk or impact of conducting an activity, such as maintaining separation distances from land when discharging wastes to mitigate the potential impacts on coastal environments	

The aim of the controls is to reduce the residual risk to a *Low* ranking (**Table 32**); however, if the risk remains at a higher ranking, it must be assessed as to whether it has been reduced to **ALARP**. For example, this includes whether all reasonable and practicable control measures have been adequately considered. Reasonable and practicable controls measures are defined as those which can be applied to reduce the risk or impact, without the sacrifice being disproportionate to the benefit of risk reduction.

6.7 Risk and Impact Acceptability

Regulation 10A(c) and 13(5)(c) of the Environment Regulations requires an EP to demonstrate that the environmental impacts and risks of the activity have been reduced to **ALARP** and will be of an **Acceptable Level**. The EP must also detail the control measures that will be implemented to achieve this. The criteria used to determine whether the residual risks or impacts of an activity following the implementation of the control measures, and following the demonstration of **ALARP**, is at an **Acceptable Level**, are based on the seven criteria contained within **Table 34**.

For each criterion, 'acceptability questions' have been developed to assess compliance. Each activity, both planned and unplanned, has been assessed against the criteria within **Sections 7** and **8**. For an activity to be characterised as 'Acceptable', compliance with the requirements in **Table 34** must be demonstrated.

Table 34 Risk Acceptability Criteria

Criteria	Acceptability Questions	Acceptability is Confirmed
Ecologically sustainable development	ESD is defined 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'. Section 3A of the EPBC Act sets out three main matters; the first of which is that the activity needs to be carried out in a manner consistent with the principles of ESD. Therefore, ESD is an integral aspect in determining risk/impact acceptability. Based on this, is the management of the risks/impacts associated with the proposed activities carried out in a manner that is consistent with the five principles of ESD as defined within the EPBC Act (**Section 2.1.2**)?	The Seismic Survey is consistent with the five principles of ESD.
External context: Legislative requirement	Does the management of the risks/impacts (including the proposed control measures) associated with the activity align with the relevant Australian and International legislation, conventions, and standards such as those outlined within **Section 2** (i.e. Policy Statement 2.1, MARPOL, Marine Notices, Marine Orders)?	Compliance with all of the legislative requirements, standards and policies and can be demonstrated when audited.
Internal context	Does the management of the risks/impacts associated with the activity align with the internal policy of the titleholder (in this case SLB's QHSE Policy, **Section 1.6**)?	Internal or external audits of procedural systems confirm all policies in place that align with the EP.
Industry best practice	Has the management of the risks/impacts been conducted in accordance with industry best practice, such as the APPEA Code of Environmental Practice and the International Associated of Geophysical Contractors (**IAGC**) Environmental Manual for Worldwide Geophysical Operation (**Section 2.2**)?	The impact of potential risk, through control measures is managed so that it is compliant with all relevant industry best practice guidelines.
External context: Stakeholder expectations	Have any concerns regarding the risks/impacts which may arise from the activity been raised through consultation (described throughout **Section 5** and **Appendix I**), and have any relevant control measures been developed to address these concerns?	All stakeholder concerns and submissions have been responded to, adequately addressed and closed out.

Criteria	Acceptability Questions	Acceptability is Confirmed
External context: Existing environment	Has the development of the control measures taken into account the environmental values and sensitivities at a local, regional or global level, where relevant? Is the management of the impacts/risks in accordance with the relevant species specific or protected area management plans, such as Conservation Advice, Management Plans, or Recovery Plans? If there is no management plan in place for a World Heritage property, National Heritage Place, Commonwealth marine reserve, Commonwealth heritage place or Ramsar wetland, then is the activity (and its environmental management) consistent with Australian World Heritage, Australian IUCN reserve, National Heritage, Commonwealth heritage or Australian Ramsar management principles, as defined in the EPBC Regulations 2000? Are the risks/impacts managed in alignment with the nominated conservation values defined within the Marine Bioregional Plan for the North-west Marine Region and, where relevant, the North Marine Region?	With the implementation of the control measures, the potential impacts from each of the activities must be consistent with all of the relevant management plans, conservation advice, recovery plans and the general nature of the receiving environment of the OA and EMBA.
ALARP	Are all reasonable and practicable control measures in place to reduce the impact or risk of the activity? Have the costs (financial or otherwise) of implementing further control measures been considered? Where it is considered that costs are disproportionate to the benefit gained, has this been identified?	General agreement that the residual risk from the Seismic Survey has been demonstrated to be **ALARP**.

7 Environmental Impacts from Planned Activities

The planned activities associated with the Seismic Survey include:

- Physical presence of Seismic Vessel and towed equipment (**Section 7.1**);
- Acoustic disturbance to the marine environment (**Section 7.2**);
- Routine permissible waste discharges (**Section 7.3**);
- Atmospheric emissions (**Section 7.4**); and
- Artificial light emissions (**Section 7.5**).

Using the methodology described within **Section 6**, this section of the EP goes through the impact and risk evaluation for each of the planned activities listed above, for each of the receptors identified within the OA and relative area of impact. Where the area of impact for a planned activity extends beyond the OA, this has been identified. The purpose of this evaluation is to demonstrate that, with the inclusion of control measures, the impacts and risks associated with the Seismic Survey will be reduced to **ALARP** and will be of an **Acceptable Level**.

7.1 Physical Presence of Seismic Survey Vessel and Towed Equipment

7.1.1 Description of Source of the Impact

During the Seismic Survey, the Seismic Vessel will tow a suite of equipment including the two sub-arrays of acoustic sources at a depth of 8 m below the surface, and 12 streamers. The streamers will be 8 km in length and will be towed at 15 – 20 m below the surface. Streamers will be spaced at intervals of 120 m, so the overall lateral spread of all streamers will be 1,320 m. Each streamer will be equipped with a tail buoy that has a radar reflector and light at the terminal end. A detailed description of the proposed activity and schematic diagram showing the general configuration of towed gear is provided in **Section 3** and **Figure 4**. The total acquisition area affected by the towed gear is approximately 12,000 km^2.

A purpose-built Seismic Vessel will be contracted for the Seismic Survey that is capable of safely operating in the environmental conditions of the NWMR. The Seismic Vessel will be accompanied by one Support Vessel and one Chase Vessel at all times, which will manage potential interactions between the Seismic Vessel and other marine users. The Seismic Vessel, Support Vessel and Chase Vessel are collectively referred to as the ‘survey vessels’, where appropriate, throughout this section.

7.1.2 Known and Potential Impacts to Environmental Receptors

The physical presence of the survey vessels and towed acoustic equipment has the potential to result in the following effects on environmental receptors:

- Disruption to normal animal behaviours;
- Displacement of animals from preferred habitat;
- Collision with or entanglement of animals in towed equipment;
- Displacement of other marine users from regular routes or activity areas; and
- Collision with or entanglement of other marine users with survey vessels and/or towed equipment.

It is considered that the biggest risks that may result from the physical presence of the survey vessels and associated towed equipment is the potential for a physical impact on marine mammals, whale sharks and turtles (i.e. collision or entanglement), the displacement of marine fauna from the immediate vicinity of the survey vessels, the displacement of commercial fishers from fishing grounds and the physical interaction with deployed fishing gear.

7.1.2.1 Whale Sharks

The whale shark is a protected species listed as Vulnerable and Migratory under the EPBC Act. The OA overlaps with a foraging BIA for the whale shark (**Figure 18**). The foraging BIA represents waters where solitary whale sharks are known to forage during their migration from Ningaloo Marine Park (**NMP**), which occurs primarily in spring (September to November).

Whale sharks are pelagic and are known to spend considerable time close to the sea surface, increasing their vulnerability to vessel strike. Whale sharks tagged off Western Australia (Wilson *et al*., 2006; Gleiss *et al*., 2013) spent approximately 25% of their time less than two metres from the surface and > 40% of their time in the upper 15 m of the water columns.

The physical presence of vessels and towed equipment increases the risk of collision or entanglement with foraging whale sharks which may result in injury or mortality; however, there have been no reported cases of marine fauna becoming entangled in seismic equipment in Australian waters. Although, there is evidence of vessel strikes on whale sharks which has resulted in damage to fins, possibly resulting from propeller contact (DPAW, 2013). Although no mortalities due to vessel strike have been reported, it is difficult to determine if a vessel strike has caused deaths due to the sharks' natural reaction of diving to depth and out of sight when threatened. The large-scale impact of vessel strikes on whale sharks are therefore difficult to measure, especially because whale sharks are 'negatively buoyant', meaning that they sink to the ocean floor when they die. However, increased vessel activity within NMP has not resulted in whale shark observations decreasing and thus this impact is also considered low at present (DPAW, 2013).

Vessel speed is a key concern when considering collision risk and the outcome. Vanderlaan and Taggart (2007) observed that an escalation in speed of the vessel caused an increase in the severity of injury to large marine animals. Slower moving vessels provide greater opportunity for both fauna and vessel to avoid collision. Species detection depends on their profile on the sea surface and slower moving vessels would be afforded greater time to manoeuvre and predict their movements. While speed is a particularly important factor, so too is the movement patterns of the vessel – for example, whether a vessel is transiting a dedicated route or is a recreational vessel that is moving erratically (Commonwealth of Australia, 2017a).

Given the OA overlaps with the northernmost part of a whale shark foraging BIA, it is possible for individual whale sharks to be present in the area during September – November. The Survey Vessels (taking into account the limited manoeuvrability of the former) will adopt measures consistent with the DPAW Whale Shark Management Programme (DPAW, 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 ('contact zone') of a whale shark.

Given the proposed control measures and the fact that the Seismic Vessel will be moving in a set course and at 4.5 knots during seismic data acquisition, which allows greater time for individuals to detect the vessel, predict its pathway, and avoid a collision, as well as the presence of trained observers on-watch on the Seismic Vessel while acquiring during daylight hours, the risk for whale sharks to be adversely affected by the Seismic Survey is limited. Close-range encounters with marine fauna are, in general, expected to be infrequent and limited to isolated individuals in the immediate vicinity of the survey vessels. As a result, whale shark injury or mortality as a result of collision or entanglement is considered to be very unlikely.

The risk to populations of whale sharks arising from the physical presence of the survey vessels and towed equipment during the Seismic Survey has been assessed as **Low** (*Minor x Unlikely*).

7.1.2.2 Marine Reptiles

Two species of threatened sea snake may, or are likely to, occur in the OA and six species of threatened marine turtle are known or likely to occur (**Table 18**). The greatest potential consequence to these marine reptiles from the physical presence of the survey vessels and towed equipment, is collision or entanglement.

Historically, levels of sea snake bycatch in the Northern Prawn Fishery (**NPF**) have been high (Ward, 1996), with mortality rates linked to drowning or being crushed by the target catch weight (Wassenberg *et al*., 2001). While this suggests that the potential for entanglement with towed gear exists, physical interactions between sea snakes and seismic equipment are intrinsically different to those with a trawl net in that seismic equipment 1) has no mesh component to entrap animals and 2) no catch weight will crush individuals. On this basis, individual snakes that encounter towed gear will have a much higher chance of survival and the slow operational speed of the Seismic Vessel will promote the escape of any sea snake that does collide with towed seismic gear or the Seismic Vessel. Vessel strike is not listed as a key threat to sea snakes (Somaweera *et al*., 2021; Udyawer *et al*., 2018; DSEWPC, 2012d).

Turtles are vulnerable to vessel strike due to their relatively small size and the significant amount of time spent just below the sea surface (Commonwealth of Australia, 2017a). Collision avoidance is determined by the animal's response time, which is affected by both vessel speed and visibility. Hazel *et al*. (2007) found that 60% of green turtles were able to successfully flee from approaching vessels travelling at two knots. A turtle's ability to flee was severely reduced as the vessel's speed increased, with 22% successfully fleeing at six knots and only 4% at 10 knots. It was concluded that most turtles cannot avoid vessels travelling at speeds greater than approximately two knots (Hazel *et al.,* 2007). Turtles are likely responding to visual cues of the vessel instead of sound cues; if turtles were relying primarily on sound, the reverse result would be found with greater response rates to faster (and therefore louder) vessel approaches (Hazel *et al*., 2007). Vessel strike data for turtles is available for QL where at least 65 turtles were killed by vessel strike incidents between 1999 and 2002 (Hazel and Gyuris, 2006).

Tail buoys (at the end of each streamer) are the most likely part of the towed equipment to trap marine turtles. There are two main areas on the tail buoy which may trap turtles; between the buoy and the connecting chains (the most common area of entrapment), or underneath the buoy in the 'undercarriage' structure (Ketos Ecology, 2009). In order to become trapped in the tail buoy, the animal would have to come in close proximity to the buoy. There are two theories as to why turtles become trapped against seismic tail buoys; startle diving in front of the towed equipment, or as a result of foraging along the streamers (Ketos Ecology, 2009). Entanglement in tail buoys would be fatal due to water movement holding the turtle against the buoy, keeping the turtle from being able to reach the surface to breathe (Ketos Ecology, 2009).

Surface behaviour of the turtle increases its chance of entrapment. For example, those basking at or just below the water surface during hot and calm conditions are slow to react to threats, with dive reactions occurring at close range based on visual detections of the threat (Ketos Ecology, 2009). Startle dive reactions in turtles at the sea surface responding to approaching towed equipment and vessels have been observed at as little at 1 m from the threat (Weir, 2007). All species of marine turtle potentially present within the OA are expected to exhibit resting/basking surface behaviours, but green, hawksbill and loggerhead turtles are the species for which vessel collision is considered to be of potential concern in the NWMR (DSEWPC, 2012d); noting that collision with vessels is 'not of concern' for flatback, leatherback and olive ridley turtles (DSEWPC, 2012d).

Although there are no peer-reviewed literature documenting incidences of turtle entanglement in towed seismic equipment (Nelms *et al.,* 2016), 'turtle guards' were developed to prevent turtle interactions with tail buoys following anecdotal reports of turtle entrapments off the west coast of Africa (Nelms *et al.,* 2016) and the suggestion of entrapment as a growing concern (Ketos Ecology, 2009). Guards are fitted to the buoy and act as a physical barrier to exclude turtles from the space between the buoy and undercarriage (Ketos Ecology, 2009). Certain designs may also allow the turtle to be deflected away from the buoy. All tail buoys utilised in the Seismic Survey will be fitted with a turtle guard.

The '*National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna'* provides a guiding framework for mitigating the risk of vessel collisions with marine megafauna, including marine turtles (Commonwealth of Australia, 2017a). An intended outcome of the National Strategy is the development of a mitigation measures 'toolkit'. To date this toolkit has not yet been developed; however, installation of turtle guards on tail buoys and the slow speed of the Seismic Vessel are considered to be effective mitigation measures against ship strike and entanglement for marine turtles. There are no mitigation measures that will be implemented on board the Support Vessel to minimise the risk of collision with marine turtles; however, they will generally be operating at low speeds and any incidents with turtles will be reported, as recommended under the National Strategy.

With regard to disruption to normal animal behaviours and displacement from preferred habitat, vessel disturbance is particularly an issue for turtles in foraging habitats and nesting areas, particularly in shallow coastal areas where vessel traffic is typically high (Commonwealth of Australia, 2017a). Given the OA is located adjacent to a foraging BIA for flatback turtles, loggerhead turtles and olive ridley turtles; some disturbance to foraging behaviours and or displacement are possible for individuals of this species. Despite a 'known' or 'likely' presence (**Table 18**), other species of marine reptile are less likely to be disturbed or displaced on account of the presence of the survey vessels and towed acoustic equipment during the Seismic Survey as the OA is not identified as being particularly important habitat for other species of marine reptile.

Importantly, vessel densities within the OA moderate, with the southern portion of the OA approaching a well-used shipping route. Therefore, it's expected that the presence of the survey vessels and towed gear will not result in a significant increase to any potential displacement in the context of broader vessel disturbance.

The risk to populations of marine turtles arising from the physical presence of the survey vessels and towed equipment during the Seismic Survey has been assessed as **Moderate** (*Moderate* x Possible).

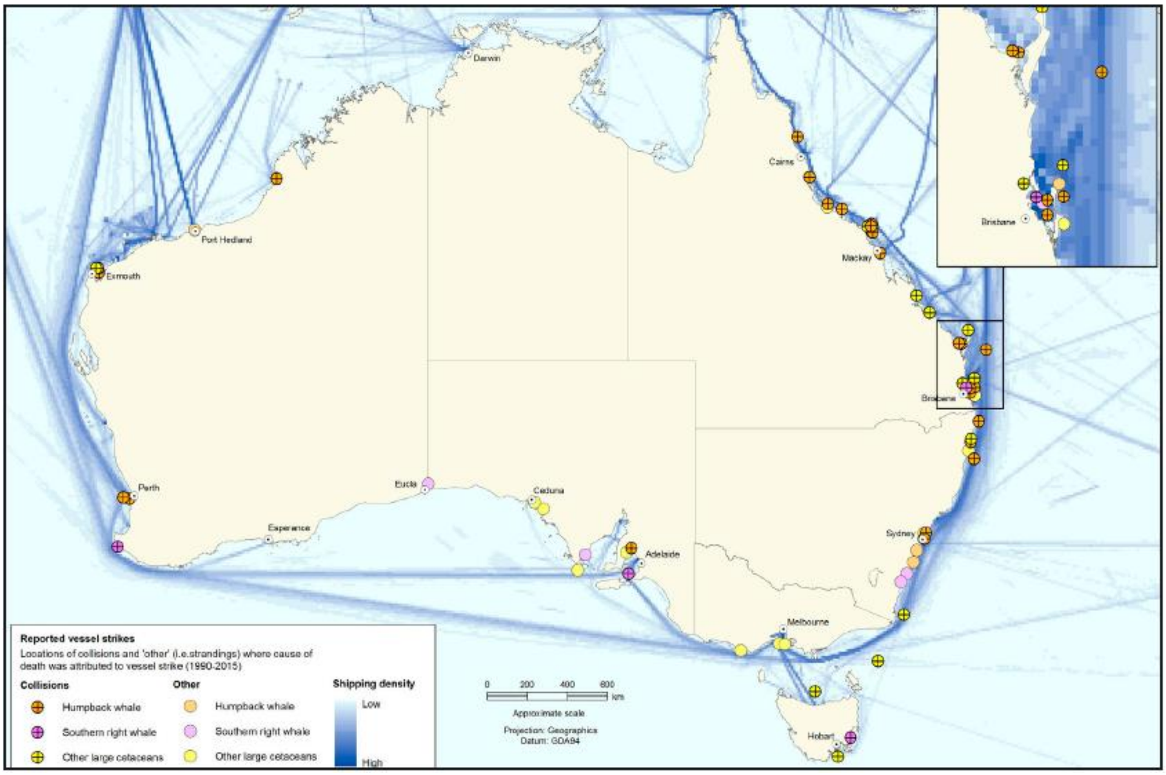
7.1.2.3 Marine Mammals

Disruption of normal animal behaviour and displacement is of particular concern when it occurs frequently or over a prolonged period and affects critical behaviours such as feeding, breeding and resting. The physical presence of the survey vessels and towed equipment may cause some temporary and localised changes in marine mammal behaviours and/or displacement from habitat. **Table 25** provides a summary timeline depicting the expected presence of marine mammals in the OA.

Marine mammals show two main stereotypical behaviours in the presence of vessels: avoidance or attraction (Wűrsig *et al*., 1998); both behaviours can affect energy expenditure and disrupt natural activities. Avoidance most commonly leads to an animal becoming displaced from an area; however, such disturbance is predicted to be temporary due to the transitory and temporary duration of seismic activities in any single location. Furthermore, marine mammals must be in relatively close proximity to the vessels and equipment in order to be affected by their physical presence.

The Commonwealth of Australia (2017a) reports that there were 109 records of ship strike on cetaceans in Australian waters from 1997 to 2015. Species affected included humpback (47%), southern right (13%), sperm (3%), pygmy blue (2%), blue (2%), pygmy sperm (2%), dwarf minke (2%), pygmy right (1%), fin (1%), Antarctic minke (1%), and 'unidentified' (26%) whales (Commonwealth of Australia, 2017a). Peel *et al*. (2018) revised this data and added to it by searching media archive databases. Their searches revealed 76 additional unreported records of vessel strike between 1877 and 2015 and overall, they concluded that of the 'known' species in the Australian ship strike record, humpback whales (59%), southern right whales (14%) and sperm whales (8%) were the most affected species. Incidents typically occurred within each species core distribution (noting that for southern right whales and sperm whales this was confined to the southern half of Australia) and there was a strong temporal correlation between ship strike and migration periods for humpback and southern right whales. Globally, the species most affected by vessel strike are fin whales, humpback whales, right whales, gray whales, minke whales, sperm whales and blue whales (Jensen *et al*., 2004).

Only one known ship strike or stranding event attributed to ship strike has been recorded in the vicinity of the OA, namely a humpback whale in the coastal waters of Broome (**Figure 38**). There are limited records of ship strike with dolphins in Australian waters (Commonwealth of Australia, 2017a). WA and the NT have the lowest number of documented whale strikes (Commonwealth of Australia, 2017a).



Source: Commonwealth of Australia, 2017a

Figure 38 Location of Reported Vessel Collisions with Whales or 'Other' Incidents where Cause of Death is attributed to Vessel Collision

Jensen *et al*. (2004) demonstrated that vessel type plays a role in the likelihood of a ship strike resulting in animal mortality. In a review of the global ship strike database, the majority of fatal strikes were caused by navy vessels and container/cargo ships/freighters, which typically travel faster than 15 knots. Seismic vessels (categorised in the study as 'research' vessels) accounted for only one ship strike incident out of a total of 292 reported incidents (Jensen *et al*., 2004).

The faster a vessel travels, the greater the likelihood of whale mortality. Jensen *et al*. (2004) reported a mean speed of 18.6 knots for vessels involved in lethal ship strikes. During data acquisition, seismic vessels typically travel at approximately 4 – 5 knots; three to four times slower than the mean fatal speed documented by Jensen *et al*. (2004). Records of sub-lethal effects are less reliable on account of the difficulty in assessing injury in free swimming cetaceans following a collision.

Marine mammals are most at risk of ship strike when exhibiting surface behaviours such as feeding and resting. Based on the assessed likelihood of encountering each cetacean species during the Seismic Survey, ship strike is of most concern for pygmy blue whales, humpback whales, fin whales, and sei whales, which are known or likely to occur in the OA.

While pygmy blue whales are not well represented in the Australian ship strike records (n < 5; Commonwealth of Australia, 2017a; Peel *et al*., 2018), collisions do occasionally occur. This species has the highest likelihood of presence during the Seismic Survey on account of the OA overlapping with their migration BIA along the NW coast of Australia into Indonesian waters. This spatial overlap increases their vulnerability to ship strike from the survey vessels. The behaviour of blue whales in response to commercial ship movement was documented in McKenna *et al*. (2015) who observed a dive reaction (a shallow dive during surface period) in response to an approaching vessel but no evidence of any lateral avoidance. This suggests that the ability of this species to avoid ships is limited (McKenna *et al*., 2015). SLB will implement additional controls to mitigate against effects of the Seismic Survey on pygmy blue whales. These controls include both spatial and temporal restrictions for acquisition in and around the blue whale migratory BIA, which has been identified as a key sensitivity for this species; the Seismic Vessel will not activate the acoustic source within this BIA or within 17 km of the buffer from mid-April (14th) to mid-January (14th) which is the period during which migrating whales are expected to be present. The controls also include an extended observation zone when operating in the BIA and buffer outside the migration period. Humpback whales represent the single species of marine mammal with the highest number of ship strike records in Australian waters, although this may be a reflection on the reasonably high abundance of humpback whales in Australia (Peel *et al.,* 2018). While the EPBC Act Protected Matters Database indicates that humpbacks are likely to occur in the OA, their breeding season is well defined between late Jun to early Oct (How *et al*., 2020) and most breeding activity occurs in the coastal Kimberley Region south of the OA (between Camden Sound and Broome (Irvine *et al*., 2018). Outside of the breeding season this species migrates to high latitude Southern Ocean feeding grounds (Pomilla and Rosenbaum, 2005). As humpback whales only have a seasonal presence in the region and their winter breeding distribution is typically coastal and south of the OA, the Seismic Survey is not predicted to represent a collision or displacement threat to this species. The slow operational speed of the Seismic Vessel and the presence of MMOs onboard will also serve as strong control measures against any potential ship strikes.

While the EPBC Act Protected Matters Database indicates that fin whales and sei whales are likely to occur in the OA, evidence suggests that:

- If fin whales do occur this far north, they will be in very low densities and their presence will be temporally constrained from Aug to Oct (Aulich *et al*., 2019). There is only one record of ship strike involving fin whales in Australian waters (Peel *et al.,* 2018); and
- Sei whales are infrequently sighted in WA waters (Commonwealth Government, 2005) and there are no records of ship strike involving sei whales in Australian waters (Peel *et al.,* 2018).

Smaller dolphin species are highly agile and are significantly less likely to collide with larger vessels (Van Waerebeek *et al*. (2007) and as a result vessel strike for these species during the Seismic Survey is not a concern.

Minimising vessel collision is ranked as a high priority action within the Conservation Management Plans for blue whales, and within the Conservation Advice for fin, sei, and humpback whales. The expected low incidence of vessel strike from the Seismic Survey will not affect the long-term recovery of these species in accordance with these plans.

The '*National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna*' acts as a guiding framework for identifying the species and areas most at risk and aims to provide appropriate mitigation measures to reduce the risk of ship strike. The National Strategy intends to develop a 'mitigation measures toolkit'. To date this toolkit has not been developed; however, once developed the mitigation measures for cetaceans will fall into three main categories: keeping vessels away from whales, slowing of vessel speeds, and implementation of avoidance manoeuvres (Commonwealth of Australia, 2017a).

The master of the Support Vessel will operate in accordance with the EPBC Regulations Part 8, Division 8.1 in regard to the minimum approach distances and vessel speed for "other craft" and follow the prescribed actions when adult cetaceans and/or calves are present within the caution zone[12]. In particular:

- The Support Vessel will operate at a constant speed of less than 6 knots and minimise noise, whilst ensuring the vessel does not drift or approach closer to than 50 m to a dolphin or 100 m to a whale;
- If the cetacean shows any sign of being disturbed, the vessel must be withdrawn from the caution zone at a speed of less than 6 knots. If an adult whale approaches the Support Vessel or comes within 100 m, the master must disengage the gears and let the whale approach or reduce the speed of the vessel and continue on a course away from the whale;
- If an adult dolphin approaches the Support Vessel or comes within 50 m, the master must not suddenly change course or speed of the vessel; and
- The master of the Support Vessel will make all efforts not to let a calf enter the caution zone; however, if a calf does enter the caution zone, then the master will immediately stop the vessel, turn off the vessel's engines, or disengage the gears, or withdraw the vessel from the caution zone at a constant speed of less than 6 knots.

These control measures are included in **Table 56**.

Due to the restricted manoeuvrability of the Seismic Vessel, no further mitigation measures can be applied to reduce the risk of ship strike from the Seismic Vessel; however, the Seismic Vessel will maintain speed and course in the presence of marine mammals, this, in addition to the already low speed of the vessel, allows greater time for individuals to detect the vessel, predict its pathway, and avoid a collision or entanglement in the towed equipment. Trained observers will be on-watch while the Seismic Vessel is acquiring during daylight hours. While this will not minimise the potential for vessel strike, any incidents (i.e. ship strike or entanglement) will be observed and reported. Ship strikes will be reported into the Australian Government National Ship Strike Database (DoEE, 2018b), as is required by the EPBC Act.

[12] 150 m radius around a dolphin, and 300 m radius around a whale

Although boat strike is a recognised threat to dugongs in coastal Australia, it is typically associated with small recreational vessels in areas where densities of both dugongs and boats are high (Marsh *et al.,* 2002). The probability of boat strike is greatest in water depth < 2 m which limits an individual's ability to take evasive action by diving (Maitland *et al*., 2005). Given their reliance on seagrass habitats, dugongs typically inhabit waters less than 3 m deep (Chilvers *et al*., 2004) and although some offshore movement across the Sahul Shelf has been reported (Whiting and Guinea, 2005), this preference for shallow habitat indicates that the likelihood of interactions with the survey vessels during the Seismic Survey is highly unlikely.

Although some marine mammals could interact with and become entangled in the towed equipment, it is highly unlikely that this would occur on account of marine mammals displaying exceptional abilities to detect and avoid obstacles in the water column and there being no loose surface lines associated with the towed equipment (Rowe, 2007). Unlike interactions with fishing gear, there is no food attractant associated with MSSs. To our knowledge, there has never been a reported case of a marine mammal becoming entangled in seismic equipment. In addition, the auditory range of many cetaceans overlaps with peak intensities of transiting ships (Allen and Peterson, 2012; Veirs *et al*., 2016), thus cetaceans should have the capacity to acoustically detect an oncoming ship (Allen and Peterson, 2012) and move away from the vessel/s, minimising the likelihood of a ship strike and entanglement.

The presence of the vessels may also act as an attractant to certain species, particularly smaller species of dolphin which may approach the vessel to bow-ride (Wűrsig *et al*., 1998). Bow-riding behaviours have been observed during periods of active seismic acquisition (e.g. Moulton and Miller, 2005). However, the seismic array is located a reasonable distance behind the bow waves that small dolphins like to play in.

As a result, the risk to marine mammal populations arising from the physical presence of the survey vessels and the towed equipment during the Seismic Survey has been assessed as **Moderate** (*Moderate* x *Possible*).

7.1.3 Known and Potential Impacts on Stakeholders and Other Marine Users

7.1.3.1 Potential Impacts to Commercial Fishing Operations

Effects on commercial fishing from the Seismic Survey may occur via two main mechanisms:

- The physical presence and interaction of the Seismic Vessel and towed equipment has the potential temporarily exclude fishers from their fishing grounds and inconveniences in needing to plan their fishing operations around the planned survey routes; and
- Underwater sound from the acoustic source has the potential to affect fish species which are targeted to be caught (discussed in **Section 7.2.3**).

The Seismic Vessel will be restricted in its ability to manoeuvre while it is acquiring data and, in most instances, this prevents active avoidance of fishers and fishing gear in the water. Fishers will continue to be able to fish within the Acquisition Area; however, they will be temporarily impacted by the physical presence of the Seismic Vessel, Chase Vessel and Support Vessel. SLB will provide any potentially affected commercial fishers with 48-hour look-ahead plans of where the survey vessels will be to enable them to incorporate the survey route into their fishing plans. This look-ahead will be updated and distributed every 24 hours.

There are several commonwealth and state managed fisheries which exist in and around the area of the proposed Seismic Survey, these being discussed in **Section 4.7.3**. However, the only managed fishery which overlaps with the Acquisition Area and OA is the NDSMF, as shown in **Figure 29**.

As discussed in **Section 4.7.3.2.1**, the main method of fishing within the NDSMF is trap fishing. The licence holders that actively fish in the OA have been identified through the engagement process and continual engagement and notification (e.g. 48-hour look-ahead plans) will take place with these licence holders and their respective associations to ensure they are aware of where the vessel will be throughout the duration of the survey. Likewise, all methods of communication will be made available to the licence holders to contact the survey vessels should they need to be in contact with SLB or the survey vessels at any time.

SLB will be requesting all marine traffic remain 10 km away from the Seismic Vessel and the towed streamers, this will essentially create a moving temporary exclusion zone around the Seismic Vessel. The size of this temporary effective exclusion zone will be ~520 km^2. The Chase Vessel will try to make contact with any vessel it sees in the exclusion area, and if there are traps remaining on the seabed (marked by surface buoys), the Chase Vessel would try to contact the fishers whose gear is still in the water in the first instance to warn of the oncoming survey vessel. Should this fail, the last resort would be to haul the traps out of the water, so they are not lost, and then replace them once the Seismic Vessel has gone past.

As discussed in **Section 4.7.3.2.1**, the area of fishing effort between 2015-20 within the Kimberley subregion of the NDSMF was 127,613 km^2, as shown in **Figure 29**. The temporary effective exclusion area around the Seismic Vessel of ~520 km^2 represents just 0.4% of the entire area fished within the Kimberly subregion of the NDSMF. In terms of the fishing effort recorded to have occurred within the Acquisition Area (2015-20), being 6,290 km^2, the temporary effective exclusion area represents ~8% of this fished area.

In addition to fishing within NDSMF, there is a very minor amount of fishing regulated under the MMF within the OA (but not the Acquisition Area) as shown in **Figure 30**. While the Seismic Vessel will not traverse the two identified 10 x 10 NM CAES blocks shown to be within the OA in this figure, the temporary exclusion area around the Seismic Vessel will extend over ~27% of the single block located closest to the Acquisition Area – this area represents 0.2% of the total fished area within the MMF over the 2015-2020 period. It should be noted that there were <3 vessels fishing in the single affected block over 2015-20 so the impact on any mackerel fishers will be insignificant.

Given the Seismic Vessel during the Seismic Survey will be continually moving at a speed of 4 to 5 knots throughout the OA, the impact to fishing activities through temporary displacement from the physical presence of the survey vessels and towed equipment will be transitory in nature. Overall, the risk to commercial fishing operations, in particular those fishers managed under the NDSMF, due to the physical presence of the survey vessels and towed equipment (i.e. temporary displacement) during the Seismic Survey has been assessed as **Low** (*Minor* x *Likely*).

7.1.3.2 Potential Impacts to Marine Traffic

As discussed in **Section 4.7.4** and depicted in **Figure 3**, a variety of vessels travel through the OA. As discussed in Section **7.1.3.1**, SLB will be requesting all maritime traffic remain 10 km away from the Seismic Vessel and the towed streamers. Vessels will still be able to transit through the OA; however, the presence of the Seismic Vessel and its associated temporary exclusion area will cause a minor inconvenience to some vessels as they may need to alter their normal routes to deviate around the Seismic Vessel.

The Seismic Vessel and supporting vessels will intermittently cross areas of commercial shipping traffic. The presence of the Seismic Vessel and towed streamers presents a potential navigational hazard to commercial vessels transiting through the area due to the length of the towed streamer and the vessel's restricted ability to manoeuvre.

Due to the survey vessels constantly making way through the OA, any deviation that commercial ships will have to take to avoid the Seismic Vessel and the streamers is likely to be relatively minor given the notification they will receive through the Notice to Mariners, as well as the radar, Automatic Radar Plotting Aids (**ARPA**) and AIS notifications they will be able to receive, in addition to maritime radio communications. As a result, any change of course over the open ocean which the OA is within, is unlikely to add any significant time delays to the passage or result in any increased costs through avoiding large areas of ocean, to the commercial shipping companies. Any required deviations to a ship's course would be conducted without compromising navigational safety following the rules of the road at sea and would be undertaken in accordance with the COLREGS and the Notice to Mariners that would be issued, providing the information of the Seismic Vessel towing streamers up to 8 km long and being restricted in its ability to manoeuvre.

There have been no collisions to date involving seismic vessels and any commercial vessels (or recreational vessels) recorded within the Australian Transport Safety Bureau's marine safety database (ATSB, 2018) and likewise, SLBs most recent 2D MSS in the Otway Basin did not result in any collisions or near misses with commercial or recreational vessels. This is a result of the vessel Master's ability to manage the safe operation of their vessels out at sea through the appropriate communication processes, and that is also why SLB will have a Support Vessel and Chase Vessel on standby for the interception of any vessels that cannot be communicated with or are not aware there is any submerged gear behind the Seismic Vessel.

Pre-activity notification procedures for the Seismic Survey will facilitate the issuing of maritime warnings and a Notice to Mariners, which will be effective for the duration of the survey. These notifications enable commercial vessel Masters to be aware of potential hazards in the area in which they are transiting and to safely plan their courses to avoid possible interference with those hazards such as the Seismic Survey. The vessel Masters of the survey vessels will maintain radio contact with all commercial vessels in the immediate vicinity of the area being surveyed within the OA that are detected on radar or AIS to ensure they are aware that they are a Seismic Vessel engaged in seismic activities (and therefore limited in their ability to manoeuvre).

With the presence of the Seismic Vessel in the offshore marine environment for up to three months, there is the potential that the Seismic Survey could displace commercial vessels transiting through the area causing them to alter their planned course. However, given the Seismic Vessel will be continually moving the actual zone of displacement that would influence commercial shipping will be transitory in nature. Therefore, the risk to commercial shipping operations due to the physical presence of the survey vessels and towed equipment during the Seismic Survey has been assessed as **Low** (*Minor* x *Likely*).

7.1.4 Control Measures

Control/mitigation measures that will be implemented during the Seismic Survey to manage the impacts associated with the physical presence of the survey vessels and towed acoustic equipment have been listed in **Section 7.1.4**. The listed control measures that will be adopted are those that have been assessed and characterised as effective and practicable to implement. Reasonable and practicable controls measures are defined as those which can be applied to reduce the risk or impact, without the sacrifice being disproportionate to the benefit of risk reduction.

Table 35 Assessment of Control Measures for the Physical Presence of Survey Vessels and Towed Equipment

Control measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Implemented Control Measures:				
Adherence to the requirements of the Navigation Act 2012, specifically Marine Order Part 30: Prevention of collisions	P = Yes E = Effective	The survey vessels must adhere to the Navigation Act 2012. Procedures under the Navigation Act 2012 are standard and well-understood among commercial vessels.	Yes	Yes
24/7 acquisition	P = Yes E = Effective	Where possible, data acquisition will occur 24/7 in order to minimise the total duration of the Seismic Survey.	Yes	Yes
24-hour bridge and radar watch by qualified watch-keepers to monitor for other marine users	P = Yes E = Effective	The Seismic Survey will adopt standard flag and class practices for watch-keeping and radio use to ensure that warnings and preventative actions can be readily implemented. This will notify relevant persons of the presence of the Seismic Vessel and equipment. Watch-keepers will have the relevant qualifications for the task. This practise is compliant with STCW Convention.	Yes	Yes
Compliance with relevant legislation and conventions with regard to maritime safety	P = Yes E = Effective	Vessel Masters will operate vessel in a manner that is consistent with national and international legislation and conventions. These include: • The Navigation Act 2012; • The COLREGS; • UNCLOS; and The STCW Convention.	Yes	Yes
Support Vessels present around the Seismic Vessel	P = Yes E = Effective	Support vessels (Support Vessel and Chase Vessel) will be present around the Seismic Vessel to intercept other vessels in the area that are at risk of interacting with the Seismic Vessel and/or equipment. This is a health and safety requirement and is standard practice for all MSSs.	Yes	Yes

Control measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Lights and visual communication at sea	P = Yes E = Effective	The vessel will use standard international safety procedures for radio communication and the display of navigational lights and day shapes including the use of Automatic Radar Plotting Aids (**ARPA**) and AIS. AIS sends and receives ship information including identity, position, course, and speed, and updates as often as every two seconds. The Seismic Vessel will display day shapes and lights to indicate that the vessel is towing equipment and is restricted in its ability to manoeuvre. Tail buoys will be fitted with a light and radar reflector indicating the end of each streamer.	Yes	Yes
Markings on tail buoys	P = Yes E = Effective	Under COLREGS and the Navigation Act, all possible measures need to be taken to indicate the presence of a towed object. Tail buoys indicates the end of each towed streamer and will be fitted with markings to indicate the presence/location. Markings will include reflective tape, lights, and radar reflector. An AIS transponder will be fitted to each tail buoy to allow for the detection of the end of each streamer by commercial marine users with AIS receiving capabilities.	Yes	Yes
Avoidance of Exclusion Zones of other marine users	P = Yes E= Effective	Oil and gas installations have established Petroleum Safety Zones (**PSZ**) prohibiting any vessel approaching closer than 500 m without prior approval/provision of a permit. These are established under the OPGGS Act. The OA does not encroach into any PSZ.	Yes	Yes

Control measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Temporal and spatial exclusion zones to avoid sensitive areas for marine mammals	P = Yes E= Effective	The Support Vessel and Chase Vessels will comply with the DPAW Whale Shark Management Programme (DPAW, 2013), in order to reduce the risk of disturbing whale sharks and avoiding collisions between a whale shark and the vessels: • Taking action to avoid approaching or drifting closer than 30 m of a whale shark; and • Not exceeding 8 knots within 250 m ('contact zone') of a whale shark.	Yes	Yes
	P = Yes E= Effective	Potential impacts from the overlap between important habitat for marine mammals and seismic acquisition will be minimised by spatially and temporally restricting the acquisition window in relation to pygmy blue whale migration. A 17 km buffer will be established around the blue whale migratory BIA where it overlaps with the OA to minimise the potential for behavioural impacts on this species. The Seismic Vessel will not activate the acoustic source within the blue whale migratory BIA or buffer from mid-April (14th) to mid-January (14th) which represents the period during which most migrating whales are expected to pass through the Timor Sea. Outside of this period (15 Jan to 13 April), seismic operations may occur inside the blue whale migratory BIA and buffer but will be subject to increased observational efforts to detect marine mammals within an extended 5 km radius (compared with 3 km outside). This extended observation zone will help reduce the potential for marine mammal interactions with the physical presence of the Seismic Vessel and towed equipment.	Yes	Yes

Control measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Stakeholder engagement	P = Yes E = Effective	Pre-survey stakeholder engagement allows stakeholder objections, claims, or expectations to be heard and understood and incorporated into the development of the EP (NOPSEMA, 2020). Early identification of issues allows mitigation measures to be developed to reduce the risk to **ALARP** and an **Acceptable Level**. Pre-survey engagement with identified stakeholders is a requirement of the OPGGS Act. Throughout the development of this EP, stakeholder engagement was undertaken using mail, email and phone contact, face-to-face meetings has not been possible due to COVID-19. The engagement leading up to the survey and the ongoing engagement whilst the survey is being acquired will allow for operational changes, if needed and possible. Any new stakeholders that are identified prior to, or during the Seismic Survey will be consulted with to ensure that all stakeholders are aware of the survey.	Yes	Yes
Ongoing communication with marine users such as through provision of a ’48-hour look-ahead’ plan and publication of a Notice to Mariners	P = Yes E = Effective	Communication with marine users allows those potentially affected by the Seismic Survey to plan activities in a manner that reduces the risk of interactions with the survey vessels and towed equipment (e.g. commercial fishers can avoid deploying gear in the path of the Seismic Vessel), including daily communication and a week look-ahead in addition to 48 hr look-ahead). Provision of a 48 hr ‘look-ahead’ plan which is distributed every 24 hrs allows commercial marine users (e.g. commercial fishers or commercial shipping) to understand the future movements of the Seismic Vessel and plan accordingly to avoid interactions. Under the Navigation Act 2012, Australian Hydrographic Office (AHO) can publish and distribute a Notice to Mariners. This Notice outlines potential hazards and restrictions to marine users.	Yes	Yes

Control measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Reporting of incidents or near misses between the Seismic Vessel and other marine users	P = Yes E = Effective	An incident or near miss includes any situation where another vessel intentionally does not respond to warnings threatening the safety of the Seismic Vessel and where remedial action by the Support Vessel or Chase Vessels or avoidance measures by the Seismic Vessel is required. Standard warnings such as radio communication between vessels are not considered an incident or near miss.	No	Yes
Spatial separation between concurrent MSSs	P = Yes E = Effective	Spatially separating concurrent MSSs reduces the potential for cumulative noise impacts and also provides a buffer between vessels and equipment so that entanglement of towed equipment or vessel collision is avoided. SLB will implement a 40 km spatial separation between its Seismic Vessel and any other operating Seismic Vessel in the Bonaparte Basin area.	Yes	Yes
Installation of 'turtle guards' on streamer tail buoys	P = Yes E = Effective	Almost all reported turtle entrapments during MSSs are associated with the 'undercarriage' of tail buoys (Ketos Ecology, 2009). 'Turtle guards' are fitted to the front of the tail buoys and act to physically exclude turtles from the gap at the front of the tail buoy undercarriage. SLB will ensure that the tail buoys used for the Seismic Survey has turtle guards fitted.	Yes	Yes

Control measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Recording of marine fauna ship strike and entanglement incidents	P = Yes E = Effective	While recording of any ship strike incidents does not reduce likelihood of an incident occurring, it is a requirement of the EPBC Act and Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009. SLB will have two dedicated MMOs onboard for the duration of the Seismic Survey and any incidents that occur between the Seismic Vessel and all fauna, including marine mammals and marine turtles will be recorded. In addition, two extra MMOs will be stationed on the Chase Vessel to assist with observations out to 5 km when operating inside the blue whale BIA and buffer.	No	Yes
Vessel crews are briefed on marine fauna entanglement and collision risk and reporting requirements	P = Yes E = Effective	All vessel crew will be required to remain vigilant for marine fauna collision and entanglement incidents. The MMOs participating during the Seismic Survey will also be on the lookout for any entanglements or risks of collisions.	No	Yes
Vessel masters' of the support vessels will reduce speed and maintain minimum distances through a 'caution zone' in the presence of cetaceans	P = Yes E = Effective	The Support Vessel and Chase Vessel will comply with the EPBC Regulations 2000 Part 8, Division 8.1 in order to reduce the risk of disturbing cetaceans (adult and calf) and avoiding collisions between a cetacean and the support vessels.	Yes	Yes
Towed equipment will be retrieved when the Seismic Vessel is in transit (e.g. to and from port)	P = Yes E =Effective	Retrieval of towed equipment will reduce the potential for more coastal species interacting with the towed equipment whilst in transit.	Yes	Yes
Compensation to fishers for loss or damage to fishing gear that is proven to have occurred as a result of direct impact from the Seismic Vessel, acoustic array or streamer configuration.	P = Yes E = Effective	Consideration will be given to any reasonable claims from fishers who incur damage to fishing equipment by the Seismic Vessel or towed equipment while operating outside of the OA. For SLB to accept a payment claim, fishers will need to provide enough evidence to demonstrate displacement and financial loss.	Yes	Yes

Control measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Alternative Control Measures:				
Daily contact with marine users to update on survey plans	P = No E = Effective	It would not be possible to contact all marine users on a daily basis, particularly recreational users. If requested, marine users will be notified every 24 hours with the 48-hour look-ahead of vessel movements, a Notice to Mariners will be in place throughout the duration of the survey, and the survey vessels will be contactable on marine radio.	Yes	Partially
Seismic acquisition will only occur outside of fishing seasons.	P = No E = Effective	As commercial fishing activities occur year-round, SLB are unable to operate outside of all fishing seasons.	Yes	No
All seismic acquisition will only occur during daylight hours	P = No E: Limited	24/7 operations will occur to minimise the duration of the survey. Limiting all acquisition to daylight hours only extends the duration of the survey. Cost of additional time outweighs the benefit of restricting the entire Seismic Survey to daytime operations.	Limited	No
Reduction in the length of the towed equipment	P = No E = Limited	The length of the streamers planned to be used for the Seismic Survey is 8 km. The acoustic equipment (including streamer length) has been designed to meet the survey objectives and guarantee data quality. Reducing the length of the towed equipment will reduce the footprint of the Seismic Survey; however, as the vessel and towed equipment are continuously moving, the benefit to marine users would be minimal and costs would be disproportionate to any benefit gained.	Limited	No
Increase of acquisition line spacing	P = No E = Limited	Although increasing line spacing would reduce the spatial overlap of survey lines with fishing grounds, as well as the overall duration of the Seismic Survey, survey objectives would not be met on account of reduced data coverage. Costs would be disproportionate to the benefit that may be gained.	Limited reduction	No

Control measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Vessel master of the Seismic Vessel will take evasive action to avoid marine fauna and other users	P = No E = Ineffective	The Seismic Vessel has limited ability to manoeuvre. It is unlikely any attempt to avoid a collision will have the desired result. The Seismic Vessel will instead maintain a constant speed and will not deviate from survey lines with the exception of line turns.	Limited	No
Removal of towed equipment when not in use	P = No E = Limited	Removal of towed equipment when not in use (i.e. during line turns) would temporarily remove the likelihood of an entanglement but is not practical, would increase the overall duration of the survey, and would increase potential for health and safety risks to vessel crew. Costs would be disproportionate to the benefit that may be gained.	No	No
Removal of support vessels	P = No E = Limited	Support vessels are required to avoid interactions with other marine users (i.e. other vessels) as a health and safety requirement as well as implementing the control measures. Increased risks associated with the removal of the Support Vessel or Chase Vessel are disproportionately higher than the benefit of removing a vessel.	No	No

Control measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Modification of survey/OA design - avoidance of commercial shipping routes	P = No E = Limited	Major commercial shipping routes are generally based on a direct line from major ports and it has been shown that there is some overlap with the OA. Avoiding these shipping routes would result in very large data gaps meaning that the Seismic Survey would not meet survey objectives. Numerous control measures will be implemented during the Seismic Survey, such as the use of AIS and radar on the Seismic Vessel and towed equipment, broadcasting of Notices to Mariners, and radio contact with Seismic Vessel will reduce the likelihood of any interactions with commercial vessels. These measures are considered sufficient to manage vessel interactions. It is also noted that there has been no collision to date between Seismic Vessel and commercial vessels. Commercial vessels are able to plot courses and manoeuvre themselves to avoid the Seismic Vessel without compromising their overall transit times, especially with the advanced notification they will receive. Costs would be disproportionate to the benefit that may be gained.	Limited	No
Seismic acquisition will only occur during daylight hours to allow for visual identification of the Seismic Vessel and towed equipment.	P = No E = Limited	This measure would result in significant extensions to the time required to acquire survey data. Interactions between Seismic Vessel and other marine users could still potentially occur during daylight hours. The vessels associated with the Seismic Survey will display the appropriate navigation lights and will use ARPA and AIS for identification to other vessels. Vessels will be contactable through radio-communications at all times. The towed equipment will be visually identifiable through display of lights, radar reflectors and use of AIS transponder on the tail buoys to mark the end of all the streamers.	Limited	No

Control measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Seismic transects will run parallel with shipping routes to avoid interference	P = No E = Limited	Careful consideration has been given to the survey design, including the orientation of survey lines. The quality of acquired data is maximised by running in the proposed direction across the sub-surface structures. Additional lines and time spent within the OA would be required in order to obtain the same quality level of data. Costs would be disproportionate to the benefit that may be gained.	Limited	No
Use of alternative geological imaging technology that does not require towed equipment	P = No E = Unknown Effectiveness	Alternative technologies are not yet commercially available or have not been proven or demonstrated the ability to meet geophysical data quality objectives, operational safety, and reliability requirements (IOGP, 2017). Costs would be disproportionate to the benefit that may be gained.	Unknown	No

7.1.5 Environmental Performance

The EPOs for the management of environmental impacts from the physical presence of the Seismic Vessel and towed equipment are:

- Survey information provided to regulatory authorities and marine users directly affected by planned activities prior to commencement of the Seismic Survey;
- No interference with other marine users and concurrent activities (i.e. commercial fisheries, maritime shipping, oil and gas activities, tourism operations, and recreational users) to a greater extent than is necessary to complete the Seismic Survey in a reasonable and timely manner;
- No injury or death of protected marine fauna due to collisions or entanglements; and
- No loss or damage to fishing equipment.

It is considered that the above EPOs, as a result of the implementation of the control measures (**Section 7.1.4**), will allow the ongoing environmental performance of the Seismic Survey in accordance with the **Acceptable Levels** described within **Section 7.1.8** while ensuring that the relevant legislation is complied with, in order to avoid any health and safety risks as far as practicable.

The EPSs within **Table 35** have been defined to manage impacts from the physical presence of the survey vessels and towed equipment to **ALARP** and an **Acceptable Level**. Compliance with these standards will ensure that the identified EPOs will be achieved for the duration of the Seismic Survey.

Table 36 Environmental Performance Outcomes and Standards for Physical Presence of the Seismic Survey Vessel and Towed Equipment

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
EPO: No interference with other marine users and concurrent activities (i.e. commercial fisheries, maritime shipping, oil and gas activities, tourism operations, and recreational users) to a greater extent than is necessary to complete the Seismic Survey in a reasonable and timely manner; and **EPO: No loss or damage to fishing equipment.**			
Compliance with relevant legislation and conventions with regard to maritime safety	**EPS 1**: At all times the Vessel Masters will comply with the requirements of national and international legislation and conventions including (but not limited to) the Navigation Act 2012 (specifically Marine Order Part 30: Prevention of Collisions), COLREGS, **UNCLOS**, Chapter IV (Radio communications) and Chapter V (Safety of Navigation) of **SOLAS** (International Convention on the Safety of Life at Sea 1974) and the STCW Convention.	Pre-mobilisation audit and inspection prior to operations beginning, along with crew inductions. Bridge logs.	Vessel Master.
Operational procedures: 24/7 operations	**EPS 2**: Acquisition will occur under 24/7 operations (where possible) so that the survey can be completed in the shortest possible time to minimise the amount of potential conflict.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 show when operations occurred. Bridge logs.	Vessel Master. MMO.
24/7 watch keeping by qualified and competent maritime crew	**EPS 3**: Qualified crew will maintain 24/7 watch-keeping during the survey in compliance with the STCW Convention. Monitoring of vessel position (radar and plotter) and water depth at all times during seismic acquisition.	Bridge log verifies watch has been undertaken.	Vessel Master.
	EPS 4: Watch keepers will be qualified in accordance with STCW95 (or equivalent).	Induction records outline qualifications/training of crew members.	Vessel Master.
Lights and visual communication at sea	**EPS 5**: Lighting and communications to maintain compliance with COLREGS, the Navigation Act 2012 and with AMSA Marine Orders Part 30: Prevention of collisions, Part 21: Safety and emergency arrangements and Part 27 (safety of navigation and radio equipment).	Pre-mobilisation audit and inspection prior to operations beginning, along with crew inductions. Bridge logs.	Vessel Master.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	EPS 6: The Seismic Vessel will display day shapes and lights to indicate that the vessel is towing equipment resulting in the Seismic Vessel being restricted in its ability to manoeuvre.	Pre-mobilisation audit and inspection prior to beginning of survey will confirm that the relevant equipment is onboard, tested and operational.	Vessel Master.
	EPS 7: The Seismic Vessel will be equipped with Radar and AIS systems which will be operating and monitored at all times for both transmitting and receiving vessel positions in the surrounding vicinity.	Pre-mobilisation audit and inspection prior to vessel leaving port.	Vessel Master.
	EPS 8: The Seismic Vessel will have ARPA onboard for the detection of other vessels, where the system can track other vessels speed and heading and can monitor for the potential of any collisions so they can be contacted prior to any situation occurring.	Pre-mobilisation audit and inspection of all systems prior to vessel leaving port. Bridge Logs confirm ARPA is used.	Vessel Master.
Marking of tail buoys	**EPS 9**: The tail buoy on each streamer will be appropriately marked for other marine users. The tail buoy will include a radar reflector, lights and an AIS transponder to identify the end of each streamer to other vessels capable of receiving AIS data.	Pre-mobilisation audit and inspection prior to vessel leaving port.	Vessel Master.
Radio communication	**EPS 10**: The survey vessels will be contactable by radio at all times (i.e. VHF and SSB radio).	Bridge Communication logs.	Vessel Master.
Support vessels present at all times (Support Vessel and Chase Vessel)	**EPS 11**: Support vessels will be present around the Seismic Vessel and towed equipment at all times and will patrol the area to prevent, and to escort, third-party vessels away from interacting with the streamers.	Vessel track records confirm movement and location of Support Vessel and Chase Vessel. Bridge logs.	Vessel Master.
	EPS 12: The support vessels will manage vessel interactions and maintain communications with commercial shipping and commercial fishers in the OA.	Bridge Logs.	Vessel Master.
	EPS 13: The Chase Vessel will also have two MMOs onboard while operation within the blue whale BIA and buffer and will operate in accordance with the Management Plan.	Vessel track records and AIS track records demonstrate compliance. Communication records between the survey vessels.	Vessel Master. MMO.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
Depth limitations to activation of acoustic source	**EPS 14**: There will be no acoustic release from the acoustic source within water depths less than 40 m in the OA.	Vessel records show no breach of these requirements. Bridge logs and vessel track records. MMO daily and weekly logs.	Vessel Master. MMO.
Spatial separation between concurrent surveys	**EPS 15**: The NOPSEMA database of approvals will be searched to identify the potential for temporal and spatial overlap with other MSSs in the Bonaparte Basin.	Search of the NOPSEMA activity status and summaries website, looking in particular for EP submissions or decisions in the surrounding areas to the OA.	SLB Project Manager.
	EPS 16: All other submitted MSS EPs for in the region will be reviewed to determine any spatial or temporal potential overlap.	Documented search in EP.	SLB Project Manager.
	EPS 17: SLB will maintain at least 40 km separation distance with any concurrent MSS at all times to avoid cumulative impacts to marine fauna.	Vessel track records as well as AIS track records demonstrate compliance. Communication records between the survey vessels.	Vessel Master. Vessel Party Chief.
Pre-survey communication with relevant stakeholders	**EPS 18**: Stakeholder engagement will be conducted with all identified stakeholders prior to the commencement of the Seismic Survey.	EP submitted to NOPSEMA confirms stakeholder engagement.	SLB Project Manager.
	EPS 19: Any new stakeholders that are identified prior to, or during the Seismic Survey will be consulted with.	Documentation of consultation records.	SLB Project Manager.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	EPS 20: Stakeholders will be notified prior to the commencement of the Seismic Survey in accordance with the following Pre-Activity Notifications: • Director of National Parks following approval of EP; • All relevant stakeholders – 4 weeks prior; • Australian Defence Force – 4 weeks prior; • Australian Hydrographic Office – 4 weeks prior; • Director of National Parks – 10 days (at least) prior to seismic activities occurring within the marine park and conclusion of that activity; • NOPSEMA – 10 days prior; and • AMSA's JRCC – up to two days prior.	Documentation of consultation and notification demonstrates compliance.	SLB Project Manager.
Post-survey notification	**EPS 21**: Stakeholders will be notified following the conclusion of the survey as per the following Post-Activity Notifications: • All relevant stakeholders – relevant time post completion; • AMSA – relevant time post completion; • NOPSEMA – 10 days post completion advising the completion of the Seismic Survey; and • NOPSEMA – As soon as practicable advising that all of the activities and obligations covered under the EP have been completed.	Documentation of consultation and notification demonstrates compliance.	SLB Project Manager.
Commercial fishers 48-hour look-ahead plan	**EPS 22**: A 48-hour 'look-ahead plan' will be provided to marine users detailing the survey activities over the next 48 hours. The 48-hour look-ahead plans will be updated and issued every 24 hours and distributed to relevant stakeholders via email.	Documentation of consultation and issuing of weekly and 48-hour look-ahead plans demonstrate compliance. Forms part of ongoing consultation strategy.	SLB Project Manager.
Notice to Mariners	**EPS 23**: A Notice to Mariners will be published and distributed by the AHO under the Navigation Act 2012.	Record of Notice to Mariners.	Vessel Master. SLB Project Manager.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	EPS 24: All Notice to Mariners will be updated during the survey should changes occur.	An updated Notice to Mariners will be issued.	Vessel Master. SLB Project Manager.
Compensation to commercial fishers for loss or damage to fishing gear	**EPS 25**: Compensation will be paid to commercial fishers who experience loss or damage to fishing gear that is proven to have occurred as a result of direct impact from the Seismic Vessel, acoustic array or streamer configuration.	Documentation of consultation outlines compensation claims and consideration of claims by commercial fishers.	Vessel Master. SLB Project Manager.
Contact of recreational fishers and charter boats	**EPS 26**: All recreational fishing bodies and representative bodies identified as part of the engagement process and those fishing and dive charter operators will be kept updated of the survey and if requested 48-hour look-ahead plans provided and updated every 24 hours.	Issuing of 48 look-ahead plans demonstrate compliance. Updates to ongoing consultation strategy.	SLB Project Manager.
Reporting of any incidents or near misses involving the Seismic Vessel and other marine users	**EPS 27**: Any incidents or near misses that threaten the safety of the Seismic Survey and/or require remedial action by the Seismic Vessel will be reported to AMSA.	Bridge log. Bridge Communication log. Copy of report to AMSA. Recorded in a complaints register.	Vessel Master. SLB Project Manager.
Retrieval of towed equipment when the Seismic Vessel is in transit	**EPS 28**: Towed equipment will be retrieved and brought onboard the Seismic Vessel when not required (e.g. vessel is in transit to/from port).	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4. Bridge log.	Vessel Master.
Avoidance of Petroleum Safety Zones of other marine users	**EPS 29**: The Seismic Vessel will not enter within established PSZ unless by prior arrangement with the installation master and all correct permits are obtained.	Vessel records demonstrate compliance. Vessel log.	Vessel Master.
Retrieval of any lost seismic equipment	**EPS 30**: Any in-water equipment that is lost will be recovered where it is safe and practicable to do so. Pressure activated streamer recovery devices will be fitted along the streamer.	Any lost equipment will be notified to AMSA and AHO as soon as possible. Vessel Log. AMSA records.	Vessel Master. SLB Project Manager.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	EPS 31: Seismic Vessel conform to the hardware requirements of AMSA: Marine Order 30: Prevention of Collisions for AIS, navigation lighting, sound signals, day shapes, and ARPA; and Marine Order 27: Safety of Navigation and radio Equipment.	Class survey certificate verifies that navigational safety equipment is compliant with the requirements of Marine Order 30 & 21.	Vessel Master.
Ongoing stakeholder engagement with marine users.	**EPS 32**: SLB will take reasonable steps to avoid or minimise conflict with other marine users, should such a conflict be identified during ongoing consultation with stakeholders.	Ongoing engagement. Complaints register.	SLB Project Manager.
EPO: Survey is conducted in a manner that avoids injury or death of protected marine fauna due to collisions or entanglements.			
Installation of 'turtle guards' on tail buoys	**EPS 33**: The tail buoys will be fitted with protective 'turtle guards' that is appropriate for excluding turtles from entering gaps in the subsurface structure of the tail buoys.	Audit/inspection records verify turtle guards are installed.	Vessel Master. SLB Project Manager.
Compliance with relevant legislation.	**EPS 34**: When the streamers and acoustic array are deployed, the Seismic Vessel will comply with the EPBC Policy Statement 2.1 (Part A) to reduce any potential for interactions with marine mammals.	MMO and PAM daily and weekly logs	SLB Project Manager. MMO. PAM Operator.
Maintenance of marine mammal watch.	**EPS 35**: Two trained and experienced MMOs will be onboard the Seismic Vessel at all times. At least one MMO will be on the bridge of the Seismic Vessel for the visual detection of marine mammals at all times during daylight hours. In addition, two extra MMOs will be stationed on the Chase Vessel when operations are occurring inside the blue whale BIA and buffer to assist with observations out to 5 km.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 show when operations occurred. Bridge logs. MMO daily and weekly logs.	MMO.
Record any marine fauna ship strike or entanglement incidents	**EPS 36**: Marine fauna ship strikes will be recorded as per the requirements of the EPBC Act and Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009.	Sighting reports and documentation of any reportable incident. MMO daily and weekly logs	SLB Project Manager. MMO.
	EPS 37: All observed ship strike and entanglement incidents will be reported to the DoEE.	Sighting reports and documentation of any reportable incident. Bridge log. MMO daily and weekly lobs.	Vessel Master. SLB Project Manager. MMO.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	EPS 38: Incidents involving marine fauna will be reported on the National Ship Strike Database.	Sighting reports and documentation of any reportable incident. MMO daily and weekly logs.	SLB Project Manager. MMO.
Vessel crew are briefed on entanglement and collision risk and reporting requirements	**EPS 39**: All vessel crew are to be briefed on the risk of marine fauna collision and entanglement and the reporting requirements.	Induction records outline content of vessel induction and those in attendance.	Vessel Master. MMO.
	EPS 40: All crew will go through an induction that details their responsibilities as required regarding marine fauna interactions.	Induction records and agenda outline. Attendance register.	Vessel Master. SLB Project Manager. MMO.
Retrieval of towed equipment when the Seismic Vessel is in transit	**EPS 41**: Towed equipment will be retrieved and brought onboard the Seismic Vessel when not required (e.g. vessel is in transit to/from port). Any interactions between vessel and cetaceans during the survey when the seismic equipment is not deployed will be managed in accordance with Part 8 of the EPBC Regulations (2000).	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4. Bridge log.	Vessel Master. Seismic Operator.
Support vessels (Support Vessel and Chase Vessel) mitigation measures – Compliance with EPBC Regulations 2000	**EPS 42**: The Vessel Masters of the support vessels will maintain a minimum of 100 m from any cetacean.	Bridge log. MMO log (if onboard Chase Vessel).	Support Vessels Masters.
	EPS 43: The Vessel Masters will maintain a minimum of 50 m from any dolphin.	Bridge log. MMO log (if onboard Chase Vessel).	Support Vessels Masters.
	EPS 44: If a cetacean approaches closer than the 100 m, the Vessel Master will either disengage gears or allow the whale to approach or reduce speed to less than 6 knots and steer a course away from the cetacean.	Bridge log. MMO log (if onboard Chase Vessel).	Support Vessels Masters.
	EPS 45: If a dolphin approaches closer than the 50 m, the Vessel Master must not change course or speed of the vessel suddenly.	Bridge log. MMO log (if onboard Chase Vessel).	Support Vessels Masters.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	EPS 46: The vessel master will make all efforts not to let a calf enter the caution zone (either whale or dolphin). However, if it occurs, the Vessel Master will immediately stop the vessel, turn off engines, or disengage gears, or withdraw the vessel from the caution zone at a constant speed of less than 6 knots.	Bridge log. MMO log (if onboard Chase Vessel).	Support Vessels Masters.
Temporal and spatial exclusion zones to avoid sensitive areas for marine mammals	**EPS 47**: The Vessel Masters will avoid getting closer than 30 m of a whale shark. However, if it occurs, the Vessel Master will slow down and withdraw the vessel from the contact zone (250 m) at a constant speed of less than 8 knots.	Bridge log. MMO log (if onboard Chase Vessel).	Vessel Master. MMO.
	EPS 48: Potential impacts from the overlap between important habitat for marine mammals and seismic acquisition will be minimised by spatially and temporally restricting the acquisition window in relation to pygmy blue whale migration. A 17 km buffer will be established around the blue whale migratory BIA where it overlaps with the OA to minimise the potential for behavioural impacts on this species.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4. MMO/PAM and Bridge Logs verify the implementation of these procedures.	Vessel Master. SLB Project Manager. MMO. PAM Operator.
	EPS 49: The Seismic Vessel will not activate the acoustic source within the blue whale migratory BIA or buffer from mid-April (14th) to mid-January (14th) which represents the period during which most migrating whales are expected to pass through the Timor Sea. Outside of this period (15 Jan to 13 April), seismic operations may occur inside the blue whale migratory BIA and buffer but will be subject to increased observational efforts to detect marine mammals within an extended 5 km radius (compared with 3 km outside). This extended observation zone will help reduce the potential for marine mammal interactions with the physical presence of the Seismic Vessel and towed equipment.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4. MMO/PAM and Bridge Logs verify the implementation of these procedures.	Vessel Master. MMO. PAM Operator.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
EPBC Act Policy Statement 2.1: B6 – Adaptive Management	**EPS 50**: If high numbers of whale detections result in three or more shut-downs in a 24-hour period, the Seismic Vessel will relocate to another survey line at least 17 km away that is outside of the blue whale BIA and buffer zone before commencing Pre Start-up Visual Observations and Soft Start Procedures. If three or more other baleen whale instigated shut-downs occur within a 24-hour period, the Seismic Vessel will relocate at least 10 km away.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. MMO and PAM daily and weekly logs.	Vessel Master. MMO. PAM Operator.
Retrieval of any lost streamers	**EPS 51**: Any in-water equipment that is lost will be recovered when it is safe and practicable to do so. Pressure activated streamer recovery devices will be fitted along the streamers.	Any lost equipment will be notified to AMSA and AHO as soon as possible. Vessel Log. AMSA records.	Vessel Master. SLB Project Manager.
	EPS 52: Support vessels will be nearby for assistance in the recovery of any lost streamer.	Vessel log.	Vessel Masters.
Marine fauna incidents	**EPS 53**: Any recovered entangled marine fauna will be returned to the sea as quickly as possible.	MMO daily and weekly logs. Vessel Log.	Vessel Master. MMO.

7.1.6 Residual Risk of Impact

Following the implementation of the control measures in **Section 7.1.4,** and the assessment completed within **Section 7.1.2** and **7.1.3,** the worst-case likelihood of the physical presence of the survey vessels and towed equipment having any impact on marine fauna and marine users is considered *Likely*, and the worst-case consequences of the associated known risks are considered *Moderate*. Therefore, the worst-case residual risk of an impact occurring from the physical presence of the vessels and towed equipment is considered to be **Moderate** (**Table 37**). The magnitude of this residual risk is mostly associated with possible interactions between commercial fishing vessels and the Seismic Survey, due to potential spatial and temporal overlap in activities.

Table 37 Residual Risk Summary for Physical Presence of the Seismic Survey Vessels and Towed Equipment

Likelihood	Consequence	Residual Risk
Likely	Moderate	Moderate

7.1.7 Demonstration of ALARP

To demonstrate that any potential impacts from the presence of the survey vessels and towed equipment are managed to **ALARP**, SLB has considered a number of control measures to determine the benefits of their implementation towards risk reduction (**Table 35**), based on a Hierarchy of Controls methodology (**Table 38**). The adopted control measures that will be implemented throughout the Seismic Survey are considered appropriate to reduce the environmental impacts from the presence of the survey vessels and towed equipment and assessments have been undertaken to ensure that all reasonable and practicable control measures or solutions have not been overlooked. As a result, through the application of industry best practice and/or comparable standards to further control risk reduction, it is considered that any impacts from the presence of the vessels have been reduced to **ALARP**, where the residual risk from adoption of these control measures is **Moderate** (**Table 37**).

Additional control measures were considered as part of the assessment process towards further risk reduction; however, it was considered that they did not provide any further environmental benefit or were not reasonably practicable to implement. In addition, the costs (based on the experience of SLB) of implementing such measures would be disproportionate to the benefits that would be gained through their implementation.

Table 38 Hierarchy of Controls for Physical Presence of the Seismic Survey Vessel and Towed Equipment

Eliminate	Due to the offshore nature of the OA, the Seismic Vessel and towed equipment are required for data acquisition and cannot be eliminated. The presence of support vessels is a health and safety requirement which acts to reduce the risk of collision between the Seismic Vessel/towed equipment and other marine users and/or entanglement between fishing gear and seismic equipment.
Substitute	Alternative data acquisition methods that do not require towed equipment are not yet commercially available or proven to meet geophysical data quality objectives, operational safety, and reliability requirements.
Reduce	The Seismic Vessel will operate 24/7 to reduce the duration of the Seismic Survey and thereby allowing the survey objectives to be met.
Mitigate	Control measures have been assessed within **Table 35** to mitigate impacts from the physical presence of the Seismic Vessel and towed equipment to **ALARP** and **Acceptable Levels**. Those measures which are appropriate and are not impractical or unfeasible will be implemented during the Seismic Survey.

The proposed control measures minimise the risk of impacts from the presence of the Seismic Vessel and towed equipment and are considered appropriate to the localised and transitory nature of potential environmental impacts associated with the Seismic Survey. The proposed control measures have been developed in accordance with industry best practice. No further practicable controls have been identified to reduce the impact and risks to the marine environment, marine organisms or other marine users from the presence of the Seismic Vessel and towed equipment.

The effects of the physical presence of the Seismic Vessel and towed equipment will be relatively localised and transitory in nature. As a number of mitigation measures will be in place to reduce the likelihood of any effects on marine users and marine fauna, it is considered that the potential impacts from the physical presence of the survey vessels and towed equipment are reduced to **ALARP** and **Acceptable Levels**.

7.1.8 Risk Acceptability

The total elimination of survey vessels and towed equipment from the project cannot be achieved due to the offshore location of the Seismic Survey, lack of commercially available and proven alternative acquisition methods, and health and safety requirements for a Support Vessel. Following the implementation of the control measures (**Table 35**), the potential impacts to the marine environment and marine users arising from the physical presence of the survey vessels and towed equipment will be short-term and restricted in extent to within the immediate vicinity of the vessel and equipment. Given the vessel will traverse parallel and adjacent sail lines located 720 m apart, the physical presence of the survey vessels across the relatively large OA will be transitory in nature.

The criteria for risk acceptability are detailed in **Table 39**. The control measures that will be implemented throughout the Seismic Survey have been developed in accordance with these criteria. Where uncertainty exists around the criteria or the risk, SLB has taken a precautionary approach.

Table 39 Demonstration of Risk Acceptability for Physical Presence of Survey Vessels and Towed Equipment

Criteria for Acceptance	Acceptability Summary
SLB's internal context	The proposed management of the impacts and risks from the presence of the survey vessels and towed equipment are consistent with SLB's Environmental and QHSE Policy.
Industry Best Practice	Implemented control measures are based on Industry Best Practice including: • The IAGC Environmental Manual for Worldwide Geophysical Operations. Geophysical vessels must exercise care to reduce risk to aquatic life, including marine fauna and other marine users and, where possible minimise interruption to operations and equipment of other marine users; and • The APPEA Code of Environmental Practice Details within this document relate mainly to offshore operations such as offshore exploration and/or drilling and production facilities where disturbance to marine fauna and marine users should be reduced to ALARP and Acceptable Levels. It emphasises the importance of maintaining public health and safety during all phases of operations. A similar expectation is likely expected of Seismic Vessels operating in offshore waters.

External Context – Commonwealth and State Legislative Criteria	The control measures for reducing the risk associated with the presence of the survey vessels and towed equipment throughout the duration of the Seismic Survey are consistent with the following relevant standards/documents:
	• International Maritime Organisation (**IMO**) conventions (i.e. STCW, SOLAS);
	• Relevant ship safety requirements under the Navigation Act 2012:
	  ◦ MARPOL;
	  ◦ UNCLOS;
	  ◦ COLREGS;
	  ◦ Marine Order 21: (Safety of navigation and emergency procedures), 2012;
	  ◦ Marine Order 28: (Operations standards and procedures), 2012; and
	  ◦ Marine Order 30: (Prevention of collisions), 2009;
	• Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations;
	• Watch-keeping will occur in accordance with the standards set by the '*International Convention on Standards of Training, Certification and Watchkeeping for Seafarers'*; and
	• Support vessels will adhere to the EPBC Regulations 2000 with regard to interacting with cetaceans.

Criteria for Acceptance	Acceptability Summary
External Context – Management Plans, Species Recovery Plans and Conservation Advice	Minimising vessel collision has been ranked as a high priority action within the Conservation Management Plans for blue whale, humpback whale, fin whale and sei whale. During the development of mitigation measures for the Seismic Survey, the National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna has been taken into account, reducing the potential for risks associated with ship strike to **ALARP** and **Acceptable Levels** with regard to marine mammals; and The Recovery Plan for Marine Turtles in Australia outlines that the long-term recovery objective for marine turtles is to '*minimise anthropogenic threats*' and to '*allow for the conservation status of marine turtles to improve so that they can be removed from the EPBC Act threatened species list*'. The National Strategy for Reducing Vessel Strike on Cetaceans and Other Marine Megafauna has been taken into account during the development of mitigation measures including the use of best-practice mitigation measures (i.e. turtle guards). The low speed of the Seismic Vessel and installation of turtle guards on each tail buoy is considered to further reduce the potential for risks associated with vessel disturbance to **ALARP** and **Acceptable Levels** with regard to marine turtle populations in the OA.
Social Acceptance – Stakeholder expectations	SLB are committed to ongoing engagement with stakeholders and will provide 48-hour look-aheads throughout the survey to all stakeholders that request this information. Under the Navigation Act 2012, Australian Hydrographic Office (**AHO**) can publish and distribute a Notice to Mariners.
Ecologically Sustainable Development	The management of the impacts associated with the presence of the Seismic Vessel and towed equipment proposed by SLB can be carried out in compliance with principles of ecologically sustainable development as defined within the EPBC Act. The risk assessment undertaken within this EP has not identified any adverse impacts, and is consistent with the principles of ESD, namely: • Decision-making processes integrated long-term and short-term economic, environmental, social and equitable considerations (e.g. exclusion of the blue whale BIA and the 17 km behavioural disturbance buffer from mid-April (14th) to mid-January (14th) to avoid peak periods for migration of blue whales); • No threats of serious or irreversible environmental damage were identified by the risk assessment; • The principle of inter-generational equity is maintained as potential disturbance impacts from the vessel presence is relatively localised and of medium-term; • The conservation of biological diversity and ecological integrity were fundamental considerations in decision-making and development of control measures, for example the installation of turtle guards on the tail buoys will reduce possible impacts to any turtles in the area and retrieval of equipment during transit to and from port will lessen risks of equipment interactions with marine species; and Proposed control measures have considered improved valuation, pricing and/or incentive mechanisms – control measures that had environmental benefits that outweighed the costs of their implementation were proposed to be undertaken.

Criteria for Acceptance	Acceptability Summary
Existing Environmental Context	Through the development of the EP, the potential interactions and disturbances were assessed between the Seismic Vessel and associated array, the OA within which the Seismic Survey will be acquired, and the different receptors in the receiving environment. This included the evaluation of the overlap and interactions with the marine environment (i.e. marine reptiles and mammals, commercial fisheries, recreational fisheries, tourism, other oil and gas activities, and commercial shipping). It is considered that the proposed control measures provide appropriate protection to marine fauna and existing users from the potential effects associated with the physical presence of the Seismic Vessel and towed equipment. A number of control measures were considered as part of the assessment process, and it was concluded that the addition of any further control measures not already considered would provide little or no additional protection from the presence of the Seismic Vessel and towed equipment while potentially compromising the ability of survey objectives to be met.
ALARP	The total elimination of survey vessels and towed equipment from the project cannot be achieved due to the offshore location of the Seismic Survey, lack of commercially available and proven alternative acquisition methods, and health and safety requirements for a MSS. Following the implementation of the control measures, the potential impacts to the marine environment and marine users arising from the physical presence of the survey vessels and towed equipment will be short-term and restricted in extent to within the immediate vicinity of the vessels and equipment. Based on the discussions within the EP, including the potential impacts on the environment and the associated control measures to be implemented, the residual risk of impacts arising from the physical presence of the survey vessels and towed equipment throughout the Seismic Survey is considered to be **Moderate**. This impact is predicted to be a medium scale effect in terms of encounter with marine mammals and reptiles; however, it is envisaged that the control measures, especially the temporal and spatial controls will avoid displacement to the sensitive stages of blue whales, as will the adaptive management measures in the BIA. With the control measures in place, it is considered that the Seismic Survey will be acquired so that the environmental risk and impacts on the marine environment and associated receptors within and surrounding the OA are reduced to **ALARP**. Therefore, residual risk from the physical presence of the survey vessels and towed equipment associated with the Seismic Survey is considered to be at an **Acceptable Level**.

7.1.9 Physical Presence Impact Summary

Based on the assessment above, including the potential impacts on the environment and the associated control measures to be implemented, the residual risk of impacts arising from the physical presence of the survey vessels and towed equipment throughout the Seismic Survey is considered to be **Moderate**.

Based on the control measures (**Table 35**) that have been proposed for implementation, in addition to those that have been assessed and characterised as not practicable, it's considered no further mitigations measures are available which can be reasonably adopted for the Seismic Survey. The suite of control measures to be implemented have been developed in accordance with industry best practice, Environment Regulations and all other relevant regulations. Consequently, it is considered that the environmental risk and impacts on the marine environment and receptors within and surrounding the OA, arising from the physical presence of the survey vessels and towed equipment throughout the Seismic Survey, are reduced to **ALARP**.

In accordance with the Risk Ranking Descriptions in **Table 32**, where risk cannot be reduced to '**Low**', control measures must be applied to reduce the risk to **ALARP**. Since the **Moderate** risk ranking is mostly associated with potential interactions with marine mammals and commercial fishing operations within the OA, adaptive management measures and ongoing consultation, including the communication of survey plans and 48-hour look-aheads, in association with an official Notice to Mariners provide effective measures to reduce the potential residual risk to **ALARP**.

Therefore, residual risk from the physical presence of the survey vessels and towed equipment associated with the Seismic Survey is considered to be at an **Acceptable Level**.

7.2 Acoustic Disturbance to the Marine Environment

7.2.1 Description of Source of the Noise Impact

Noise will be generated from two sources during the Seismic Survey, including the survey vessels, and the active acoustic source. The active acoustic source generates much higher noise levels than the vessels and would dominate overall underwater noise emissions at times when data acquisition is occurring.

7.2.1.1 Vessel Noise

Noise from ships (i.e. propellers, machinery, and the passage of the hull through water) is the dominant anthropogenic sound in marine waters and adds to the constant ambient noise level in the marine environment. In general, older vessels produce more noise than more modern vessels, and larger vessels produce more noise than smaller vessels (Gordon and Moscrop, 1996). Commercial vessels produce relatively loud and predominantly low frequency sounds, with the exact characteristics' dependant on vessel type, size, and operational mode (**Table 40**). A study undertaken by MacGillivray & Li (2018) recorded vessel noise in Haro Strait and found underwater noise generated by commercial vessels is significantly reduced at slower vessel speeds. For vessel noise, the strongest energy tends to be at frequencies below several hundred hertz, with source levels generally ranging from 180 – 190 dB re 1 µPa (Southall and Hatch, 2008). Despite the presence of many marine mammal species in coastal areas with high levels of shipping, relatively few studies have investigated the effects of ship noise on marine mammals (Blair *et al*., 2016).

Table 40 Noise Outputs from a range of Commercial Vessels

Source	Source level (dB re 1 µPa at 1 m)	Reference
Container ship (294 m & 298 m length)	184.2 – 186.6 & 188.1	McKenna et al., 2012
Container ship	183.8 – 199.1	MacGillivray & Li, 2018
Vehicle carrier (173 m & 199 m length)	180.0 & 180.8	McKenna et al., 2012
Vehicle carrier	183.6 – 195.2	MacGillivray & Li, 2018
Bulk carrier (167 m & 229 m length)	187.4 & 185.1	McKenna et al., 2012
Bulk carrier	181.9 – 193.9	MacGillivray & Li, 2018
Open hatch cargo ship (190 m & 213 m length)	183.8 & 181.1	McKenna et al., 2012
Chemical products tanker (148 m & 182 m length)	182.4 & 184.9	McKenna et al., 2012
Crude oil tanker (229 m & 243 m length)	181.3 & 182.1	McKenna et al., 2012
Product tanker (180 m & 228 m length)	181.8 & 182.7	McKenna et al., 2012
Tanker	183.6 – 195.2	MacGillivray & Li, 2018
Super tanker (266 m & 337 m length)	187 & 185	Thiele, 1983
Cruise ship	175.5 – 198.3	MacGillivray & Li, 2018
Fishing trawler	158	Malme *et al.*, 1988

Noise emissions from the survey vessels would be similar in level, frequency range and character to noise from general shipping traffic already in the study area and is not considered to represent a significant additional environmental impact above the noise from normal shipping activities (see **Section 7.2.1.1**).

7.2.1.2 Underwater Acoustic Modelling

7.2.1.2.1 Introduction

UAM was undertaken to predict received noise levels, or the 'footprint' of acoustic emissions generated from the Seismic Survey. UAM increases the understanding of the acoustic footprint over a given bathymetric environment with unique environmental parameters (i.e. sound speed profile and geology) for a specific acoustic source proposed for a seismic survey.

Results from this UAM are used to confirm the extents of the Precaution Zones required under the EPBC Act Policy Statement 2.1 and to enable an assessment of the potential risk to various marine fauna in the OA based on comparisons with known injury and behavioural onset thresholds. Potential risks to the ecological character of sensitive marine areas in the surrounding areas to the OA have also been considered.

The UAM was undertaken by JASCO (Connell *et al*., 2022) and its report which outlines the methodology and results is included in **Appendix A**.

In summary, the UAM approach involved three key components:

- Array source modelling – used to predict acoustic signatures and spectra accounting for individual airgun volumes, airgun bubble interactions, and array geometry. This modelling is used to yield accurate source predictions;
- Underwater acoustic propagation modelling – used to estimate sound levels over a large area around the acoustic array sources, taking into account source directivity and range-dependent environmental properties likely to be encountered within the Acquisition Area. Single-impulse (or per-pulse) and accumulated (24 hour) sound exposure fields were predicted; and
- Animal movement and exposure modelling (**animat modelling**) – this modelling considers the movement of both the sound source and animals over time. In this case, the animat modelling involved simulations to predict the distance at which migrating pygmy blue whales (*Balaenoptera musculus brevicauda*) are expected to be exposed above specified thresholds.

In the case of the Seismic Survey, UAM was conducted specifically for the discharge of the 3,000 in^3 source array. As described in **Appendix A**, the selected sound speed profile (the month of March) represents a worst-case scenario (precautionary) for noise propagation and has been chosen so that in the event of any delays to the programme the predicted impacts are conservative, and representative of source locations and seasons expected to exhibit noise propagation over the greatest distances.

The seabed chosen for the modelling was derived from sedimentary grain size measurements from the Australian Government's Marine Sediments (**MARS**) database, being sandy silt.

A total of four acquisition scenarios were considered using both acoustic propagation modelling and animat modelling, with one additional scenario considered using animat modelling only. All five scenarios considered continuous 24 hour acquisition, including on turns. Therefore, the simulated source tracks followed a 'racetrack' configuration. A speed of 4.5 knots and an inter-pulse interval of 16.66 m results in a total of approximately 12,000 impulses per scenario. At the time and location of each seismic pulse, the modelled source location with the closest distance was selected for exposure modelling. The track lines along with the acoustic modelling locations are shown in **Figure 39**.

The single impulse sites and the accumulated SEL scenarios were determined based on proposed survey line plans with lines orientated either at 26/206° or 159/339°. The locations were selected based on their proximity to shoals and were inclusive of depths that support the greatest sound propagation into deep waters towards the pygmy blue whale migratory BIA. The single impulse sites and accumulated SEL scenarios are representative of the range of water depths and the potential sound propagation characteristics within the OA.

Seafloor sound levels were assessed at five different representative depths within the OA (75, 100, 125, 150, and 200 m). Sound levels were assessed for receivers located at both 5 cm and 50 cm above the seafloor interface, the former being relevant to benthic invertebrates and the latter relevant to sponges, corals, fish, fish eggs, and larvae.

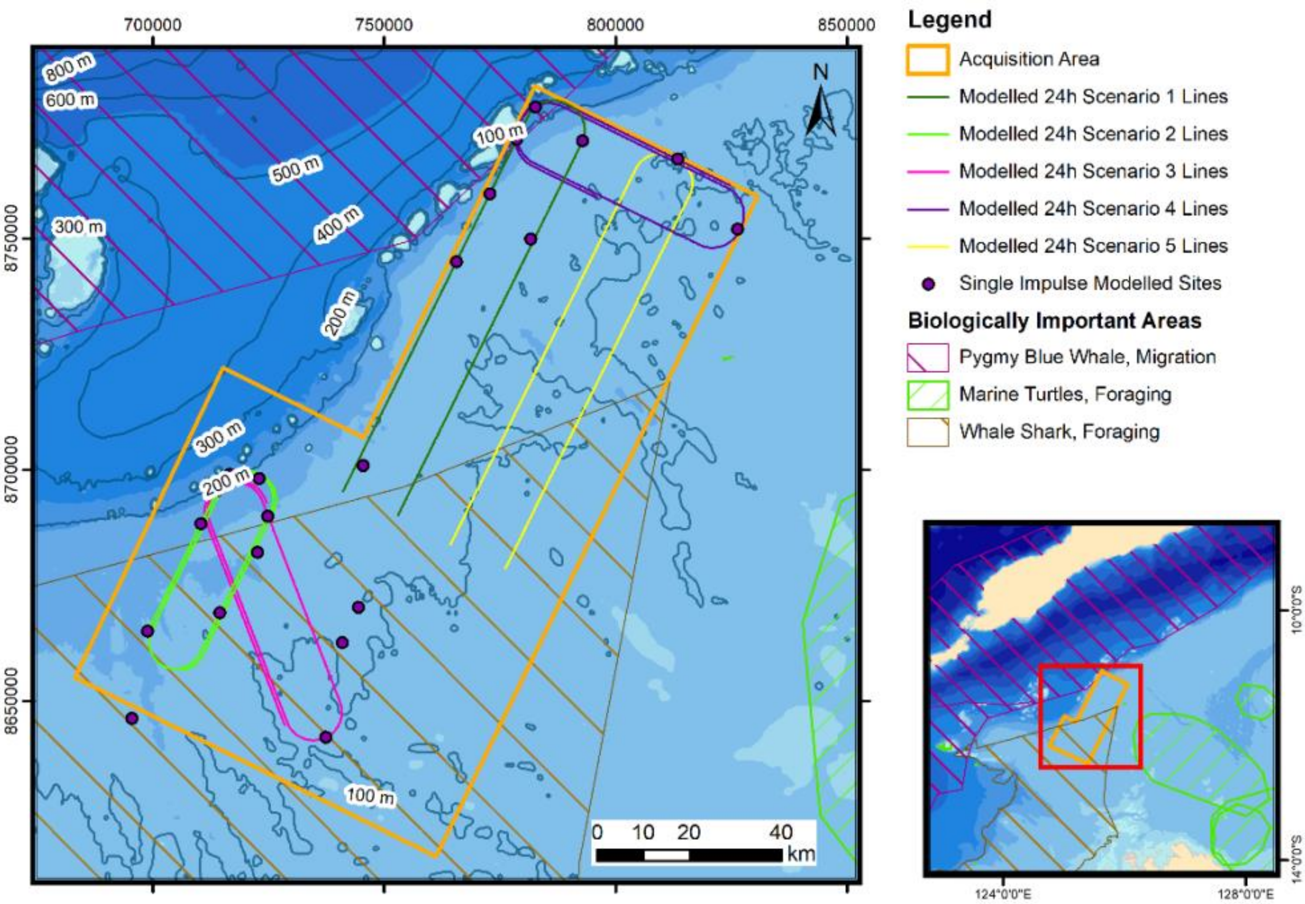


Figure 39 Overview of Modelled Sites and Acquisition Lines

7.2.1.2.2 Noise Effect Criteria

The following discussion is based on, and in some cases an excerpt from, the UAM contained within **Appendix A**, by Connell *et al*., 2022.

The perceived loudness of sound, especially impulsive noise such as from an acoustic source, 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 are commonly used to evaluate noise and its effects on marine life. The period of accumulation associated with SEL is defined, referencing either a "per pulse" assessment or over 24 hours (**Appendix A**). Appropriate subscripts indicate any applied frequency weighting; unweighted SEL is defined as required. The acoustic metrics used 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), United States National Marine Fisheries Service (NMFS 2018), and Southall *et al*. (2019). The number of studies that have investigated the level of behavioural disturbance to marine fauna by anthropogenic sound has also increased substantially. JASCO notes that research is ongoing into the relationship between sound and its effects on benthic invertebrates, 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. Particle motion relates to the movement of fluid particles in a sound field. Water depth and seismic source size are related to the particle motion levels at the seafloor, with larger arrays and shallower water being related to higher particle motion levels, more likely relevant to effects on crustaceans and bivalves. Particle motion can be measured in terms of three different (but related) quantities: displacement (m), velocity (ms^{-1}), or acceleration (ms-^{2}). Acoustic particle motion has been reported in terms of acceleration.

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-pk}**), and either single-impulse (i.e., per-pulse) or accumulated sound exposure levels (**SEL; L_E**) as appropriate for different noise effect criteria. In addition, particle acceleration (ms^{-2}) was estimated at the seafloor.

The following noise criteria and sound levels for this study were chosen because they include standard thresholds, thresholds suggested by the best available science, and sound levels presented in literature for species with no suggested thresholds:

1. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from (Southall *et al*., 2019) for the onset of Permanent Threshold Shift (**PTS**) and Temporary Threshold Shift (**TTS**) in marine mammals;
2. Marine mammal behavioural threshold based on the current US National Oceanic and Atmospheric Administration (NOAA, 2019) criterion for marine mammals of 160 dB re 1 µPa (SPL; L_p) for impulsive sound sources;
3. Sound exposure guidelines for fish, fish eggs and larvae (including plankton) (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 PTS and TTS in turtles;
5. Sea 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; L_p) (McCauley *et al*.; 2000a; 2000b);

6. Peak-peak pressure levels (PK-PK; L_{pk-pk}) and particle acceleration (ms^{-2}) at the seafloor to help assess effects of noise on crustaceans through comparing to results in Day *et al*. (2016), Day *et al*. (2019), Day *et al*. (2016a), Day *et al*. (2017) and Payne *et al*. (2008); and
7. A sound level of 226 dB re 1 µPa (PK; L_{pk}) reported for comparing to Heyward *et al*. (2018) for sponges and corals.

Additionally, to assess the size of the low-power zone required under the Australian Environment Protection and Biodiversity Conservation (EPBC) Act Policy Statement 2.1, Department of the Environment, Water, Heritage and the Arts (DEWHA, 2008), the distance to an unweighted per-pulse SEL of 160 dB re 1 $\mu Pa^2 \cdot s$ (LE) was assessed.

Further details of the relevant noise effect criteria used are presented in **Section 7.2.2.**

7.2.1.2.3 Acoustic Source Levels and Directivity

The Seismic Vessel will tow an acoustic array comprised of two sub-arrays with thirteen acoustic sources per sub-array (26 in total), providing an overall effective volume of 3,000 in^3 (**Figure 6** and **Table 7**).

The UAM methodology addresses the horizontal and vertical directionality of the emissions from the acoustic source based on the specific configuration to be used during the survey. Also considered within the model are the varying water depths found throughout the OA.

The source levels and directivity of the seismic source presented in the UAM report included in **Appendix A** were predicted using JASCO's Airgun Array Source Model (**AASM**). AASM, which includes low- and high-frequency modules for predicting different components of the seismic source spectrum, was used to predict the horizontal and vertical overpressure signatures and corresponding power spectrum levels for the seismic sources, with results provided in Appendix B.3 of the report contained in **Appendix A**, along with the horizontal directivity plots for the selected source. All seismic sources considered were modelled over AASM's full frequency range, up to 25 kHz.

Table 41 presents the peak and per-pulse SEL source levels in the horizontal-plane broadside (perpendicular to the tow direction), endfire (along the tow direction), and vertical directions for the modelled array signature (3,000 in^3 source). 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.

Table 41 Far-field Source Level Specifications for 3,000 in^3 Source for an 8 metre Tow Depth

Direction	Peak source pressure level ($L_{S,pk}$; dB re 1 µPa m)	Per-pulse source SEL ($L_{S,E}$; dB 1 $\mu Pa^2 m^2 s$)	
		10–2000 Hz	2000–25000 Hz
Broadside	250.1	225.3	185.4
Endfire	245.0	223.0	186.4
Vertical	256.3	228.8	195.1
Vertical (surface affected source level)	256.3	231.0	198.3

Note: 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.

7.2.1.2.4 Single-impulse Sound Fields

Acoustic source and propagation modelling was done at 21 individual single-impulse sites, with some sites being modelled at several tow azimuths to account for acquisition on turns. The modelling assessed the sound fields in terms of maximum-over-depth SPL, SEL, PK, and seafloor PK and PK-PK. These metrics were assessed as they are used for peak thresholds, as inputs into 24-hour SEL scenarios or correspond with the relevant behavioural thresholds.

The maximum and 95% distances to per-pulse SEL and SPL metrics for the water column are presented in Tables 9 to 16 of the report contained in **Appendix A**. The water column SPL sound fields, and distances to relevant isopleths are shown on the contour maps presented in Figures 7 to 33 of the same report. The water column SPL sound fields are also presented in Figures 34 to 39 of the same report as vertical slices for selected sites along the endfire and broadside directions out to 50 km, with the airgun array in the centre. Two examples of the SPL sound fields are presented in **Figure 40**. The implications of these estimations are presented in **Section 7.2.2**.

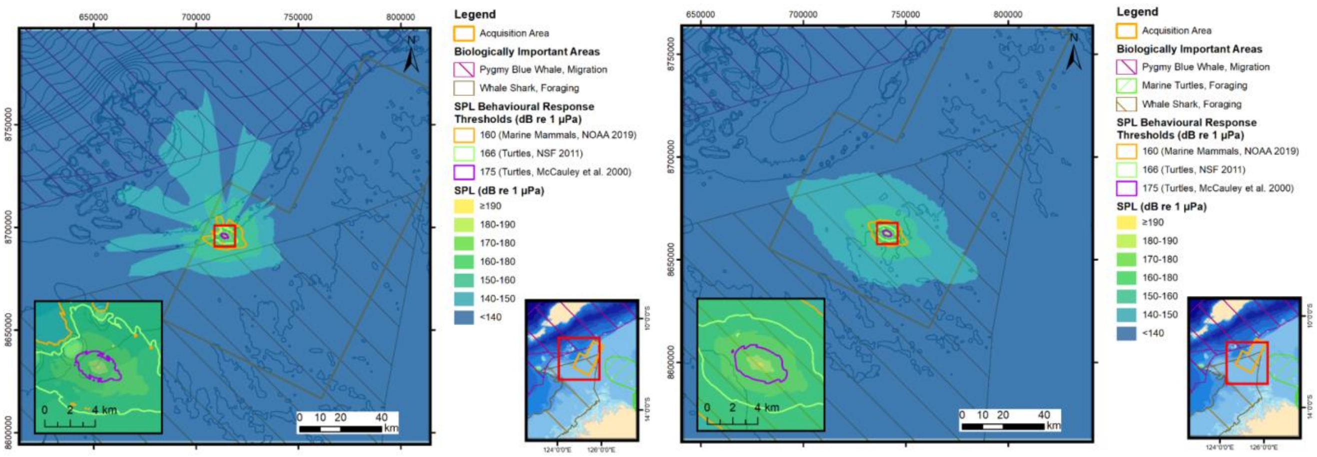


Figure 40 Example Sound Level Contour Maps of Unweighted Maximum-over-depth Water Column SPL Sound Field (Left: Site 8; Right: Site 6)

Specific modelling was undertaken to assess sound levels at the seafloor, with two receptor locations assessed (5 cm and 50 cm above the seafloor interface). Table 18 in the report contained in **Appendix A** presents the results for receptors located 50 cm above the seafloor (relevant to sponges, corals, and fish) and Table 19 of the same report presents the result for receptors located 5 cm above the seafloor (relevant to benthic invertebrates).

In addition, JASCO modelled particle acceleration for a receiver 5 cm above the seafloor at three water depths (75, 100, and 150 m). These were modelled to a maximum distance of 1,000 m from the centre of the seismic source in the endfire and broadside directions. The results show that the effects are greater for the broadside directions than the endfire directions (as shown in **Figure 41**). The maximum horizontal seafloor distance from the sound source to the particle acceleration threshold of 37.57 ms^{-2} (this threshold being derived from work on the impacts of seismic surveys on scallops presented in Day *et al*. (2016)) was 10.5 m for the shallowest water scenario (75 m depth). This threshold was not exceeded for the two deeper depths assessed (i.e. 100 and 150 m).

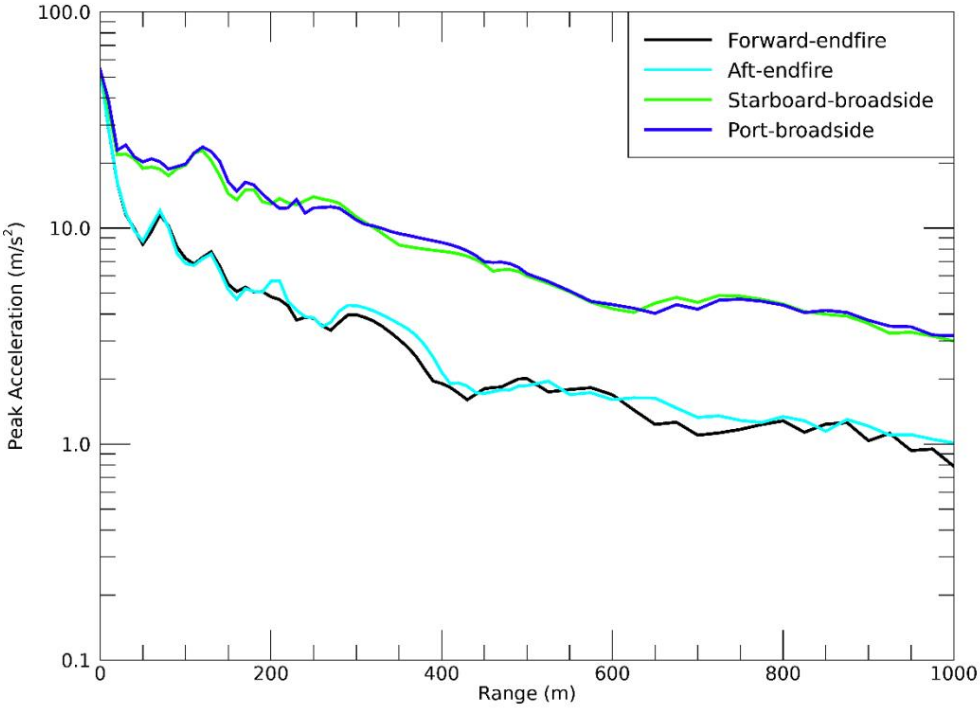


Figure 41 Peak Particle Acceleration at the Seafloor as a Function of Horizontal Range from the Centre of the Seismic Source along four directions at 75 m Water Depth

7.2.1.2.5 Multiple Source Sound Fields

Sound fields in terms of SEL accumulated over 24 hours of survey within the water column and at the seafloor were determined for the modelled scenarios. Frequency-weighted SEL_{24h} sound fields were used to estimate the maximum horizontal distances (R_{max}) to marine mammal and sea turtle PTS and TTS thresholds, and to estimate maximum distance and the area for mortality, injury, and TTS guidelines for fish.

The SEL_{24h} sound fields for water column and seafloor are presented as contour maps in Figures 43 to 50 of the report contained in **Appendix A** and an example of each is presented in **Figure 42**.

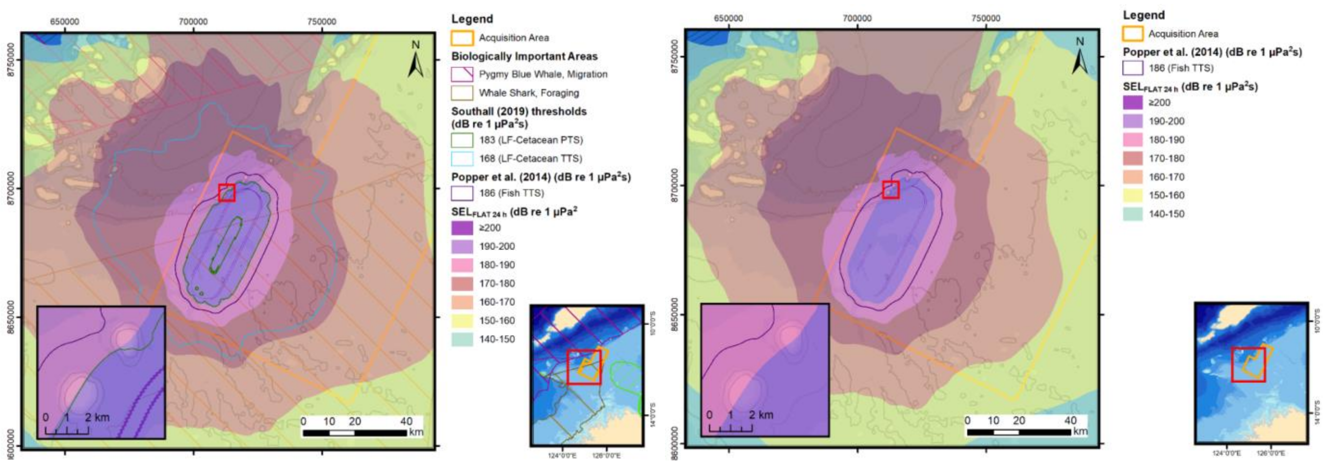


Figure 42 Example Sound Level Contour Map of Unweighted Maximum-over-depth Water Column SEL_{24h} Results (left) and Unweighted Seafloor SEL_{24h} (Both for Scenario 2)

7.2.1.2.6 Animal Movement and Exposure Modelling (Animat Modelling)

JASCO's Animal Simulation Model Including Noise Exposure (**JASMINE**) was used to predict the exposure of animats to sound arising from the seismic activity. JASMINE integrates the predicted sound field with biologically meaningful movement rules for each marine mammal species (pygmy blue whales in this case) that results in an exposure history for each animat in the model.

Animats are programmed to behave like the marine animals that may be present in an area. The parameters used for forecasting realistic behaviours (e.g., diving and foraging depth, swim speed, surface times) are determined and interpreted from marine mammal studies (e.g., tagging studies) where available, or reasonably extrapolated from related or comparable species – a depiction of animats movements in a moving sound field is shown in **Figure 43**, with the example animate (red) shown moving with each time step.

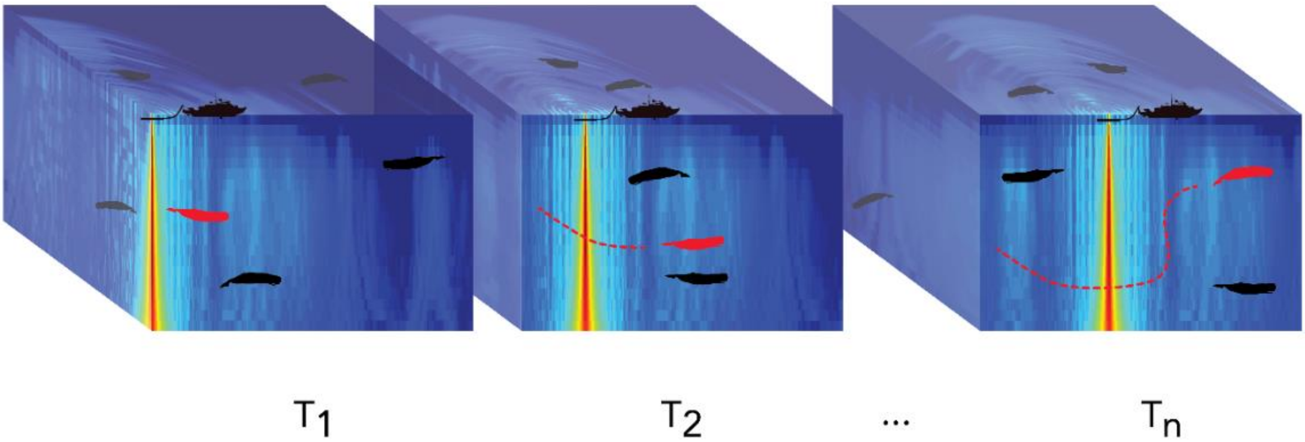


Figure 43 Depiction of Animats in a moving Sound Field

For cumulative metrics, an individual animats sound exposure levels are summed over a 24 h duration to determine its total received energy, and then compared to the relevant threshold criteria. For single-exposure metrics, the maximum exposure is evaluated against threshold criteria for each 24 h period.

The sound received by an animat at any given time depends on its location relative to the source. Because the true locations of the animats within the sound fields are unknown, realistic animal movements are simulated using repeated random sampling of various behavioural parameters. In this case the animat modelling involved simulations to predict the distance at which migrating pygmy blue whales (*Balaenoptera musculus brevicauda*) are expected to be exposed above threshold criteria for PTS, TTS, and behavioural response. Sound exposure distribution estimates were determined by moving large numbers of animats[13] 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 SPL and SEL_{24h} for comparison against the relevant thresholds.

A total of four acquisition scenarios were considered using both acoustic and animat modelling. A fifth scenario was included for animat modelling only, in this scenario the considered survey lines were further from the BIA, and it was considered with the aim of determining potential buffer zones around the BIA through the use of unrestricted animat seeding. All animat simulations were run in two configurations: one with animats restricted to the BIA, and another with unrestricted animat seeding.

[13] To generate statistically reliable probability density functions, model simulations were run with animat sampling densities of 4 animats/km^2.

7.2.2 Known and Potential Impacts to Environmental Receptors and Exposure Criteria

Noise exposure thresholds are indicative noise levels at which there is potential for certain effects (e.g. mortality, temporary hearing impairment, injury, behavioural changes) to occur to marine receptors. When noise exposure thresholds are published, the response of that particular receptor being exposed to that level of noise is generally defined for a single noise exposure or for cumulative exposure to successive events. For the purpose of this assessment, threshold criteria for different fauna have been selected to assist in determining and assessing potential physical, physiological, behavioural and, ultimately, ecological impacts. The threshold criteria are based on current relevant scientific literature, accepted industry and international standards and are considered to be appropriate for this assessment process.

Generally speaking, a high intensity external stimulus such as an acoustic disturbance will elicit a behavioural response in animals; typically, avoidance or a change in behaviour. The duration and intensity of an animal's observed response is impacted by the nature (continuous or pulsed), source (visual, chemical or auditory) and the intensity of the stimulus, as well as the individual's species, gender, reproductive status, health and age.

Behavioural responses are instinctive survival mechanisms that serve to protect animals from injury. Consequently, animals may suffer temporary or permanent physiological effects in cases when the acoustic disturbance is too high, or the animal is unable to elicit a sufficient behavioural response (e.g. swim away fast enough).

Depending on the exposure level and sensitivity threshold of each species, the effects of acoustic disturbance can include:

- Physiological effects – changes in hearing thresholds – TTS or PTS damage to sensory organs or traumatic injury; (**Section 7.2.2.1**);
- Behavioural effects (and related impacts) – displacement/avoidance, disruption of feeding, breeding or nursery activities etc. (**Section 7.2.2.2**);
- Perceptual effects (auditory masking) – interference with communication (**Section 7.2.2.3**) and detection of predators/prey; and
- Indirect effects – behavioural changes in prey species that affects other species higher up in the food chain and could lead to ecosystem level effects (discussed throughout **Section 7.2.2** as relevant, in particular see **Section 7.2.2.2.1**, **7.2.2.2.2, 7.2.2.2.5** and **7.2.2.2.7**).

The following subsections go through each of the different marine receptors that are likely to be present in the OA and a risk assessment is undertaken for those species expected to be exposed to the acoustic disturbance arising from the Seismic Survey. Threshold criteria for behavioural disturbance, TTS, PTS and other injuries are discussed in the following subsections and then summarised in **Table 54**, alongside the maximum distance from the acoustic source at which these thresholds were reported to occur.

7.2.2.1 Potential Physiological Impacts

Underwater noise, such as that produced during an MSS, has the ability to cause lethal and non-lethal physiological trauma or injury in marine organisms (Gordon *et al*., 2003).

Of particular concern with regard MSSs and marine organisms is the potential for auditory damage from the acoustic release. Tissue damage to sensory organs from MSS acoustic releases have been experimentally studied in captive/captured fish, cephalopods and invertebrates, while shifts in hearing thresholds have been experimentally observed in some small pinnipeds and small cetaceans and hypothesised based on observed effects in terrestrial animals. To date there is no direct evidence of damage to the ears of marine mammals from MSS acoustic releases (Gordon *et al*., 2003).

The following provides a discussion on the potential physiological effects of MSSs on marine organisms.

7.2.2.1.1 Plankton

The term 'plankton' describes the drifting organisms that inhabit aquatic environments and includes phytoplankton (plants) and zooplankton (animals), as well as fish and invertebrate eggs and larvae, called ichthyoplankton. There is currently no published information regarding the potential for noise-induced effects on phytoplankton and no functional cause-effect relationship has been established; therefore, impacts from acoustic disturbance on phytoplankton is not considered further.

In comparison to fish and mammals, less research has been conducted on the effects of seismic outputs on zooplankton. This is because zooplankton do not have hearing structures although they can detect changes in pressure (Richardson *et al.,* 2017). Zooplankton are generally the same density as the surrounding water column and as such, it is assumed that pressure changes associated with seismic activity will not cause physical damage (Parry & Gason, 2006).

Most studies have shown that exposure to emitted sound levels from a seismic survey has no significant adverse effects on the abundance or mortality of zooplankton; such as:

- CarbonNet (2018) assessed zooplankton communities in Australia's Gippsland Basin before and after a seismic survey. Ten sites were sampled during the pre-survey period, consisting of six sites occurring within the survey area and four reference sites. During the post-survey period, three sites were sampled near the survey line, as well as three reference sites. Post-survey sampling occurred within three days of acquiring the last survey line. Copepods, cladocerans and salps dominated the pre-survey samples, whereas the dinoflagellate *Noctiluca scintillans* dominated the post-survey samples. There was a high level of variance among samples and no lobster or scallop larvae occurred in any of the samples. Mortality rates were high in both pre- and post-survey samples and the high proportion of dead cladocerans was contributed to their delicate structure being destroyed by the sampling process rather than attributable to any MSS impacts; and
- Sætre & Ona (1996) examined the mortality rates for fish larvae and fry (taken from Booman *et al*., 1996) for five fish species (cod, saithe, herring, turbot and plaice) to investigate the consequences that seismic-induced mortality may have at the population level. Under a 'worst-case' scenario, the number of larvae killed during a typical seismic survey (>10 days) was 0.45% of the total larvae population. However, when compared with the high natural mortality rates for each species (e.g. cod and herring eggs/larvae have a natural daily mortality of 5 to 15%) the impacts of seismic surveys on these zooplankton at a population level were considered to be negligible.

In studies where seismic impacts have been observed, they are generally limited and localised to within a range of approximately 10 m from an operating seismic array (Richardson *et al*., 2017), with lost individuals quickly being replaced due to rapid generational turnover rates. For example, Kostyuchenko (1973), Booman *et al*., (1996), and Payne *et al.,* (2009) have reported physiological/pathological effects occurring in zooplankton exposed to an acoustic source up to 5 m away, and mortality occurring when exposed to an acoustic source up to 3 m away. Using a 10 m impact range, McCauley (1994) calculated that plankton mortality would be <1% of plankton in the surveyed area assuming total plankton mortality within this range.

In a recent study, Day *et al.* (2021) examined the potential impacts of seismic surveys on the larval stages of southern rock lobster to determine whether early development and recruitment of this species might be affected. This study assessed three aspects, the mortality rates following exposure, impairment of the righting reflex, and the development of exposed lobsters through assessment of progression through the moult cycle. The key results from this study on these three aspects are as follows:

- Exposure did not result in any elevated mortality for puerulus or juveniles;
- Righting was significantly impaired for all exposure treatments immediately after exposure compared to their respective controls which indicated that the impact range extended to at least 500 m from the source, which was the maximum range tested in the study; and
- The results provided evidence of a range threshold for recovery, where juvenile lobsters at a nominal distance of 500 m from the source recovered from impairment after the first moult. Increased intermoult duration suggested impacted development and potentially slowed growth, through the proximate cause was not identified.

In contrast to the studies outlined above, McCauley *et al*. (2017) found that after exposure to a single 150 in^3 acoustic source there was a statistically significant lower abundance of zooplankton, with a median 64% decrease one hour after exposure. McCauley *et al*. (2017) observed impacts out to the maximum 1.2 km range sampled, which was more than two orders of magnitude greater than the previously assumed impact range of 10 m. However, this study was compromised by methodological design (small samples sizes, large daily variability in the baseline and experimental data) and the statistical robustness of the data and conclusions (large number of speculative conclusions that appear inconsistent with the data collected over a two-day period).

Richardson *et al*. (2017), through the Commonwealth Scientific and Industrial Research Organisation (**CSIRO**) simulated the large-scale impact of a seismic survey on zooplankton in the Northwest Shelf region of WA, based on the mortality rate associated with seismic noise exposure reported by McCauley *et al.* (2017). The mortality rate associated with seismic exposure reported by McCauley *et al*. (2017) was applied alongside other natural/typical variable values. The survey area was 80 km by 36 km in water 300 – 800 m deep and the survey was conducted over 35 days. Overall, the results showed that zooplankton populations were substantially impacted within the seismic survey area out to a distance of 15 km. Impacts were barely discernible within 150 km of the survey area and there was no apparent effect at a regional scale. The simulation showed that, following exposure, there was a rapid recovery of zooplankton populations due to their fast growth rates and the dispersal and mixing of individuals from inside and outside of the impacted region (Richardson *et al*., 2017). The assessment of these results by the IAGC (2017) review was that even if the full effect claimed by McCauley *et al*. (2017) did in fact exist, zooplankton abundance would not be adversely affected due to the extensive movements of water masses carrying zooplankton through survey areas and the rapid reproductive cycle and high reproductive potential characteristics of planktonic organisms. The IAGC (2017) review concluded that the purported findings of McCauley *et al*. (2017) were of no ecological consequence, given the life history parameters of zooplankton.

In addition to Richardson *et al*. (2017), Fields *et al.* (2019) exposed captive zooplankton (copepods) at a variety of distances from a seismic sound source in order to determine the effect of seismic blasts on *Calanus spp.*, which is a key food source for commercially important fish. The results of this study found that immediate mortality of copepods was significantly different from controls at distances of 5 m of less from the airguns, and mortality one week after the airgun blast was significantly higher (9% relative to controls) in the copepods placed 10 m from the airgun blast, but not significant different for those 20 m from the airgun blast. The increase in mortality (relative to controls) did not exceed 30% at any distance. Fields *et al.* (2019) concluded that these results suggest that seismic blasts have limited effects on the mortality of escape response of *Calanus sp*. within 10 m of the blast and no measurable impact at greater distances. Fields *et al.* (2019) also commented on the results of McCauley *et al*. (2017), stating that it is difficult to reconcile the high mortality reported by McCauley *et al*. (2017) with the low mortalities reported in the body of earlier research and the results in the experiment that Fields *et al.* (2019) undertook.

7.2.2.1.1.1 Plankton UAM

As outlined in **Section 7.2.2.1.1**, there are only a few studies in which threshold criteria for plankton can be based on. Popper *et al.* (2014) cites many of the references and studies on potential impacts of noise emissions on fish eggs and larvae prior to 2014, and results in Day *et al.* (2016) for embryonic lobsters and Fields *et al*. (2019) for copepods align with those presented in Popper *et al.* (2014). These studies conclude that mortality and sub-lethal injury are limited to within tens of metres of seismic sources. It is also worth noting that the criteria defined by Popper *et al.* (2014) have been extrapolated from simulated pile driving signals which have a more rapid rise time, and greater potential for trauma than pulses from a seismic source. The results of McCauley *et al*. (2017) indicate the potential for effects at a longer range, and at levels of 178 dB PK-PK; however, as outlined above, Fields *et al.* (2019) noted that it was difficult to reconcile the high mortality reported by McCauley *et al*. (2017) with the low mortalities reported in the greater previous body of earlier research and their own experiment.

Based on the above, the threshold values from Popper *et al.* (2014) have been utilised as part of the UAM report (**Appendix A**), with the results contained within **Table 42**.

Table 42 Noise Exposure Criteria and Zones of Impact for Mortality and Potential Injury for Zooplankton, Fish Eggs and Larvae

Zooplankton, Fish Eggs & Larvae	Mortality and potential injury threshold levels	Maximum threshold distance (m)
Based on Popper *et al.*, (2014) for fish eggs and larvae	PK: >207 dB re 1 µPa	200
	SEL_{24hr}: >210 dB re 1 µPa^2.s	80

7.2.2.1.1.2 Duration and Extent of Zooplankton Exposure

Natural mortality estimates for zooplankton are generally high and variable. Tang *et al*. (2014) reviewed available research and reported zooplankton daily mortality rates of 11.6% (average minimum) to 59.8% (average maximum) but in some instances these authors found that 100% of samples died within a day. Predation accounted for some of this mortality; however, non-predatory factors (e.g. inadequate food resources, physical exposure or poor water quality and diseases/parasites) have been estimated to account for approximately 25% - 33% of the total mortality among marine copepods (Fuiman and Werner, 2002; Tang *et al*., 2014; Dubovskaya *et al*., 2015). In other studies, Houde and Zastrow (1993) estimated the mean mortality rate for fish larvae to be 21.3% per day, and Saetre and Ona (1996) estimated zooplankton mortality to be 5-15% per day.

Compared to the high (5-59.8%) natural mortality rates reported by the above studies, seismic-related reductions in zooplankton abundance associated with the Seismic Survey are likely to be very low and cumulative effects of natural mortality and seismic-related mortality are likely to be within the range of natural mortality rates observed in other studies. This assessment is consistent with Richardson *et al*. (2017) who reported seismic impacts on zooplankton will only be discernible locally and are expected to be insignificant at a regional scale relative to the natural spatial and temporal variability in plankton abundance, and the very high rates of natural mortality.

In addition to the inconsequential seismic mortality rates in comparison to natural mortality rates, it is also important to consider the following points when assessing the predicted impact of the Seismic Survey on zooplankton:

- The simulation by Richardson *et al*. (2017) showed that, following exposure, there was a rapid recovery (on the scale of days) of zooplankton populations due to their fast growth rates and the dispersal and mixing of individuals from inside and outside of the impacted region. The high energy nature of the offshore marine environment in the OA will help promote rapid recovery of zooplankton populations on account of dispersal, mixing and replenishment by currents from non-impacted areas. Due to the short time required for zooplankton populations to replenish following any reductions in biomass that may occur due to the Seismic Survey, any effects will be temporary and short-lived and are not expected to have any ecological consequences on zooplankton populations;
- Due to the magnitude of such localised impacts is negligible (based on **Table 42**), it is not expected that these impacts will be discernible at a regional scale, especially when considering the variability and scale of plankton and spawning biomass in the wider region; and
- Zooplankton occurring within the OA will not be evenly distributed. They will move in accordance with the currents and are likely to exhibit considerable spatial patchiness zooplankton less likely to be impacted multiple times by a seismic gun.

Overall, there is the potential for localised temporary impacts to zooplankton as a result of the Seismic Survey; however, population recovery is expected within days after the Seismic Survey has ceased and no lasting ecosystem population impacts are expected based on the findings detailed above. As such, based on the scientific literature provided above, the Seismic Survey will not have any temporal or spatial impacts that are serious or irreversible on any areas that are known to have high productivity within the OA at certain times of the year and any impacts to local zooplankton populations as a result of the emitted sound levels from the Seismic Survey will be localised, temporary and recoverable in the short-term.

7.2.2.1.1.3 Ecological Impacts of Plankton Exposure

Zooplankton are an important food source to many fish species and cetaceans in the ocean, and any significant reductions in zooplankton biomass has the potential to affect the wider food chain due to cascading effects. This is particularly important to consider in sensitive areas like those associated with the carbonate bank and terrace system of the Sahul Shelf KEF and BIAs, which partially overlap with the OA (**Section 4.4.3**).

Ecological effects of reduced zooplankton biomass may include changes in the distribution of species which rely on zooplankton as a food source, such as pelagic fish, seabirds and some marine mammals, where they temporarily have to relocate to another foraging ground to find the food they require for survival.

For example, distributional changes in zooplankton (particularly krill) flow could have effects to whale sharks which are known to forage within the OA and for which there is a corresponding BIA. Catch rates of commercially fished species could also conceivably change in response to flow-on effects associated with changes in the abundance or distribution of zooplankton prey.

Based on the extensive literature reviews, the weight of the scientific literature supports that any potential flow-on effects to marine food webs through impacts on zooplankton are expected to be spatially restricted. For the Seismic Survey, the UAM (**Table 42**; **Appendix A**) predicts the zone of impact for zooplankton to be 200 m for fish eggs and larvae (based on Popper *et al*., (2014)). Baseline conditions are expected to resume relatively quickly after survey completion (see Richardson *et al*., 2017) due to replenishment of zooplankton back into the area.

There are unlikely to have any wider ecosystem-related impacts as a result of cumulative natural and seismic-related mortality effects. Even after they die, zooplankton remain available as a food source for higher organisms as their carcasses remain in the water column for several days. If they are not consumed, they then fall to the seafloor and where they are available as a food source for benthic organisms (Kirillin *et al*. 2012; Tang *et al*. 2014).

Overall, the residual risk to zooplankton physiology on a population level arising from acoustic disturbance during the Seismic Survey has been assessed as **Negligible** (*Negligible* x *Likely*).

7.2.2.1.2 Benthic Invertebrates

Marine invertebrates are most sensitive to the vibrational component of sound, owing to a lack of anatomical structures involved in detecting the pressure component of sound. Like elasmobranchs, marine invertebrates lack a gas-filled bladder and are thus unable to detect the pressure changes associated with sound waves. However, marine invertebrates such as crustaceans, bivalves and echinoderms have a sac-like structure called a statocyst (Carroll *et al*., 2017). The statocyst includes a mineralised mass (statolith) and associated sensory setae which help them to detect particle motion in their immediate vicinity. For example, in crustaceans, the main vibration receptors are in the statocysts and the walking legs (Aicher *et al*., 1983). McCauley (1994) reported that for many benthic species, these receptors will perceive seismic acoustic outputs, but this will only occur within a few metres from the sound source.

There have been several recent reviews regarding the potential impacts of low frequency sound on the physiological responses of marine invertebrates, though there is an overall paucity of studies which reflect commercially relevant acoustic signatures and exposure scenarios. Whilst research into the relationship between sound and it's effects on marine invertebrates is, therefore, ongoing, thresholds have been identified and adopted for three main groups including crustaceans, bivalves and sponges and corals.

Of particular relevance to the Seismic Survey are impacts to decapods (crabs and shrimp), octocorals and sponges which inhabit the soft sediment and hard substrate, respectively, that comprise the OA (see **Section 4.5.2**. Whilst polychaete worms were identified as the most predominant invertebrate taxa within soft sediment habitats during macrofauna sampling undertaken within license area AC/RL7 (ERM, 2012; O2 Marine, 2018), located in the western portion of the OA, the effects of seismic exposures on these organisms have not been studied.

For completeness, the potential impacts to bivalves are also considered herein.

Crustaceans

Crustaceans are the most studied marine invertebrate group with respect to impacts associated with low-frequency acoustic disturbance, such as that generated by seismic airguns (Carroll *et al.,* 2017). Owing in-part to their commercial value, studies are largely constrained to decapod crustaceans (lobsters, prawns, crabs), investigating a broad range of metrics, including catch rates, physical, behavioural and physiological effects (Edmonds *et al*., 2016). The reported impacts of seismic exposure are highly variable in nature and scale, though none have found any evidence of increased mortality.

Payne *et al*. (2008) conducted a pilot study on the effects of seismic sound exposure on various health indicators on American lobster. Adult lobsters were exposed to a seismic source for 20 or 200 pulses at an average pressure of 202 dB re 1 µPa PK-PK or 50 pulses to 227 dB re 1 µPa PK-PK. Studies subjects were located 2 m from the acoustic source. The study investigated potential changes to survival, food consumption, turnover rate and serum biochemistry. No immediate or delayed mortality was observed, nor damage to mechano-sensory systems and the ability of lobsters to right themselves when turned over. However, there was evidence of a decrease in serum enzymes and increases in food consumption in the weeks to months post exposure, interpreted to indicate potential stress effects or osmo-regulatory disturbance. Whilst no impacts to long-term survival and population ecology were observed, the results indicate the potential for sub-lethal effects.

Day *et al*. (2019) examined the impacts of seismic surveys on the physiology of southeast Australian rock lobster species. Exposure experiments were carried out at the seabed, in a field setting selected to emulate the natural habitat of the study species. The study found that adult rock lobsters (*Jasus Edwardsii*) which were exposed to seismic sound levels up to a maximum of 209 -212 dB re 1 µPa PK-PK did not show an increase in mortality, even at close proximities to the sound source. However, there was evidence of sub-lethal effects occurring following seismic sound exposure; specifically, impairment of reflexes involved with tail control and righting, damage to the sensory hairs of the statocysts (balance organ), and a reduction in numbers of haemocytes (indicative of reduced immune response function). Reflex impairment and statocyst damage persisted up to 365 days post-exposure and did not improve following moulting. Ecological impacts were not evaluated as part of the study; however, it stands to reason that the reported physical and physiological impacts to individuals could translate to changes in foraging ecology, predation and mortality. Therefore, the potential for ecological impacts should not be dismissed.

In another study focusing on rock lobster, Fitzgibbon *et al*. (2017) examined the impact of seismic acoustic exposure on the haemolymph physiology and nutritional condition of this species and found no effect of seismic exposure on 24 haemolymph biochemical parameters, hepatopancreas index or survival. However, this study did report evidence of:

- A chronic negative impact on immune competency for up to 120 days post-exposure;
- A potential immune response to infection after 365 days post-exposure; and
- Chronic impairment of nutritional condition 120 days post-exposure.

These authors concluded that the biochemical hematological homeostasis of rock lobster is reasonably resilient to seismic acoustic signals; however, exposure may negatively influence the rock lobster's nutritional condition and immunological capacity. The impact of these results at an ecological level is not known.

Though marine invertebrates are most sensitive to the vibrational component of sound, rather than sound pressure, it is not clear what level of particle motion relates to an effect. Therefore, where available, sound level thresholds have been used to inform acoustic modelling (Connell *et al*., 2022). Whilst no published threshold criteria currently exist to enable an evaluation of potential mortality or lethal injury effects on crustaceans, a PK-PK sound level of 202 dB re 1 µPa (per pulse) (Payne *et al*., 2008) is considered to be associated with no effect and therefore adopted for the purpose of the assessment (Connell *et al*., 2022). For context related to different levels of potential impairment, results were also compared against the PK-PK sound levels determined for crustaceans in Day *et al*. (2019) and Day *et al*. (2016) (ranging from 209 -213 dB re 1 µPa PK-PK cross both studies) (see **Appendix A**).

Bivalves

As is the case for crustaceans, studies undertaken on bivalves are largely constrained to commercially important taxa such as scallops and oysters. Recent Australian studies have focussed on Southern Scallops, *Pecten fumatus*, and found no evidence of immediate mortality or change in condition following exposure to seismic disturbance. However, sub-lethal effects to scallops were observed, including a compromised capacity for homeostasis and potential immunodeficiency over acute (hours to days) and chronic (months) timescales following exposure (Day *et al*., 2016; 2017).

Day *et al*. (2016; 2017) concluded that repeated exposure to seismic disturbance resulted in physiological damage, changes in behaviour and reflexes and increased risk of mortality, though not beyond naturally occurring rates of mortality. Injured scallops did not recover over the four-month period of the experiment. The authors reported that, compared with unexposed scallops, the daily mortality odds were found to be 0.1%, 1.2%, and 1.3% higher in scallops exposed to 1, 2 and 4 acoustic passes, respectively. Though the size of the air gun appeared to have no effect (Day *et al*., 2017). Uniquely, Day *et al*. (2017) measured the response of *Pecten fumatus* to ground roll acceleration associated with different experimental regimes as a proxy for particle acceleration. As particle motion is the more relevant metric to invertebrate sensory systems, the study provides novel insight into bivalve response to seismic disturbance.

In contrast, a study conducted by Przeslawski *et al*. (2018) found no evidence of increased scallop mortality, or effects on scallop shell size, adductor muscle diameter, gonad size, or gonad stage attributable to exposure to seismic disturbance. However, this study did not examine any long-term sub-lethal effects.

No published threshold criteria currently exist to enable an evaluation of potential mortality or lethal injury effects on bivalves. Likewise, the literature does not present a sound level associated with no impact. Consequently, the maximum measured particle acceleration reported within Day *et al*. (2017) of 37.57 ms^{-2} has been adopted to represent the level of acoustic disturbance known to elicit reduction in physiological condition for the purpose of this assessment.

Sponges and Corals

There is limited published literature on the potential impacts of seismic noise on hard and soft corals and sponges. Unlike other faunal groups, currently there is no peer-reviewed criteria against which potential noise impacts to corals and sponges can be assessed.

Heyward *et al*. (2018) monitored the condition of Scleractinia corals at South Scott Reef, within the NWMR, before and after a 3D seismic survey. There were no observable impacts to coral mortality, skeletal damage or visible signs of stress immediately after and up to four months following the acoustic disturbance event. Similarly, there was no evidence of a behavioural response, such as polyp withdraw or flaccidity in the soft corals assessed. The survey involved a maximum peak sound level of 226 dB (i.e., 226 dB re 1 µPa PK) at the coral monitoring sites.

In lieu of published threshold criteria, a PK sound level of 226 dB re 1 µPa (per pulse) is adopted for the purpose of the assessment (Connell *et al*., 2022). Importantly, this 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.

7.2.2.1.2.1 Benthic Invertebrate UAM

As outlined in **Section 7.2.2.1.2**, there are few studies upon which threshold criteria for benthic invertebrates can be suitably developed. Based on the above, the threshold values used to inform the UAM report (**Appendix A**) and corresponding threshold distances are described in **Table 43**.

Table 43 Noise Exposure Criteria and Zones of Impact for Mortality and Potential Injury for Crustaceans, Bivalves and No Effect Threshold for Corals/Sponges

Benthic Invertebrates	Mortality and potential injury threshold levels	Maximum threshold distance (m)
Based on Payne *et al*. (2008) for crustaceans	PK-PK: >202 dB re 1 µPa	426
Based on Day *et al.* (2017) or bivalves	35.75 ms^{-2}	10.5
	No effect threshold level	Maximum threshold distance (m)
Based on Heyward *et al.* (2018) for corals and sponges	PK: >226 dB re 1 µPa	-

The results of the UAM indicate that:

- The adopted criteria of 202 dB re 1 µPa PK-PK for crustaceans, which is representative of no effects, was reached at ranges between 307 and 426 m for the 3,000 in^3 source;
- The adopted criteria of 37.57 ms^{-2} was reached at horizontal distance of 10.5 m for modelled scenarios comprising a seafloor depth of 75 m. It was not reached at any modelled depths (i.e., 100, 125, 150, 200 m); and
- The adopted criteria of 226 dB re 1 µPa PK for sponges and coral was not reached, including at the seafloor directly underneath the seismic source.

7.2.2.1.2.2 Impacts of Benthic Invertebrate Exposure

Based on the research summarised in **Section 7.2.2.1.2** and in **Appendix A**, limited impacts to benthic invertebrates are expected. Of particular relevance to the decapod crustaceans (crabs and shrimp) comprising the OA, the UAM predicts sub-lethal effects could occur out to 427 m from the active source. Effects to molluscs are predicted to be highly localised and constrained to within 10.5 m of the active source (see **Section 7.2.2.1.2**). Given the response of organisms such as polychaete worms to seismic exposure have not been studied, and therefore the precautionary principle applies, it's considered they could also experience a range of sub-lethal effects.

The reported zones of impact for benthic invertebrates within the UAM represent a considerably small portion of the available benthic habitat, comprising both soft sediment and hard substrate, within the broader NWMR. Based on available macrofauna survey data obtained through extensive literature reviews, benthic faunal assemblages with the OA and surrounds are consistent with the broader NWMR and do not include any species endemic to the local or regional environment (Kirkendale *et al*., 2019; ERM, 2012).

In the event that repeat passes of a given acquisition line occurs, due to infill or in response to shutdown management measures, it's likely that mobile and sessile invertebrates will experience repeat exposure to the seismic source. Based on the findings of Day *et al*. (2016; 2017), it is possible that repeat exposure could result in an increased incidence of sub-lethal effects and elevated mortality rates up to 1.3% higher than those of unexposed individuals (reported to range between 11 – 51%, Day *et al*., 2017). Though, these areas over which repeat pass may occur will likely constitute a small portion of the OA.

The investigations through which the adopted threshold criteria have been developed both concluded that mortality rates observed during exposure to treatment (i.e., seismic sound) were within the natural range of variation which may be expected to occur due to changes in environmental conditions and anthropogenic stressors. Where sub-lethal and lethal effects do occur, the natural cycle of death, recovery and recruitment of invertebrates from adjacent benthic habitats will occur in parallel over the same timescales and therefore, no net impacts to relative abundance, benthic community composition and structure are anticipated.

This information, in conjunction with the assessment of potential impacts to benthic invertebrate larvae completed in **Section 7.2.2.1.1** suggests there are unlikely to be any wider ecosystem-related impacts as a result of cumulative natural and seismic-related effects.

No significant impacts to sponges and corals which occur in association with hard substrate, such as the banks, shoals and pinnacles within the OA, are expected. The threshold value of 226 dB re 1 µPa PK was not reached at any of the modelling sites (**Appendix A**). Overall, the residual risk to benthic invertebrates arising from acoustic disturbance during the Seismic Survey has been assessed as **Low** (*Minor x Likely).*

7.2.2.1.3 Fish

Indications of a stress response to vessel noise include increased production of stress hormones and alterations to regular heart rate. An increase in the secretion of the stress hormone cortisol has been demonstrated in captive fish subjected to exposure to simulated boat noise (Wysocki *et al*., 2007). Increased cardiac output (associated with an increase in heart rate and decrease in stroke volume) was measured in response to exposure to vessel noise, with effects increasing with increasing vessel noise (Graham and Cooke, 2008). Elevated motility of several blood parameters has also been observed in response to vessel noise, indicating increased muscle activity caused by stress (Buscaino *et al*., 2010). A TTS may also occur in response to noise generated by vessels, as was demonstrated in fathead minnows by Scholik and Yan (2002) following two hours of exposure to playback of vessel noise at 142 dB re 1 µPa @ 1 m.

Although effects of noise on fish have been demonstrated in the above studies, it is important to note that the studied fish were captive animals and therefore unable to avoid the noise emission as would be possible in the wild. Furthermore, the OA is already utilised by a number of marine users (e.g. shipping, fishing vessels and oil and gas exploration activities) and subject to vessel noise emissions.

In terms of the noise generated from the Seismic Survey itself, and as discussed in **Section 7.2.2.2.2**, fish will typically move away from a loud acoustic source if they are uncomfortable with the noise, thereby minimising their exposure and the potential for any physiological effects (Vabø *et al*., 2002; Pearson *et al*., 1992; Wardle *et al*., 2001; Hassel *et al*., 2004; Boeger *et al*., 2006). The studies and information discussed in this section can therefore be interpreted as a 'worst-case scenario' for fish that remain in close proximity to the seismic source and undertake no avoidance behaviours. Demersal fish may exhibit higher fidelity to specific sites (e.g. rocky reefs); these 'site attached' species may be more prone to disturbance than pelagic species (Wardle *et al*., 2001). However, a recent large-scale experiment that quantified the impacts of a commercial seismic source on assemblages of tropical demersal fish on the North West Shelf of Australia found there were no short-term (days) or long-term (months) effects of exposure on the composition, abundance, size structure or behaviour of these fish (Meekan *et al*., 2021).

Sound can affect fish physiology in a number of ways including increased stress levels (Santulli *et al.*, 1999; Smith, 2004; Buscaino *et al*., 2010), temporary or permanent threshold shifts (Smith, 2004; Popper *et al*., 2005), and/or damage to sensory organs (McCauley *et al.*, 2003a). Not all species will be affected equally when exposed to the same acoustic source under the same conditions. For example, Popper *et al*. (2005) exposed three different fish species to a series of acoustic seismic releases and found that two of the species experienced TTS while the third showed no evidence of an impact.

It is difficult to measure the physiological effects of seismic exposure on fish *in situ* and consequently, many studies are conducted under laboratory conditions or by deploying caged individuals in the field (Carroll *et al*., 2017) and applying experimental underwater seismic acoustic outputs. There are limitations associated with these approaches which are discussed in **Section 7.2.2.2.2**. Due to these limitations, caution must be taken when relating the relevance of the findings of laboratory and caged field experiments to actual seismic exposure in open-water conditions.

Woodside (2007) conducted a comprehensive investigation to assess the effects of an MSS on reef fish in WA. Water depths during this study ranged from 20 – 1,100 m and the study used a seismic source with a source volume of 2,005 in³. This study assessed fish diversity and abundance, coral health, and pathology changes in sensitive auditory tissues. Sound loggers and remote underwater video were deployed, and fish exposure cages were utilised to contain captive reef fish. The study report indicated that no temporary or permanent threshold shifts were detected in any species and identified no long-term impacts on fish populations.

McCauley *et al*. (2003a) examined the effects of seismic source exposure on snapper (*Pargrus auratus*); a species whose distribution includes the OA. This controlled exposure experiment simulated a seismic vessel approaching then moving away, during which caged fish were exposed to seismic outputs that exceeded 180 dB re 1 µPa^2-s. Fish were sacrificed after the experiment so that their ear structures could be examined for any damage. This study found that a small number (2.7%) of the total number of sensory hair cells sustained severe damage in several of the exposed fish even two months after exposure. While this result could represent permanent auditory damage, the authors note that the caged fish had no ability to escape the sound field; hence, could have been exposed to seismic outputs much greater than those of wild fish in the vicinity of a seismic vessel.

Hastings *et al*. (2008) exposed four tropical fish species (a hearing specialist and three species of hearing generalists) to a cumulative seismic exposure of 190 dB re 1µPa^2-s using a 2,055 in^3 acoustic array. These authors found no evidence of physiological injury, even in the hearing specialist species, which was sensitive to a broader range of frequencies of sound than the other three species.

Santulli *et al*. (1999) exposed sea bass (*Dicentrarchus labrax*) to seismic emissions and found significant changes in cortisol, glucose, lactate, AMP, ADP, ATP and cAMP levels in different tissues after exposure, indicating a primary and secondary stress response. However, no mortality or physical trauma was observed, and biochemical parameters returned to normal values within 72 hours post-exposure. Radford *et al*. (2016) also found that sea bass exposed to playbacks of recordings of impulsive MSS noise showed increased ventilation rates, indicating a stress response. However, this response was temporary, and those fish exposed to the playbacks for 12 weeks ceased to display increased ventilation rates or differences in stress, growth or mortality in comparison to the control group.

Scholik and Yan (2002) reported that a hearing threshold shift in fathead minnows was directly correlated to the sound frequency and duration of exposure. A temporary threshold shift was observed after one hour of exposure to white noise at >1 kHz; however, no threshold shift occurred at 0.8 kHz. MSSs typically use an acoustic source that operates at a significantly lower frequency (2 – 250 Hz) than that used to demonstrate an effect in this study.

Sverdrup *et al*. (1994) found that exposure of Atlantic salmon (*Salmo salar*) to experimental seismic noise resulted in significant change in adrenaline and cortisol levels, and Popper *et al*. (2005) observed varying degrees of threshold shifts in northern pike, broad whitefish and lake-chub when fish were exposed to a 730 in^3 acoustic source. In this latter study, despite varying amounts of threshold shift, recovery of all species occurred within 24 hours post-exposure.

A review of the potential impacts of low-frequency seismic sound on the physical and physiological attributes of fish is provided by Carroll *et al*. (2017) and a summary of this is shown in **Table 44**. In accordance with the above discussion, **Table 44** shows that studies have reported varying results; the majority demonstrate no evidence of physical or physiological responses at either realistic or unrealistic exposure levels. Others however, report evidence of otolith/inner ear damage, temporal threshold shifts and stress bioindicators when exposed to low-frequency seismic sound at realistic exposure levels (**Table 44**).

Table 44 A Summary of the Potential Impacts of Low Frequency Sound on Fish

Effects	Adult/juvenile fish		
Physical			
Swim bladder damage	2 (green)		
Otolith/inner ear damage	1 (green)	1 (red)	
Temporal Threshold Shift	1 (green)	2 (red)	
Permanent Threshold Shift	1 (green)		
Organ/tissue damage	3 (green)		
Mortality	8 (green)		
Physiological			
Metabolic rates	(grey)		
Stress bio-indicators	1 (green)	1 (red)	1 (yellow)
Metamorphosis/settlement	(grey)		
Behavioural			
Startle/alarm response	2 (green)	6 (red)	
Sound avoidance/migration	4 (green)	9 (red)	1 (blue)
Other changes in swimming	1 (green)		
Predator avoidance	(grey)		
Foraging	(grey)		
Reproduction	(grey)		
Intraspecific communication	(grey)		
Key			
(green)	No response at either realistic or unrealistic exposure levels		
(red)	Response at realistic exposure levels		
(yellow)	Response at unrealistic/unknown exposure levels		
(blue)	Possible response (conflicting results)		
(grey)	No data, has not been tested		

Notes: Numbers represent the number of studies reporting the result (as reported by Carroll *et al.,* 2017)

Impacts are classified according to the sound exposure treatments as realistic (i.e. short bursts of low-frequency sound at a distance of >1 – 2 m) or unknown/unrealistic (i.e. long duration and/or short distance of <2 m to sound source, nearfield sound exposure in aquaria).

There is no data for elasmobranchs (Carroll *et al.,* 2017)

Source: Table adapted from Carroll *et al.,* (2017) The CarbonNet study (detailed in **Section 7.2.2.1.2**) assessed fish abundance pre- and post- MSS in Australia's Gippsland Basin by deploying baited remote underwater video stations across ten sites (six sites within the survey area and four reference sites). The results showed that 637 individual fish were observed pre-survey compared to 523 individuals post-survey. In contrast, species richness was lower pre-survey (39) compared to post-survey (43). Based on the results, no conclusion could be made regarding the impact of the survey on fish.

In 2003 and 2004, Fisheries and Oceans Canada ran workshops focusing on the documented effects of seismic noise on marine fauna, which were attended by scientific experts and regulators. Following the workshops, teams of scientists prepared major literature reviews of experimental and field studies, and international standards and mitigation methods. With respect to seismic impacts on fish physiology and mortality, the key conclusions from the workshops were:

- There were no documented cases of fish mortality upon exposure to seismic sound under field operating conditions; and
- Exposure to seismic sound was considered unlikely to result in direct fish mortality.

The workshop conclusions indicated that, under experimental conditions, sub-lethal and/or physiological effects have sometimes been observed in fish exposed to seismic acoustic outputs. However, experimental designs have made it impossible to determine the sound intensity responsible for the observed effects, as well as the biological significance of the results. Further field experiments attempting to target these issues have been inconclusive. As such, it was concluded that the current information was inadequate to evaluate the likelihood of sub-lethal or physiological effects under field operating conditions. The ecological significance of these effects, where they occur, could range from trivial to important, depending on their nature.

A Working Group (Popper *et al*., 2014) was established to re-examine these same issues and reported that there was still a lack of directly relevant data on the effects of seismic noise on fish. Additionally, there were no documented cases of fish kills during MSSs or in experimental studies (Popper *et al*., 2014). An output from this Working Group was the development of threshold sound levels for which harm to fish species is likely to occur. These thresholds, presented in **Table 45**, are based on the sound exposure guidelines for fish proposed by the ANSI Accredited Standards Committee S3/SC 1, Animal Bioacoustics Working Group. The guidelines are derived from data from several sources. The mortality and recoverable injury guidelines for fishes are based on predictions derived from effects of impulses since there are no quantified data for seismic acoustic sources. The 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; and
- TTS.

Popper *et al*. (2014) point out that the nominal thresholds for fish injury and mortality presented in **Table 45** should not be used as firm criteria and must be applied cautiously. These thresholds can greatly over-estimate the level of potential impact if taken at worst-case effect for a listed range of potential effects and may increase error in an impact assessment. For example, Wagner *et al*. (2015) exposed gobies to six seismic discharges at an average peak SPL of 229 dB re 1 µPa. This was at a level greater than the mortality and potential mortality threshold listed in **Table 45**. Results showed that no mortality or significant physiological effects were observed in the 60 hours following exposure; however, longer term sublethal effects were not investigated.

As indicated in **Table 45**, studies generally show that physiological effects of seismic acoustic exposure are greater in fish which have a swim bladder than in those which do not (Casper *et al*., 2013). However, there are also a number of studies reporting no physiological effects from seismic exposure on fish which have a swim bladder. For example, Hastings *et al*. (2008) exposed different reef fish species to seismic acoustic outputs and examined the effects on hearing. These authors reported that no hearing loss occurred following sound exposures up to 190 dB re 1 µPa s SEL_{cum} for one species in which the swim bladder was connected to the ear, and in three species where it was not. 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. The results from the sound modelling undertaken by JASCO (Connell *et al*., 2022), see **Section 7.2.1.2**, predicted distances to criteria from the acoustic modelling using dual metrics (PK and SEL_{24h}). The results are incorporated in **Table 45**. More detailed results are available in **Appendix A**.

Table 45 Noise Exposure Criteria (Popper *et al*., 2014) and Zones of Impact (Maximum Distances from Source to Impact Threshold Levels) for Mortality and Impairment of Fish, Fish Eggs and Fish Larvae.

	Mortality and potential mortal injury		Impairment					Behaviour
	Criteria	Maximum threshold distance (m)	Recoverable injury		Temporary Threshold Shift		Masking	
			Criteria	Maximum threshold distance (m)	Criteria	Maximum threshold distance (m)		
Fish with no swim bladder^ (particle motion detection)	>213 dB PK	80 (76)	>213 dB PK	80 (76)	>>186 dB SEL$_{24hr}$	10,500 (9,310)	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
	>219 dB SEL$_{24hr}$	80 (*)	>216 dB SEL$_{24hr}$	80 (*)				
Fish with swim bladder that is not involved with hearing (particle motion detection)	>207 dB PK	200 (252)	>207 dB PK	200 (252)	>>186 dB SEL$_{24hr}$	10,500 (9,310)	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
	210 dB SEL$_{24hr}$	80 (*)	203 dB SEL$_{24hr}$	10 (*)				
Fish with swim bladder that is involved with hearing (primarily pressure detection)	>207 dB PK	200 (252)	>207 dB PK	200 (252)	186 dB SEL$_{24hr}$	10,500 (9,310)	(N) Low (I) Low (F) Moderate	(N) High (I) High (F) Moderate
	207 dB SEL$_{24hr}$	80 (*)	203 dB SEL$_{24hr}$	10 (*)				
Fish eggs and fish larvae**	>207 dB PK	200 (252)	(N) Moderate (I) Low (F) Low	-	(N) Moderate (I) Low (F) Low	-	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low
	>210 dB SEL$_{24hr}$	80 (*)						

Notes: Peak sound pressure levels (PK) dB re 1 µPa; SEL dB re 1 µPa^2·s. Cumulative sound exposure level (SEL24$_{hr}$) dB re 1 µPa^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, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

Maximum modelled water column threshold distances as reported first, with maximum modelled seafloor threshold distances reported in brackets.

* indicates that the threshold was not reached

^ Fish with no swim bladder is also appropriate for sharks in the absence of other information.

** See zooplankton subsection (above) for further discussion on fish eggs and larvae.

The key points from the UAM results in **Table 45** indicate that:

- The modelling predicts that exposure to a single pulse of the acoustic source at full power could elicit mortality or recoverable injury in fish inhabiting the water column and seabed out to 200 and 252 m from the source, respectively;
- Cumulative exposure to multiple pulses from the moving noise source or infill lines increases the potential for mortality or recoverable injury to fish inhabiting the water column to a distance of approximately 80 m; and
- There is potential for cumulative exposure, accumulated over a 24 hour exposure period, to cause TTS at distances out to 10,500 m.

The SEL_{24h} is a cumulative metric that reflects the dosimetric effect of noise levels within 24 h based on the assumption that an animal is consistently exposed to such noise levels at a fixed position and thereby often represent an unlikely worst-case scenario. More realistically, fish would not stay in the same location for 24 hours, but rather a shorter period, depending upon their behaviour, the proximity and movements of the source. Therefore, a reported radius for SEL_{24h} criteria does not mean that fish travelling within this radius of the source will be impaired, but rather that an animal could be exposed to the sound level associated with impairment (either PTS or TTS) if it remained in that location for 24 h. Most pelagic fish are expected to avoid the area if sound levels become uncomfortable. However, as shown in Meekan et al. (2021), the acoustic source from a seismic survey did not alter demersal fish abundance or behaviour in a large-scale experiment on the North West Shelf of Australia. The continual moving nature of the vessel and acoustic source and the use of soft starts also provide an opportunity for fish to move away from the source before being exposed to a full power noise impulse.

Popper *et al*. (2014) summarises that in all TTS studies considered, fish that showed TTS recovered to normal hearing levels within 18–24 hours and importantly, no studies have linked the mortality of fish, with or without swim bladders, to seismic noise (Popper *et al*., 2014). Based on all of the literature provided above, the results from the UAM, 720 m line spacing's, as well as the control measure where no infill lines will be acquired without a delay of at least 24 hours break in acquisition in that area to minimise cumulative effects, the residual risk to fish physiology arising from acoustic disturbance during the Seismic Survey has been assessed as **Low** (*Minor* x *Likely*).

7.2.2.1.4 Cephalopods

As described in **Section 4.5.4**, cephalopods that could be found in or around the OA include nine species of cuttlefish, twelve species of squid, and one species of octopus, none of which are listed as EPBC threatened fauna and none of the species are being commercially fished within the EMBA.

Given their pelagic lifestyle, where they spend the daytime near the seabed and then rise to the surface waters to feed at night, there is the potential for squid and cuttlefish to come near the acoustic source during the Seismic Survey. Octopus, on the other hand, are primarily reef dwelling benthic species so are less likely to be encountered in concentrations of significance in the OA.

Acoustic trauma has been observed in captive cephalopods. Andre *et al*. (2011) exposed four species (two squid, one octopus and one cuttlefish species) to low frequency sounds with SELs of 157 ± 5 dB re 1 µPa (peak levels at 175 re 1 µPa). All exposed animals exhibited changes to the sensory hair cells (statocysts) responsible for balance, with damage becoming more pronounced in animals continuously exposed for up to 96 hours. This study estimated that trauma effects could occur out to 1.5 – 2 km from an operating acoustic source.

Fewtrell (2003) found that southern calamari squid (*Sepioteuthis australis*) were able to detect acoustic noise at approximately 158 dB re 1 µ Pa, or at a distance of 2.1 km from a 2,678 in^3 acoustic source, although no trauma examination was conducted. However, Fewtrell (2003) did conclude that MSS noise of up to 192.4 dB re 1 µ Pa (0.2 km from a 2,678 in^3 acoustic source) is not lethal for *S. australis*.

In regards to octopus, there are no reported studies regarding the response of octopus to an acoustic source. Fewtrell and McCauley (2012) have studied responses of squid through a number of experiments to examine the received per-pulse SEL for caged squid. In one trial, where the received level of the first impulse of the acoustic source was 162 dB re 1 µPa²·s, the squid inked. During the trial, this response was not observed again; however, the authors stated that it was unknown whether this was due to depleted ink reserves or habituation. Two other trials used an acoustic source with lower initial received levels (132 and 146 dB re 1 µPa²·s per-pulse SEL), and no inking behaviour was observed. It was hypothesised by the authors that the results suggest a gradual increase in received sound levels and prior exposure to impulses from an acoustic source could decrease the severity of alarm responses in squid. More recent work by Jones et. al. (2020) supports this where potential rapid, short habituation was found in squid in response to impulsive nose. However, a similar response was observed to impulsive noise 24 hours later, which indicates that squid may re-sensitise to acoustic noise.

As a result of the Fewtrell & McCauley (2021) findings, where 162 dB re 1 µPa²·s per-pulse SEL was associated with inking, this was considered to be a startle response level for squid.

Carroll *et al*. (2017) undertook a literature review on the physiological and physical effects of MSSs on fish and invertebrates, including cephalopods (**Table 46**). Carroll *et al*. (2017) categorised relevant studies into the presence or absence of a response from cephalopods depending on the level of exposure. The level of exposure was determined to be either "*realistic*" for MSSs (i.e. few short bursts of low frequency sound at >1 – 2 m), or "*unrealistic / unknown*" (i.e. continuous sound exposure, >100 bursts of near-field sound exposure in aquaria).

Table 46 A Summary of the Potential Impacts of Low Frequency Sound on Cephalopods

Effects	Cephalopod
Physical	
Otolith/statocyst damage	3
Organ/tissue damage	1
Mortality/abnormality	1
Physiological	
Metabolic rates*	1
Stress bio-indicators	1
Immune response	
Energy stores	
Behavioural	
Startle response	5
Sound avoidance	1
Predator avoidance	
Foraging	

Reproduction	
Bioturbation	
Key	
	No response at either realistic or unrealistic exposure levels
	Response at realistic exposure levels
	Response at unrealistic/unknown exposure levels
	Possible response (conflicting results)
	No data, has not been tested

Notes: *Includes proxies for metabolic rate such as food consumption, growth, respiration, developmental rate.
Numbers represent the number of studies reporting the result (as reported by Carroll *et al*., 2017).
Impacts are classified according to the sound exposure treatments as realistic (i.e. short bursts of low-frequency sound at a distance of >1 – 2 m) or unknown/unrealistic (i.e. long duration and/or short distance of <2 m to sound source, nearfield sound exposure in aquaria).

Source: Table adapted from Carroll *et al.*, (2017)

Carroll *et al*. (2017) found no studies that had used "*realistic*" exposure levels and five that had used "*unrealistic/unknown"* exposure levels, including Andre *et al*. (2011), described above. Three had found damage to the statocyst (Andre *et al*., 2011, Solé *et al*., 2013; 2013a), one found respiratory suppression (Kaifu *et al*., 2007), and another found wider ecosystem consequences / stress bio-indicators (Solan *et al*., 2016).

Keevin and Hempen (1997) provide a literature review of the effects of underwater noise on aquatic invertebrates. The studies, most of which took place in the 1940s and 1950s, often lacked good experimental design such as adequate sample size, control, and measurements of pressures at distance from the blast. While cephalopods were not present in any of the studies, shrimp, crab and oysters featured most often. Nonetheless, Keevin and Hempen (1997) conclude that invertebrates are insensitive to pressure related to underwater noise. This is plausible since they speculate that this could be due to the lack of gas containing organs, such as a swim bladder, which has been implicated in the mortality of fish in similar experiments.

The effect of MSSs on cephalopod larvae and eggs is unknown, although larvae and juveniles are most often found in shallow coastal waters (AFMA, 2018d), which are mostly outside the OA.

Squid are generally short-lived, fast growing species with high fecundity rates and studies have shown that squid can produce eggs year-round. So, if there was any potential for loss in recruitment over a three-month period, then the squid's life history traits mean they are well adapted to disturbance and the populations would not be at the same risk as those species which only spawn once a year.

The survey design of 720 m line spacing's that SLB have proposed, with 140 km long survey line lengths which will take approximately 32 hours to acquire will also assist in reducing any focused effects in a given area, and at this spatial scale would be at the levels that would not cause any population effects to fish eggs or larvae as a result of their life history traits. Given this is the closest threshold value we have from published literature to apply to the eggs and larvae of squid we would expect similar zones of impact as being applicable to squid eggs and larvae.

This, combined with the finding that a relatively high SEL, was found to be non-fatal to squid, and that larvae and juveniles are most often found in shallow coastal waters, suggests that there is no anticipated long-term risk to squid populations presented by the Seismic Survey.

There is no evidence to suggest that other cephalopod species are more prone to physiological impacts from underwater noise then squid, consequently, the residual risk to cephalopod physiology arising from acoustic disturbance during the Seismic Survey has been assessed as **Low** (*Minor* x *Unlikely*).

7.2.2.1.5 Marine Reptiles

As described in **Section 4.5.5**, two threatened sea snakes and six threatened marine turtles are known or are likely to be present in the OA. An additional 15 non-threatened sea snake species may also have a presence in the OA; indeed, the Timor Sea is regarded as a sea snake biodiversity hotspot (Guinea and Whiting, 2005; Minton and Heatwole, 1975; Smith, 1926).

To date, very little information is available regarding the hearing sensitivities for sea snakes and the potential impacts from exposure to seismic surveys. The first ever investigation of sea snake hearing abilities was undertaken by Chapuis *et al*. (2019) who measures auditory evoked potentials for two individual Stoke's sea snakes. This study found that hearing sensitivity for this species spans the range 40 – 600 Hz, with peak sensitivity occurring at 60 Hz (response elicited at 163.5 dB re. 1 µPa) and a secondary peak at 300-500 Hz (response elicited at 169.1 dB re. 1 µPa). The basis for this study stemmed from the concern that declining sea snake densities at Ashmore Reef may be linked to an increase in seismic survey activities in the vicinity, noting that without an understanding of sea snake hearing, assessing the effects of underwater noise on these animals is virtually impossible. The findings of this study concluded that, compared to other marine vertebrates (i.e. bony fish and marine turtles) sea snakes possess a relatively low hearing sensitivity for both sound pressure and particle acceleration. This aligns well with the fact that all snakes (including sea snakes) lack an external ear and a tympanic middle ear; hence snakes are generally considered to be less sensitive to sound (Hartline and Campbell, 1969). Despite this low sensitivity, Chapuis et al. (2019) suggests that high amplitude sounds (such as those from seismic operations) are likely still detectable in close proximity to the active source as well as vibrations in the substrate and water column. No noise exposure criteria to predict physiological effects on sea snakes are available but given the low relative sensitivity they would presumably occur at closer distances to the source than those predicted for turtles which are discussed below.

Nelms *et al*. (2016) conducted a thorough literature review of studies that investigate the behavioural and physical impacts of seismic surveys on turtles. Nelms *et al*. (2016) reported that for those marine turtle species for which hearing sensitivities are known (loggerhead, green, leatherback and Kemp's ridley turtles – of which all but Kemp's ridley turtles have a potential presence in the OA), all can detect frequencies between 50 and 1600 Hz, and that this range overlaps with the peak amplitude low frequency sound produced during seismic surveys (10 – 500 Hz). This suggests that turtle hearing will detect seismic operations, although hearing sensitivity is relatively poor compared to marine mammals (Finneran *et al*., 2017) and no studies have assessed physical (tissue) damage to hearing structures. One study (Gurjao *et al.*, 2005), looked for evidence of turtle mortality during 2D seismic surveys off the coast of Brazil. Of the eight dead turtles found in the vicinity, five appeared to have been recently caught and damaged by fishing activity and had subsequently died. The authors do not speculate as to the cause of death for the other three dead turtles, and it is unclear whether any post-mortems were conducted on these individuals.

TTS has been induced in captive playback experiments where loggerhead turtles were exposed to a few hundred seismic pulses at a distance of 65 m (Moein *et al.,* 1994, cited in National Science Foundation, 2011). While this demonstrates that hearing damage is theoretically possible, the results of captive experiments are of questionable relevance when assessing effects of seismic surveys in an open ocean setting as captive animals are unable to move away from the sound source. Instead, the impact of underwater noise on turtles is likely to be influenced by the exposure duration, where acute noise from seismic surveys is most likely associated with behavioural effects (see **Section 7.2.2.2.4**) rather than physiological effects (Commonwealth of Australia, 2017b). Physiological effects for marine turtles are probably limited to situations when animals might be exposed at close range for unusually long periods (National Science Foundation, 2011), such situations are unlikely during the Seismic Survey as the vessel will be moving continuously along pre-determined sail lines; hence exposure to high levels of underwater noise will be transitory for any turtles in the OA.

The underwater noise exposure criteria for physiological effects on sea turtles are presented in **Table 47**. These criteria are based on the recommendations of the US Navy (Finneran *et al*., 2017) which, on account of there being no published data regarding TTS and PTS in marine turtles from impulsive noise sources, base threshold values on extrapolations from other animal groups. UAM results for the proposed Seismic Survey do not predict PTS or TTS for marine turtles from exposure to a single pulse, but PTS could occur if a turtle was to remain within 80 m of the active source for 24-hours or TTS is possible for turtles that remain within c. 6 km of the active source for 24-hours. Noting that the likelihood of cumulative exposure is dramatically reduced on account of the movement of the Seismic Vessel, where at a speed of 4.5 knots the Seismic Vessel will travel up to 200 km in 24 hours, and the ability for turtles to spend time with their heads above the water surface to avoid exposure.

Table 47 Noise Exposure Criteria (Finneran *et al.,* 2017) and Modelled Zones of Impact (Maximum Distances from Source to Impact Threshold) for PTS and TTS in Sea Turtles

	PTS		TTS	
	Criteria	Maximum Threshold Distance (m)	Criteria	Maximum Threshold Distance (m)
Single pulse PK	232 L_{pk}; dB re 1 µPa	-	226 L_{pk}; dB re 1 µPa	-
Cumulative Weighted SEL_{24hr}	204 $L_{E,24h}$; dB re 1 µPa²·s	80	189 $L_{E,24h}$; dB re 1µPa²·s	1,820 – 6,110

Notes: A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).

Acute noise from seismic surveys is considered in the Recovery Plan for Marine Turtles in Australia 2017-2027 (Commonwealth of Australia, 2017b). This report acknowledges that loggerhead turtles are known to be sensitive to sounds of between 100 – 400 Hz, and that green, leatherback and hawksbill turtles can detect frequencies up to 1600 Hz, but despite this very little is known of the impact of noise on marine turtles. The report also states that "*Given that the impacts of noise are unknown, a precautionary approach should be applied to seismic work, such that surveys planned to occur inside important inter-nesting habitat should be scheduled outside the nesting season*." In accordance with Appendix B of the Recovery Plan (Commonwealth of Australia, 2017b), the risk assessment results presented therein for noise interference on turtle stocks of relevance to the OA are as follows, where the most critical aspect of the threat is provided in brackets:

- Green turtles on Northwest Shelf = moderate consequence, unknown likelihood (acute and chronic);
- Green turtles at Ashmore Reef = no long term effect, unlikely (acute and chronic);
- Loggerhead turtles in Western Australia = minor consequence and likely (acute);
- Flatback turtles at Cape Domett and Southwest Kimberley = minor consequence and likely (acute);
- Flatback turtles in the Arafura Sea = minor consequence and possible (acute);
- Hawkesbill turtles in Western Australia = minor consequence and possible (acute); and
- Leatherback turtles in Australia = minor consequence, but of unknown likelihood (acute and chronic).

While this clearly indicates that some effects of seismic surveys are expected on marine turtles in the region, the Recovery Plan anticipates effects to be minor in most cases, where 'minor' is defined as "individuals are affected, but no effect at stock level". The only instance for which a 'moderate' consequence is predicted is for green turtles on the Northwest Shelf, where the Recovery Plan defines a moderate consequence as "stock recovery stalls or reduces". The closest nesting and inter-nesting habitat from the OA for green turtles is at Ashmore Reef where nest numbers in the low hundreds occur annually (Whiting *et al*., 2000) and nesting occurs on a year-round basis, peaking in summer (DEH, 2005). Ashmore Reef is also an important feeding site (DSEWPC, 2012d). The closest green turtle critical habitat and BIAs (foraging, mating, nesting and inter-nesting buffer) are located approximately 87 km west of the OA in the vicinity of Ashmore Reef (see **Section 4.4.4**).

As identified in **Section 4.4.4**, the OA overlaps with a flatback turtle foraging BIA. Flatback turtles are classified by the EPBC Act as vulnerable and migratory. In addition, loggerhead turtle and olive ridley turtle foraging BIAs have been identified nearby (approximately 9 km to the east of the OA), and both these species are classified by the EPBC Act as endangered and migratory. The UAM predicts that 24-hour cumulative TTS effects for marine turtles could occur out to 6 km from the active source and lower hearing sensitivities for sea snakes suggest that the zone of impact for these species would be even smaller. While individual turtles or sea snakes could theoretically be subject to cumulative TTS during the Seismic Survey, over a 24-hour period the Seismic Vessel could travel up to 200 km, so continual exposure to an individual during that time is unlikely. The zone of impact for 24-hour cumulative PTS is restricted to 80 m around the active source; hence, the risk of PTS for individual turtles or sea snakes is very low, and no anticipated population level effects are predicted. Individual turtles could occur within the highly restricted zone (<20 m) in which PTS or TTS from single pulse exposure is expected; however, individual turtles would presumably be displaced from this area by the hull of the Seismic Vessel (which precedes the acoustic source). Consequently, the residual risk to marine reptile physiology arising from acoustic disturbance during the Seismic Survey has been assessed as **Low** (*Minor* x *Possible*).

7.2.2.1.6 Marine Mammals

Marine mammals are highly vocal and are dependent on sound for almost all aspects of their lives; foraging, reproduction, communication, detection of threats, and navigation, and as a result, are particularly sensitive to anthropogenic noise (Weilgart, 2007; Williams *et al*., 2015; Erbe *et al*., 2018). Marine mammals may suffer lethal and sub-lethal physiological effects (e.g. damage to body tissues resembling decompression sickness in humans, damage to hearing, and chronic stress (Gordon *et al*., 2003)) when exposed to high intensity underwater noises at close range. The sound intensities that would result in such effects are largely unknown for most species, with current knowledge of traumatic thresholds based on a relatively small number of experimental species and inferred for those species for which captive studies are not possible (Southall *et al*., 2019). All thresholds for permanent hearing injury are inferred for ethical reasons (Southall *et al*., 2019).

The likelihood that exposure to shipping noise would be sufficient to permanently damage the hearing of marine mammals is remote (Southall and Hatch, 2008), however, long-term exposure may induce a stress response similar to that found in humans that live near busy roads or airports (Wright *et al*., 2007).

The first evidence of chronic stress in whales in response to vessel noise was demonstrated by Rolland *et al.* (2012) in North Atlantic right whales. Vessel traffic densities and movements were significantly reduced in the Bay of Fundy, California following the events of September 11, 2001, resulting in a corresponding reduction in background noise level. This reduction in noise correlated with decreased baseline levels of stress-related faecal hormone metabolites in right whales (Rolland *et al*., 2012). Although no other factor was found that could explain the difference, the results must be interpreted with caution as analysis was based on a non-repeatable event, sample sizes were relatively small, and there are no comparable acoustic recordings from the Bay of Fundy in years other than 2001 (Rolland *et al*., 2012).

Although tissue damage by shock waves from explosives has been demonstrated for terrestrial animals, pressure pulses from seismic sources have longer rise times and are less likely to cause tissue damage than explosives. To date there is no definitive evidence of acute physical damage or mortality to marine mammals from seismic sources or seismic surveys (Gordon *et al*., 2003; Broker, 2019); however, one incident of severe behavioural distress, followed by ataxia has been noted for a pantropical spotted dolphin near a seismic array, suggesting a link between acoustic exposure and physiological damage (Gray and van Waerebeek, 2011) and Mann *et al*. (2010) reported several incidences of hearing loss in stranded odontocetes for which exposure to high levels of anthropogenic noise cannot be ruled out.

Chronic stress and physiological changes can supress the immune system, compromising the health of an animal (Weilgart, 2013). Increases in stress hormones have been observed in captive beluga whales and bottlenose dolphins exposed to sound emissions from an acoustic source (Romano *et al*., 2004; Yang *et al*., 2021).

Exposure to high intensity noises can result in a 'threshold shift'; that is changes in the ability of an animal to hear, usually at a certain frequency, whereby sensitivity to one of more frequencies is lost (Southall *et al*., 2007; Southall *et al*., 2019). Threshold shifts can be temporary, with recovery after minutes or hours, or be permanent. A TTS results in a temporary loss in hearing sensitivity that will return to normal after some time (David, 2011). Threshold shifts in marine mammals are more commonly temporary on account of their mobile, free-ranging nature which means they are usually able to avoid dangerously high SELs. However, exposure to sounds that cause TTS can cause PTS if an animal is repeatedly exposed to such levels (Kastelein *et al*., 2016). It is believed that to cause immediate permanent physiological damage to marine mammals, levels of acoustic exposure would need to be very high (Richardson *et al*., 1995; Southall *et al*., 2019).

The magnitude of any TTS effect is dependent on the frequency, bandwidth, noise level, the noise exposure duration, the recovery period, whether the noise is continuous or intermittent and the subject species (Popov *et al.,* 2013). Most TTS studies to date have been conducted on odontocetes as these are the species typically held in captivity on which controlled exposure experiments can be conducted (e.g. Finneran *et al*., 2015). No TTS studies to date have been conducted on baleen whales; hence, all estimates of TTS onset for these species are based on extrapolation from species for which data does exist (Southall *et al*., 2019).

The duration of TTS recovery depends on the magnitude of the TTS (i.e. how much hearing sensitivity has changed). For example, bottlenose dolphins exposed to 30 minutes of continuous 160 dB re.1µPa tonal noise exhibited a TTS of 8 dB five minutes after exposure, and full recovery occurred within an hour (Nachtigall *et al*., 2004), whereas dolphins exposed to continuous tonal noise of 186-194 dB re.1µPa exhibited a TTS of 45 dB with almost no recovery in the first hour post-exposure and complete recovery requiring up to four days (Finneran *et al*., 2007). Comparisons between intermittent and continuous sound exposures have been made and reveal that intermittent exposure resulted in a lower TTS than continuous exposure indicating a partial recovery during the pauses of intermittent exposure (Finneran *et al.*, 2010).

More recently Finneran *et al*. (2015) measured TTS in bottlenose dolphins from impulsive seismic sources and found that exposure to impulsive noises elicited much lower threshold shifts than those caused by continuous tones. In this study a 150 cubic inch (2,000 PSI) seismic source at a range of 3.9 m to the subject dolphins exposed the animals to SPLs of 200-212 dB re.1µPa; however, the maximum TTS recorded was only 9 dB. This study also documented an intriguing anticipatory behaviour whereby two of the three individuals tested independently learnt to turn their heads away from the seismic source just before each impulse was generated in what is thought to represent an attempt to 'self-mitigate' against the noise. While Finneran *et al*. (2015) did not comment on TTS recovery duration following seismic source exposure, given the relatively low TTS responses observed, the recovery durations would nearly certainly be short (i.e. less than one hour: cf. Nachtigall *et al*., 2004). Indeed, most TTS studies on marine mammals to date document full recovery within 24 hours of exposure (NMFS, 2018). Popov *et al*. (2013) demonstrated that regardless of frequency, an increase in exposure duration resulted in increases to both the magnitude of the TTS and the time to recovery. It is noteworthy that individuals of the same species exposed to the exact same noise under identical experimental conditions can exhibit considerably different TTS responses, indicating significant inter-individual variability in susceptibility to temporary hearing impairment (Popov *et al*., 2013).

Establishing the distance at which threshold shifts are predicted to occur from a given sound source in the marine environment is dependent on the characteristics of the acoustic source, such as frequency, sound speed profile within the water column, seabed composition, water depth and exposure duration (David, 2011). UAM is required to relate the sound source to the predicted sound pressure levels at a specific location, which enables an estimation to be made of the distance at which a threshold shift onset could occur. For intermittent noise exposures in the marine environment, cumulative SEL, defined as the total SEL calculated over the time the noise source is active, is often used to characterise exposure (Finneran, 2015). The cumulative SEL considers the received level of sound and the duration of exposure (NMFS, 2018), typically over a 24-hour period and for an individual activity only.

In order to assess the effects of underwater noise on marine mammal auditory function, marine mammals are characterised by 'hearing groups' (**Table 48**) based on their generalised hearing range (Southall *et al*., 2019). Outside of this hearing range, the risk of auditory impacts from sound is unlikely. Based on their assigned hearing groups, thresholds for the onset of TTS and PTS in marine mammals were determined by Southall *et al*. (2019) and are presented in **Table 48.**

The predicted zones of impact from a single pulse of the acoustic source for the Seismic Survey have been determined by UAM and are provided in **Table 48** along with the predicted zones of cumulative impact over a 24 hour period, during which approximately 12,000 pulses would occur (including during line turns). For this EP, the single pulse and the cumulative modelling results are used to assess the potential zones of impact on marine mammals; however, the larger threshold distance generated by the cumulative results have the greatest influence on the formulation of ecological conclusions. In reality, both scenarios are imperfect as the length of time that free-ranging wild animals would spend near the active source would inevitably be longer than a single pulse, but shorter than the 24-hour period used as the cumulative metric. Additional animal movement modelling has been undertaken for pygmy blue whales to more realistically represent the time that they might be present around the Seismic Vessel on account of the overlap between the OA and the blue whale migratory BIA.

Whales, as defined by the EPBC Act Policy Statement 2.1 include baleen whales and larger toothed whales, (e.g. sperm whales, killer whales, false killer whales, pilot whales and beaked whales). For the purpose of interpreting the UAM results it is important to note that baleen whales are classified as low frequency cetaceans, while the larger toothed whales are typically high-frequency cetaceans. The only very-high-frequency cetacean species with a potential presence in the OA are the pygmy sperm whale and dwarf sperm whale.

Table 48 PTS and TTS Onset Thresholds for Marine Mammals Exposed to Impulsive Noise (Southall *et al*., 2019) and Predicted Zones of Impact (Maximum-Over-Depth-Distances from Source to Onset Threshold; Range for Six Different Single Pulse Sites, and Four Different Cumulative Scenarios

Hearing group	PTS and TTS onset thresholds – impulsive noise events							
	PTS onset				TTS onset			
	Single pulse PK		Cumulative Weighted SEL24hr		Single pulse PK		Cumulative Weighted SEL24hr	
	PK (dB re 1µPa)	Maximum predicted distance (m)	Weighted SEL24hr (dB re 1µPa2.s)	Maximum predicted distance (m)	PK (dB re 1µPa)	Maximum predicted distance (m)	Weighted SEL24hr (dB re 1µPa2.s)	Maximum predicted distance (m)
Low frequency cetaceans	219	-	183	5,750-6,840	213	80	168	38,900-47,500
High-frequency cetaceans	230	-	185	-	224	-	170	70-80
Very-high-frequency cetaceans	202	290-480	155	80	196	790-920	140	180-500
Sirenians	226	-	190	-	220	-	175	80

Note: Low frequency cetaceans include all mysticete whales, i.e. all baleen whales,
High frequency cetaceans include most dolphins, beaked whales, sperm whales and killer whales
Very high frequency cetaceans include true porpoises, most river dolphins, pygmy/dwarf sperm whales, and Commerson's, Chilean, Heaviside's, Hector's hourglass and Peale's dolphins
Sirenians include dugongs
A dash indicates that the threshold is not reached within the limits of the modelling resolution (20 m)

In addition to acoustic propagation modelling results (i.e. UAM, as presented in **Table 48**), animal movement modelling ('Animat' modelling) was also undertaken using movement simulations for pygmy blue whales, being the cetacean species most likely to be encountered during the Seismic Survey. This modelling allowed estimations of the distance within which 95% of the TTS and PTS threshold exceedances would occur ($ER_{95\%}$), along with the probability that a blue whale within that distance would be exposed above the relevant threshold (P_{exp}). Exposure ranges from animat modelling for PTS and TTS thresholds are typically shorter than those predicted using acoustic propagation modelling because of the shorter dwell time of moving animals which represents a more realistic approach for free-ranging pelagic marine mammals. The results of the animat modelling are presented in **Table 49**, in all scenarios PTS and TTS exposure ranges were substantially less than those estimated by UAM (**Table 48**). For animat modelling, five scenarios were run both with BIA-restricted animat seeding (i.e. simulated animal movements began only in the blue whale migratory BIA) and unrestricted seeding (i.e. simulated animal movements began randomly irrespective of the BIA boundaries). Where seeding was unrestricted, the $ER_{95\%}$ distances were larger as simulated whales under this paradigm would have more opportunities to be exposed to sound fields for a longer time; this is the more conservative model approach and for this reason more emphasis is placed on the unrestricted seeding results.

As stated by Connell *et al*. (2022) in **Appendix A**, the probability of exposure within $ER_{95\%}$ varied between 10-96% for unrestricted scenarios, indicating that some, but not all, animats exposed within the 95th percentile range were exposed above threshold. This is because simulated whales can move in and out of the modelling range and change their vertical position in the water column. Hence the length of time they are within the exposure radius is moderated by their movements. For example, a whale within the predicted exposure range that is traveling quickly will not accumulate as much exposure as a whale that is travelling slower. Likewise, individual whales may spend more time at depths with quieter sound levels.

Table 49 Summary of Animat Modelling Results for Five Different Scenarios relative to Pygmy Blue Whales

Threshold		Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
	dB	$ER_{95\%}$ (m)	P_{exp} (%)	$ER_{95\%}$ (m)	P_{exp} (%)	$ER_{95\%}$ (m)	P_{exp} (%)	$ER_{95\%}$ (m)	P_{exp} (%)	$ER_{95\%}$ (m)	P_{exp} (%)
BIA-restricted seeding											
PTS	183	50	93	-	-	-	-	60	80	-	-
TTS	168	14,000	63	-	-	-	-	11,700	58	-	-
Unrestricted seeding											
PTS	183	980	20	1,000	16	1,240	10	1,390	12	1,140	24
TTS	168	15,040	75	14,750	82	17,110	75	14,570	70	16,990	71

Dashes indicate no simulated whales were exposed above threshold.

The key results from both the UAM and the animat modelling can be summarised as follows:

- The UAM predicts that if baleen whales are present within 6,840 m (max.) of the active source over a 24-hour period they could experience PTS due to cumulative exposure. The animat modelling results, however, predict that the onset distance for cumulative PTS reduces to a maximum of approximately 1,400 m for pygmy blue whales when animal movement is accounted for;
- Temporary hearing damage (i.e. a TTS) could occur for baleen whales within approximately 48 km if they remain near the active source for 24 hours. The animat modelling results, however, predict that the onset distance for cumulative TTS for pygmy blue whales is approximately 17 km;
- Exceedance of the onset threshold for PTS in high-frequency cetaceans is not predicted within the resolution limits of the acoustic propagation model. This means that even if high-frequency cetaceans are within 20 m of the active source for extended periods, no permanent hearing damage is expected. A TTS could occur if high-frequency cetaceans are within 80 m of the active source for 24 hours. However, the likelihood of this occurring is virtually nil as free-ranging pelagic animals would only be expected to remain near the source for a short time even if they were curious enough to investigate the towed seismic equipment at close range; and
- Very-high-frequency cetaceans within 80 m of the active source could suffer cumulative PTS over a 24-hour period and TTS could occur due to cumulative exposure if high-frequency cetaceans are present within 500 m of the active source. The UAM results suggested that exposure to a single pulse could elicit threshold shifts beyond these distances, with PTS out to 480 m and TTS out to 920 m. Because of this discrepancy the EP has assessed the effects of underwater noise of these species using the maximum onset distances of 480 m and 920 m respectively for PTS and TTS.

All Australian marine mammals are fully protected under the EPBC Act, so the potential for causing physiological damage during any MSS is taken extremely seriously. This is particularly important for those species that have a threat classification; of which the following have been identified as having a 'known or likely' presence in the OA during the Seismic Survey (see **Section 4.5.6**): blue whales (*endangered*), fin whales (*vulnerable*), sei whales (*vulnerable*), and humpback whales (*migratory*).

Based on the modelling results for cumulative TTS and PTS onset distances, the standard shutdown zones recommended in the EPBC Act Policy Statement 2.1[14] are insufficient to manage the risk of auditory impairment to baleen whales during the Seismic Survey. This coupled with the high likelihood of encountering pygmy blue whales in and around the blue whale migratory BIA for most months of the year (see **Table 21**) mean that additional management procedures are necessary to address the risk that the Seismic Survey poses to baleen whales.

Animat modelling was undertaken to better understand the risk that the Seismic Survey poses to pygmy blue whales. This modelling incorporated species-specific ecological parameters to understand how pygmy blue whale movement during migration (vertically and horizontally) will affect risk of exposure and on this basis provides exposure ranges that are significantly more realistic than those produced by UAM (Connell *et al*., 2022). For PTS, the $ER_{95\%}$ distance for pygmy blue whales is 1.4 km. Likewise, the onset distance for TTS is predicted to be 17 km. Based on the findings of the animat results, the following additional management procedures are proposed for blue whales during the seismic survey:

- A 2 km Extended Shut-down Zone for baleen whales will be implemented throughout the entire OA at all times. On this basis a low power zone is deemed unnecessary;
- A 17 km buffer will be established around the blue whale migratory BIA where it overlaps with the OA;
- The Seismic Vessel will not activate the acoustic source(s) within the blue whale migratory BIA or buffer from mid-April (14th) to mid-January (14th);
- Outside of this period (15 Jan to 13 April), any seismic operations inside the blue whale migratory BIA or buffer will:
  - Implement an extended observation zone of 5 km;
  - The extended observation zone in the BIA and buffer will be monitored using the Chase Vessel as an additional observation platform with two MMO's onboard. The Chase Vessel will travel c. 3 km ahead of the Seismic Vessel[15] and will conduct visual surveillance for marine mammals during daylight hours. Trained and experienced MMOs will be required to undertake these observations;
  - Where possible, two experienced MMOs will be on the bridge of the Seismic Vessel during daylight hours when the source is active within the blue whale migratory BIA or buffer;
  - Limit soft start procedures to conditions that allow visual inspection of the 5 km Observation Zone;
  - Cease night-time or low visibility operations in the blue whale migratory BIA or buffer if three or more whale instigated shut-downs or power-downs are made during the preceding 24 hour period. Note that this applies irrespective of shut-down/power-down locations relative to the blue whale migratory BIA or buffer. Night-time and low visibility operations may only resume in the blue whale migratory BIA or buffer after 24 hours of no blue whale instigated shut-downs (again, irrespective of location relative to the blue whale migratory BIA or buffer);
  - If species identity is uncertain at any location inside the blue whale migratory BIA or buffer, any unidentified whale will be assumed to be a blue whale; and

[14] A 3+ km observation zone, a 2 km low power zone and a 500 m shutdown zone.
[15] Defined as an 180° arc ahead of the seismic vessel, noting that the Chase Vessel should focus on the portion of the arc closest to the blue whale migratory BIA and buffer.

- Note: PAM is not considered to be a particularly reliable method for detecting low-frequency cetaceans. On this basis, the proposed adaptive management approach at night or during periods of low visibility serves to remove the reliance on PAM while still maintaining a high level of protection for low frequency cetaceans, particularly blue whales.

- For operations outside of the blue whale migratory BIA or buffer, the standard observation zone of 3+ km will be implemented (Figure 3);
- If three or more blue whale instigated shut-downs occur within a 24-hour period, the Seismic Vessel will relocate to another area at least 17 km away (and outside of the blue whale migratory BIA or buffer) before commencing Pre Start-up Visual Observations and Soft Start Procedures. This mitigation will be implemented throughout the entire OA (i.e. shut-downs both inside and outside the blue whale migratory BIA and buffer will contribute to this count); and
- If a blue whale mother and calf pair is observed during the Seismic Survey, the acoustic source will be immediately shut-down and the Seismic Vessel will relocate to another area at least 17 km away (and outside of the blue whale migratory BIA or buffer) before commencing Pre Start-up Visual Observations and Soft Start Procedures. This mitigation will be implemented throughout the entire OA (i.e. sightings both inside or outside the blue whale migratory BIA and buffer will trigger this mitigation measure).

Regarding ‘other’ baleen whale species (i.e. all other species of baleen whale, excluding blue whales), the UAM results (**Table 48**) predict that 24-hour cumulative PTS could occur out to a maximum of c. 7 km, but that exposure to a single pulse from the active acoustic source would not elicit PTS even if an animal was very close to the source (< 20 m). The maximum onset distance for 24-hour cumulative TTS is predicted to be 48 km while the single pulse onset distance for TTS is 80 m. It is noteworthy that UAM results show a high degree of variance between modelling scenarios, and, unlike the animat modelling, they do not account for animal movement.

The following other baleen whale species could have a potential presence in the OA (see **Section 4.5.6**): humpback, fin, sei, Bryde’s, Omura’s and dwarf minke whales. A very summary of distribution and density for these species in relation to the OA is provided in **Table 50**.

Table 50 Other Baleen Whales and their Distribution and Density in the OA

Species	EPBC Protected Matters Database; presence ranking in OA	Distribution and Density Considerations
Humpback whale	Likely	Well documented breeding distribution and migratory pathway south and inshore of OA. But seasonal presence (late Jun to early Oct; How *et al.*, 2020) at low densities has been assumed for OA. See **Section 4.5.6.1**.
Fin whale	Likely	Distributional information is limited, but this species is either thought to occur south of OA or at very low densities in vicinity of OA. A seasonal presence (May to Oct; Aulich *et al.*, 2019) at very low densities has been assumed for OA. See **Section 4.5.6.3**.
Sei whale	Likely	Distributional information is very limited but known to feed during summer months at high latitudes. Infrequently sighted in WA (Commonwealth, 2005), hence density is assumed to be very low and seasonal (c. Apr to Nov). See **Section 4.5.6.5**.
Bryde's whale	May	Distributional information is limited, but year-round acoustic presence at Scott Reef (McCauley, 2011). No density data available. Year-round presence in OA assumed. See **Section 4.5.6.6**.
Omura's whale	-	Distributional information is limited, but year-round acoustic presence at Barossa Field to the northeast of the OA (McPherson *et al.*, 2016). No density data available. Year-round presence in OA assumed. See **Section 4.5.6**.
Dwarf minke whale	-	Distributional information is limited, but acoustic detections from Scott Reef from May to Sep (McCauley, 2011). No density data available. Seasonal presence in OA assumed. See **Section 4.5.6**.

It is noteworthy that for those species considered by the EPBC Protected Matters Database as having a 'likely' presence in the OA, evidence suggests that densities will be low or very low. Contrary to this, those species that are not included in the EPBC Protected Matters Database (Omura's whale and dwarf minke whale) or are recorded by the database as having an uncertain presence in the OA (Bryde's whales) are potentially the species with a more consistent presence here (**Table 50**). This discrepancy suggests that, even if Bryde's whales, Omura's whales or dwarf minke whales do have a higher likelihood of presence in the OA than what is indicated by the EPBC Protected Matters Database, their density here is presumably low.

On the basis that other baleen whales are probably only present in the OA at low or very low densities and that UAM does not account for animal movement, it is considered that the 24-hour cumulative UAM results are excessively conservative for defining the extent of observation or shutdown zones for other baleen whales. Instead, the following mitigations are proposed for other baleen whales during the Seismic Survey on the basis that free-ranging pelagic animals are not expected to remain in the vicinity of the Seismic Vessel for extended periods and the movement of the Seismic Vessel means that any potential exposure will be transitory:

- A 2 km Extended Shut-down Zone for baleen whales will be implemented throughout the entire OA at all times. On this basis a low power zone is deemed unnecessary;
- If three or more baleen whale instigated shut-downs occur within a 24-hour period, the Seismic Vessel will relocate at least 10 km away before commencing Pre Start-up Visual Observations and Soft Start Procedures;

- If a baleen whale mother and calf pair is observed during the Seismic Survey, the acoustic source will be immediately shutdown and the Seismic Vessel will relocate to another area at least 10 km away before commencing Pre Start-up Visual Observations and Soft Start Procedures; and
- For any adaptive management procedures outside of the blue whale migratory BIA or buffer, if species identity is uncertain, any unidentified whale will be assumed to be an 'other baleen' whale.

For all other 'whales' (e.g. larger toothed whales, such as, sperm whales, killer whales, false killer whales, pilot whales and beaked whales, following EPBC Policy Statement 2.1) the standard management procedures as recommended in the EPBC Act Policy Statement 2.1 will be followed (i.e. a 500 m shutdown zone and a 2 km low power zone). Noting that in instances when species identification is uncertain, a precautionary approach will be taken, and the other baleen whale management procedures will be followed until identification is otherwise confirmed.

A full description of the control measures to be implemented to address the effects of underwater noise on marine mammals are detailed in **Table 56** and a summary of all proposed marine mammal control measures is provided in **Appendix K**.

While the additional management procedures for blue whales and other baleen whales do not eliminate the risk of cumulative PTS or TTS during the Seismic Survey, the extended 2 km shut-down zone provides complete protection from short-term exposure to underwater noise and based on the animat model results, also protects blue whales from cumulative PTS. The temporal and spatial exclusions from the blue whale migratory BIA and buffer during the migration season also offer strong protection for this endangered species.

UAM results do however suggest that there is the potential for cumulative TTS to occur over distances out to 48 km if an individual whale is exposed to repeated noise impulses over a 24-hour period (**Table 48**). However, on account of both Seismic Vessel movement and the free-ranging nature of any exposed animals, the likelihood of this occurring is low. For pygmy blue whales, the animat modelling suggests that the 95th percentile exposure range is c. 17 km and not all animals within this range will be exposed above threshold levels. The establishment of the 17 km buffer around the blue whale migratory BIA will protect endangered pygmy blue whales from acoustic impairment; hence TTS in pygmy blue whales is unlikely.

In summary and given the control measures that will be implemented during the Seismic Survey, it is unlikely that any whale will approach close enough to the active acoustic source during periods of full operational power for PTS to occur. The potential for temporary hearing damage to individual whales has been identified, although this would only occur if a whale went undetected inside the proposed precaution zones or if they remain in the general vicinity of the active source for 24 hours.

Based on this information, the residual risk to whale physiology arising from acoustic disturbance during the Seismic Survey has been assessed as **Low** (*Moderate* x *Rare*).

With specific regards to the objectives of the blue whale recovery plan, the Seismic Survey will be consistent with the objectives within this recovery plan, and it is considered that anthropogenic noise in the blue whale migratory BIA will be managed through survey design and control measures so that any blue whale may continue to utilize the area without injury (based on the PTS onset thresholds predicted and the full protection afforded by the extended shut down zone); and will not be displaced from migratory pathways (based on the low risk of cumulative TTS and the spatial and temporal measures to protect whales during the migration season). The spatio-temporal controls that will be implemented in and around the blue whale migratory BIA represent best international practise for minimising noise disturbance in areas of high density and biological importance during key periods (following Chou *et al*., 2021).

The EPBC Act Policy Statement 2.1 does not require any shutdowns for smaller dolphins or dugongs, so any of these species that make close approaches to the active acoustic source could theoretically be subject to physiological effects. The UAM results for high-frequency cetaceans and dugongs (**Table 48**) indicate that no PTS is expected and that TTS could only occur if individuals were to remain within 80 m of the Seismic Vessel for extended periods; however, generally marine mammals move away from the Seismic Vessel as the generated sound levels gradually increase (Weir and Dolman, 2007). Consequently, the residual risk to the physiology of high-frequency cetaceans and dugongs from underwater noise during the Seismic Survey has been assessed as **Negligible** (*Negligible* x *Rare*).

7.2.2.1.7 Elasmobranchs

The whale shark is a protected species listed as Vulnerable and Migratory under the EPBC Act. The OA overlaps with a BIA for the whale shark (**Figure 18**). The foraging BIA represents waters where solitary whale sharks may forage during the migration from Ningaloo, which occurs primarily in spring (September to November).

There is a recovery plan in place that identifies actions to ensure this species long term viability and survival (DEH, 2005a). The main threat to the whale shark occurs outside Australian waters and is commercial harvest by a number of other range states of the whale shark. Potential threats to whale sharks visiting Australian waters are competition with fisheries, habitat damage, pollution and marine debris, climatic and ocean change, predation, disease, and direct disturbance from tourism, research or interference. At present none of these potential threats appear to have an impact on the numbers of whale sharks visiting Australian waters.

Very little research has been undertaken on the effects of acoustic noise or MSSs on elasmobranchs. Sharks differ to bony fish in that they have no swim bladder or other gas filled chambers that can act as secondary hearing organs in the body, so are unlikely to respond to changes in pressure like bony fish may be due to the physiological differences (Myrberg, 2001; Casper, 2011). As a result, sharks cannot detect pressure changes associated with sound waves (Carrol *et al*., 2011). The lateral line system of shark also does not respond to normal acoustic stimulus and is not able to detect sound-induced water displacements beyond a few body lengths, even with large sound intensities (Myrberg, 2001).

The results of the sound modelling undertaken by JASCO (Connell *et al*., 2022) for fish without a swim bladder is also applicable for sharks and applied to whale sharks in the absence of other information, see **Section 7.2.1.2.2**. Thresholds for fish injury and mortality is presented in **Table 45.** Studies generally show that physiological effects of seismic acoustic exposure are greater in fish which have a swim bladder than in those which do not (Casper *et al*., 2013). The results from the sound modelling for fish are summarised in **Section 7.2.2.1.3** and shows distances to effect criteria for fish, fish eggs, and fish larvae along with the relevant metric. More detailed results are available in **Appendix A**. Popper *et al*. (2014) summarises that in all TTS studies considered, fish that showed TTS recovered to normal hearing levels within 18–24 hours and importantly, no studies have linked the mortality of fish, with or without swim bladders, to seismic noise (Popper *et al*., 2014).

MSS activities frequently incur shark attacks to streamers deployed from the vessel and to the PAM hydrophones, although the specific reason for these attacks is not known it is considered it is the electromagnetic fields that attracts the sharks to bite. SLB have had a number of shark bites to streamers during previous MSSs in both New Zealand and Australia, indicating that sharks will approach an active acoustic source. Likewise, MMO's often make observations that are recorded in their MMO reports of sharks (such as blue sharks and mako sharks) on the surface in close proximity to the Seismic Vessel while the source is active.

It is highly unlikely that underwater noise emissions from the acoustic source, either within or outside the OA, would result in any lethal or sub-lethal injuries leading to immediate or delayed mortality or physiological effects on shark species, including the whale shark. The use of soft starts prior to commencing the MSS will allow any sharks in close proximity to move away from the acoustic source if they are not comfortable with the frequencies, which will mitigate the risk of impacts on sharks.

Consequently, the residual risk to elasmobranch physiology arising from acoustic disturbance during the Seismic Survey has been assessed as **Low** (*Minor* x *Rare*).

7.2.2.1.8 Seabirds

Since high intensity acoustic disturbances such as those from an MSS have the potential to cause physiological harm to marine mammals and fish, it is reasonable to assume that seabirds could also suffer physiological damage. Seabirds resting on the sea surface are typically startled by an approaching Seismic Vessel and would therefore be displaced from the immediate vicinity of the acoustic source, limiting their exposure to seismic emissions. Birds on the sea surface are unlikely to suffer physiological effects as the Lloyd Mirror effect means that noise levels at the surface are lower than those deeper in the water column (Carey, 2009).

Physiological damage might only occur to those seabirds within the OA that exhibit diving behaviours, and which are in extremely close proximity to the acoustic source. Due to their largely aquatic existence and lack of flight ability, potential present little penguins are expected to be more susceptible to effects from MSSs than other seabirds (Pichegru *et al*., 2017).

However, birds such as the little penguins chase small bait fish as their prey, and it is likely that these small fish would be displaced from the immediate vicinity of the active acoustic source. Seabirds are expected to detect this change in fish distribution and cease any foraging, which would in turn reduce their exposure to any potential physiological effects.

To date there is limited evidence of effects of MSSs on seabirds, with all documented effects limited to behavioural effects (see **Section 7.2.2.2.7**).

Consequently, the residual risk to seabird physiology arising from acoustic disturbance during the Seismic Survey has been assessed as **Low** (*Minor* x *Rare*).

7.2.2.2 Potential Behavioural Impacts

Behavioural responses are a demonstrable change in the activity of an animal in response to a disturbance (Nowacek *et al.,* 2007) and include movement away from an area in order to avoid a disturbance, or a change in normal behaviours such as diving, respiration, and swimming speed. In addition to avoidance response, some animals may be attracted to areas of disturbance. The most commonly observed behavioural response to active seismic operations is avoidance, which has been widely documented for marine mammals (e.g. Goold, 1996; Stone and Tasker, 2006; Thompson *et al*., 2013) and fish (e.g. Engas *et al*., 1996; Slotte *et al*., 2004), and which can lead to the displacement of animals from preferred habitat.

Displacement from an area can lead to relocation into sub-optimal or high-risk habitats, resulting in negative consequences such as increased exposure to predators, decreased foraging or mating opportunities, alterations to migration routes etc. Displacement could also have indirect effects, for instance feeding activities of predators could be disrupted by the displacement of prey species which could lead to energetic consequences.

Discussions on the behavioural impacts from vessel noise and the acoustic source on marine fauna are provided in the subsections below for each environmental receptor. Where possible, discussions have paid particular focus to species that have been identified to be potentially present within the OA through the development of this EP. Perceptual impacts (i.e. changes in vocalisations and masking) are discussed in **Section 7.2.2.3** while physiological impacts have been addressed in **Section 7.2.2.1**.

7.2.2.2.1 Benthic Invertebrates

Exposure to seismic sound can elicit various behavioural responses in benthic invertebrates. Hawkins *et al*. (2015) reports that, at lower sound levels, behavioural responses are more likely to occur than physical and/or physiological responses. Behavioural responses are, however, the most difficult to monitor *in situ* and consequently, many studies investigating the effects of seismic operations on the behaviour of benthic invertebrates are conducted under laboratory conditions or by deploying caged individuals in the field (Carroll *et al*., 2017). The limitations of these approaches are discussed in **Section 7.2.2.2.2**.

Behavioural responses have the potential to adversely affect a population by, for example, reducing foraging and/or predator avoidance rates. Conversely, they may elicit responses that are brief and pose no overall risk (e.g. a startle response). Research has shown that avoidance behaviours to sound have longer-lasting effects on populations than startle responses. For example, in the former, individuals may move away from an area where MSSs have occurred.

Carroll *et al*. (2017) provided a summary of the potential impacts of low frequency sound on the behavioural responses of marine invertebrates based on a review of the relevant literature. For decapods, foraging, reproduction and bioturbation response at unrealistic or unknown exposure levels were each reported by one study; three studies reported a possible response, conflicting or anecdotal results with respect to predator avoidance; two studies reported a possible response, conflicting or anecdotal results for startle response; and one study reported no response to sound avoidance. Studies which examine the behavioural responses of marine decapods and bivalves to seismic acoustic exposure are discussed below.

Payne *et al*. (2008) found that when the American lobster was exposed to a seismic acoustic source, a significant increase in food intake occurred for several weeks after the exposure under both laboratory and field conditions. In the laboratory, the acoustic source reached an average peak-to-peak pressure of around 202 dB with a peak energy density of 144 – 169 dB re 1 μPa^2/ Hz; in the field, the average exposure reached 227 dB peak-to-peak and had an average peak energy density of 187 dB re 1 μPa^2/ Hz. The authors hypothesised that this may have been due to an increase in stress.

Christian *et al*. (2003) examined the behaviour of snow crabs before, during and after exposure to seismic outputs and observed that, in the laboratory, they reacted slightly when sharp sounds were made near them. However, in the field, caged crab showed no readily visible reactions to the 200 in^3 acoustic source 50 m above them. Tagged crabs did not undergo any large-scale movements out of the area.

For decapods, alarm response to sound have been shown to be highly localised, with alarm behaviour occurring only when they were <10 cm away from the sound source (Goodall *et al*., 1990) and they have shown no such behaviour in response to seismic sound at distances of 1 m or more (Goodall *et al*., 1990; Christian *et al*., 2003).

There is a lack of information with regards to the behavioural effects of MSSs on shellfish. As reported by Carroll *et al*. (2017), two studies have shown evidence of a startle response in bivalves at realistic sound exposure levels (Day *et al*., 2016a; Roberts *et al*., 2015), although only one of these studies used seismic outputs as the sound source. Day *et al*. (2016a) reported that scallops exposed to seismic outputs display a distinctive flinching response, an increase in burial rate and were slower at righting themselves than control scallops. It is possible that the slowed righting response could lead to higher predation rates; however, the ecological implications of this are not clear. No energetically costly responses, such as swimming, have been observed in scallops as a result of exposure to an acoustic source.

The OA has relatively deep waters throughout, where more than 52% of the water depths of the OA are greater than 100 m. This water depth not only determines what benthic invertebrate species are living within the OA, but it also provides a large separation distance between the seismic source and the seabed. The typical distances between the acoustic source and the seabed within the OA are far greater than most of the scientific experiments conducted in the literature to assess potential effects of seismic on marine receptors, as referenced within this EP. As such, the residual risk for behavioural impacts to benthic invertebrate species from exposure to seismic sound has been assessed as **Low** (*Minor* x *Unlikely*).

The effects of acoustic surveys on catch rates and fisheries which may manifest as a result of behavioural responses discussed in this section are assessed in **Section 7.2.3**.

7.2.2.2.2 Fish

Fish have demonstrated avoidance responses to vessels, which include both vertical and horizontal movements, as well as altering schooling behaviours. Behavioural changes of fish as a result of vessel noise have been interpreted as an anti-predator behaviour (as referenced in Skaret *et al*., 2005).

Southern Bluefin tuna (listed as Conservation Dependent under the EPBC Act) could potentially be present within the OA and studies have shown that they alter their schooling behaviour when subjected to an external noise source from an approaching vessel. When schools of bluefin tuna are captured, they are held in large oceanic pens, and when they are in the presence of boat noise, it was found that they were less coherent compared to when vessel noise was not present. This was evident by a number of individual fishes increasing their vertical movements towards the surface or bottom of the pens (Sara *et al*., 2007). However, regular schooling behaviour of the bluefin tuna returned following the passing of the vessel (Sara *et al.,* 2007), therefore long-term effects to fish are only likely to occur in areas of high vessel traffic. As part of the stakeholder engagement programme, the Australian Southern Bluefin Tuna Industry Association were contacted to inform them of the Seismic Survey; however, they confirmed that the OA is not used for feeding or breeding by southern bluefin tuna and they do not need to be kept informed of any further updates of the Seismic Survey (**Appendix F**).

Avoidance behaviour in the form of horizontal and vertical movements away from vessel noise was demonstrated in herring (Vabø *et al*., 2002) and Atlantic cod (Handegard *et al*., 2003); however, no avoidance attributable to vessel noise was observed in spawning herring by Skaret *et al*. (2005). The lack of avoidance led the authors to suggest that sensitivity of fish to vessel noise is dependent on the behavioural state of the animal (e.g. actively feeding fish have relaxed predator vigilance). Avoidance behaviours to vessel noise are likely to be short-lived, with regular behaviours continuing following the passage of the vessel.

In preparing this EP, a number of behavioural studies were reviewed. In general, little indication of long-term behavioural disruption was apparent as a result of exposure to acoustic noise. Short-term responses were relatively common and included startle responses (Pearson *et al*., 1992; Wardle *et al*., 2001; Hassel *et al*., 2004; Boeger *et al*., 2006); modification in schooling patterns and swimming speeds (Pearson *et al*., 1992; McCauley *et al*., 2000; Fewtrell and McCauley, 2012); freezing (Sverdrup *et al*., 1994); and changes in vertical distribution in the water column (Pearson *et al*., 1992; Fewtrell and McCauley, 2012). Evidence of habituation was observed through a decrease in the degree of startle response (Hassel *et al*., 2004).

Behavioural responses of fish to acoustic disturbance vary depending on species traits, particularly sensory systems and the presence or absence of a swim bladder. Species which have swim bladders (or other gas-filled chambers) are generally more sensitive to sound exposure and more likely to suffer adverse effects from such exposure.

Species that do not have swim bladders or gas-filled chambers (e.g. sharks, skates, rays, jawless fishes, some flatfish, some gobies, some tuna and others) are less sensitive to sound and less likely to experience adverse effects; these species detect particle motion rather than sound pressure. In general, most fish with swim bladders are sensitive to sound frequencies between 50 and 500 Hz; MSS acoustic outputs are generally <200 Hz (McCauley *et al*., 2000). However, due to the huge range of physiology and sensory systems among animal groups, the impacts of sound on marine organisms cannot be generalised among species.

Experimental approaches to examining the effects of MSSs on fish behaviour typically involve exposing caged individuals to an acoustic source in either a laboratory or, less commonly in a field setting. As mentioned above, it is important to appreciate the limitations of caged laboratory and field experiments investigating fish behaviour. Laboratory experiments often apply intensities or durations of sound exposures that are unlikely to be encountered in the field, particularly for simulated seismic signals in tanks (Gray *et al*., 2016), whereby restricting the applicability of their results. Caution must therefore be exercised when interpreting results from captive studies as variability in the study design (i.e. source level, line spacing, timeframe, geographic area etc.) and the subjects (species, wild or farmed, demersal or pelagic, migrant or site-attached, age, etc.) often make it difficult to draw overall conclusions and comparisons. Furthermore, such studies typically only provide information on the behavioural responses of fish during and immediately after the onset of noise (Popper and Hastings, 2009). Beyond this, all behavioural observations are potentially biased by the fact that the subjects are constrained and may be unable to exhibit avoidance behaviours which would be possible in the wild.

Studies generally report short-term and localised impacts of acoustic disturbance on fish behaviour, with normal behaviour returning within approximately one hour after the removal of the acoustic source (McCauley *et al*., 2000; Pearson *et al*., 1992; Wardle *et al*., 2001).

The only evidence of a long-term behavioural effect from an MSS was noted by Slotte *et al*. (2004) who investigated the distribution and abundance of herring and blue whiting during a commercial 3D MSS off the Norwegian coast. During this study fish distribution was mapped acoustically within the seismic area and in the surrounding waters (up to 30 – 50 km away). The acoustic abundance of pelagic fish was consistently higher outside the seismic area than inside which the authors interpreted to be an indication of long-term displacement.

Pelagic fish tend to dive deeper (McCauley *et al*., 2000) and swim faster in more tightly cohesive groups (Fewtrell and McCauley, 2012), while reef species will return to the reef for shelter as the Seismic Vessel approaches and resume normal activity once the vessel has passed (Woodside, 2007; Colman *et al*., 2008). In addition to these findings, other studies have failed to detect any changes, e.g. Peña *et al*. (2013) observed no changes in swim speed, direction or school size of herring in response to a six hour exposure to a full-scale 3D MSS, and McCauley *et al*. (2000) found fish to generally show little evidence of increased stress from exposure to seismic signals unless restricted from moving away from the source, and no significant increase in blood cortisol concentrations (i.e. no increase in stress – see **Section 7.2.2.1.3**). Hassel *et al*. (2004) also found evidence of habituation to underwater noise through time.

In 2007, Woodside engaged a team of more than 20 specialists in the fields of underwater acoustics, coral reef ecology and reef fish biology to design and execute comprehensive investigations into the impacts of seismic airgun noise on (amongst other things) fish behaviour (Woodside, 2007). Behavioural observations of free-swimming fish showed that at close range, airgun noise emissions appeared to cause prominent, short-term effects on fish behaviour. As the vessel approached, fish ceased normal behaviours and moved downward from the water column towards the seabed. Fish began to feed and behave normally again within 20 minutes after the Seismic Vessel had passed. Once the vessel had travelled beyond a distance of ~1.5 km fish numbers and behaviour had returned to normal baseline levels. For caged fish, agitation levels increased with increasing received sound exposure level for the three holocentrid (squirrel fishes and soldier fishes) species studied but were not detectable for the bluestripe seaperch. Alarm responses were too infrequent to analyse (Woodside, 2007). Sonar observations of free-swimming fish showed that individuals tended to move deeper into the water column on approach of the operating seismic array consistently out to 400 m either side of the survey test line. Within 200 m of the survey test line, fish schools moved to the seabed after passage of the operating seismic array and stayed significantly closer to the seabed out to 63 minutes post-exposure. The overall conclusion from the behavioural seismic acoustic exposure experiments was that there was minimal impact on fish behaviour and that any changes that were observed were short term and unlikely to have caused any significant biological or ecological impacts (Woodside, 2007).

The Gippsland Marine Environmental Monitoring project was developed in Australia in 2015 to provide a more ecologically realistic view of the impact of MSSs on (amongst other things) fish behaviour (Przeslawski *et al*., 2016). A component of this project involved monitoring the behaviour of unrestrained fish before, during and after the April 2015 MSSs in Gippsland Basin, Bass Strait. The study monitored multiple sites in an experimental and control zone, with tiger flathead, gummy shark and swellshark individuals being tagged and released. The results showed little evidence of behavioural changes induced by the MSS in the species studied. Individuals of both shark species moved in and out of the monitored areas across the study period, and gummy sharks were detected returning to the experimental zone during the period of MSS operations. The tiger flathead did show increased swimming speed during the MSS period, probably indicating a startle response, but if so the range of movement was not sufficient to generate a significant difference in displacement (travel) across the monitored array. The flathead also showed a change in diel movement patterns after the survey had ended; however, it is possible that this was consistent with the increase in movement events that have been previously reported for some species prior to seasonal departures (Andrews *et al*., 2010).

Demersal fish, particularly those exhibiting territorial behaviour and site fidelity, may be less likely to move to avoid sound sources than pelagic species and this is supported by the findings in Meekan *et al*. (2021) here a seismic survey did not alter fish abundance or behaviour in multiple before and after control impact experiments on the North West Shelf of Australia. Miller and Cripps (2013) also found no significant effect of MSSs on fish species from the family Pomacentridae (site-attached coral obligate fish species), with respect to diversity, abundance and direct and indirect morality. Other studies (e.g. Woodside, 2007) exposing caged reef fish to the seismic outputs have found no evidence of direct mortality, soft tissue damage, or hearing threshold shifts. The majority of fish species that might be present in the EMBA are associated to reef habitats and only seven of them have been recorded in water depths greater than 50 m. Therefore, the majority of the identified species are not expected to occur across the OA and there are no records of threatened demersal species present.

Behavioural studies show little indication of long-term behavioural disruption or population level effects in pelagic and/or migratory fish (McCauley, 1994). The only evidence of a long-term behavioural effect from an MSS was noted by Slotte *et al*. (2004) as discussed above in regard to the distribution and abundance of herring and blue whiting during a commercial 3D survey off the Norwegian coast.

Carroll *et al*. (2017) produced a summary of the potential impacts of low-frequency seismic sound on fish behaviour (**Table 44**) based on a review of the relevant literature. In accordance with the above discussion, the summary showed that there were a number of studies reporting startle/alarm responses and/or sound avoidance/migration behaviours when exposed to low-frequency seismic sound at realistic exposure levels. However, other studies showed no such responses at either realistic or unrealistic exposure levels and another study reported conflicting results (**Table 44**).

With respect to acoustic threshold levels that may elicit behavioural responses in fish, McCauley *et al*. (2000) found that fish species may actively avoid sound levels of 161–168 dB re 1µPa rms (~175 – 183 SPL peak), which corresponded to a horizontal distance of ~15 km from the 4,120 in^3 array used in the study. Fewtrell and McCauley (2012) observed significant increases in alarm responses of fish to seismic outputs exceeding 147 – 151 dB re 1 µPa. These authors reported an increase in the occurrence of alarm response with increasing noise level. However, the most recent work by Meekan et al. (2021) resulted in no observed changes in fish abundance or behaviour.

Exposure criteria thresholds for fish based on all relevant literature are summarised within **Table 54**, and the UAM outputs have been used to determine at what distances away from the acoustic source these thresholds are met.

The pelagic fish species occurring within the OA are generally highly mobile and are likely to move away from the acoustic source if sound levels become uncomfortable. As such, some short-term distributional changes for fish are possible during the Seismic Survey. However, any effects are expected to be short-lived, and fish are expected to resume normal behaviour in the days following acoustic exposure and are expected to move back to their normal habitats once the vessel has passed. Given the 720 m interval between sail lines, the vessel will not be concentrated in any particular area within the OA for a long period of time and it has been estimated that the Seismic Vessel and the entire extent of the streamer and tail buoy will have passed through a particular area in under 1.5 hours.

Pelagic fish that target zooplankton as prey could be subject to indirect effects associated with changes to the abundance and distribution of zooplankton (see **Section 7.2.2.1.1**). These potential flow-on effects to marine food webs are expected to be spatially restricted to within a few kilometres of the Seismic Vessel with baseline conditions resuming relatively quickly after the survey line is complete (see Richardson *et al*., 2017). The energetic consequences of a small shift in foraging habitat will be negligible for predatory pelagic fish.

Consequently, with the implementation of the control measures (**Table 56**) the residual risk of behavioural disruption to fish species and the consequences to fisheries from seismic sound exposure during the Seismic Survey has been assessed as **Low** (*Minor* x *Likely*).

7.2.2.2.3 Cephalopods

Behavioural changes have been documented for cephalopods (squid and octopus species) in response to acoustic disturbance. Caged cephalopods that were exposed to acoustic sources demonstrated a startle response above 151 – 161 dB re 1 µPa and tended to avoid acoustic disturbance exhibiting surface behaviours (McCauley *et al*., 2000). During this study it was found that the use of soft-starts effectively decreased the startle response, and as included within **Table 56**, SLB will be operating in accordance with the EPBC Act and undertaking soft starts when commencing a survey line if the source is not already active.

A subsequent study corroborated these findings and further demonstrated that a source level of 147 dB re 1 µPa was necessary to induce an avoidance reaction in squid. Throughout this experiment, other reactions were also observed including alarm responses (inking and jetting away from the source), increased swimming speed and aggressive behaviour. It was noted that the reaction of the animals decreased with repeated exposure to the sound suggesting either habituation or impaired hearing (Fewtrell and McCauley, 2012). McCauley *et al*. (2000) suggested that thresholds affecting squid behaviour occur at 161 – 166 dB re 1 µPa rms.

Fewtrell (2003) looked at the response of southern calamari squid (*Sepioteuthis australis*) to MSS noise, finding avoidance behaviours once noise levels exceeded 158 dB re 1 µPa, and significant increases in alarm responses with noise exceeding 158–163 dB re 1 µPa. However, there was a decrease in the frequency of alarm response for repeated exposures, perhaps suggesting that they became habituated. In a similar study, Fewtrell and McCauley (2012) found that there was a significant increase in alarm response from squid as acoustic release noise levels increased beyond 147–151 dB re 1 µPa SEL, and that there were fewer alarm responses with continued exposure to acoustic source noise. Samson *et al*. (2014) found that cuttlefish became habituated to repeated 200 Hz pips at 150 dB and 165 dB, and Mooney *et al*. (2016) found that squid became habituated during sound exposure trials using 140 – 165 dB.

Fewtrell (2003) found that feeding squid ate immediately after noise exposure, suggesting rapid recovery, where it was noted that food appears to be a powerful stimulus to these animals - "*…. the presence of food in an area could override the stimulus to leave an area affected by seismic survey noise*". This is supported by McCauley *et al*. (2000a), who found that captive squid strongly associated the service dinghy with feeding, to the point where squid approached the dinghy to be fed immediately after the cessation of acoustic noise operations (from the same location). McCauley *et al*. (2000a) also found that cephalopods moved to the water surface during MSS simulation and given sound exposure is lower at the surface due to the 'Lloyd Mirror Effect' this could indicate avoidance behaviour to the sound.

Carroll *et al*. (2017) undertook a literature review on the behavioural (and other) effects of acoustic noise from MSSs on fish and invertebrates, including cephalopods (**Table 46**). The authors categorised relevant studies into the presence or absence of a response from cephalopods depending on the level of exposure. The level of exposure was determined to be either "*realistic*" for MSSs (i.e. few short bursts of low frequency sound at >1 – 2 m), or "*unrealistic / unknown*" (i.e. continuous sound exposure, >100 bursts of nearfield sound exposure, in aquaria).

Carroll *et al*. (2017) found four studies where cephalopods exhibited a startle response to realistic MSS noise. These included Fewtrell and McCauley (2012), McCauley *et al*. (2000a), Samson *et al*. (2014), and Mooney *et al*. (2016), all described in the preceding text. Carroll *et al*. (2017) included a fifth study in this list, Komak *et al*. (2005), where juvenile cuttlefish were exposed to local sinusoidal water movements of different frequencies (0.01–1,000 Hz) produced by a vibrating sphere placed 5 mm above their heads. This resulted in a startle response with no evidence of habituation, but the methods are not realistic or comparable to an MSS under the Carroll *et al*. (2017) definition.

Given their pelagic lifestyle, there is the potential for squid and cuttlefish to come near the acoustic source during the Seismic Survey. However, squid are generally short-lived, fast growing species with high fecundity rates. These life history traits mean they are well adapted to disturbance, and it follows that there is no anticipated long-term risk to squid populations given the 720 m line spacing the actual footprint the acoustic source will cover will be small compared to the actual OA.

None of the cephalopod species recorded in the OA are included in the EPBC Act List of Threatened Fauna and octopus species potentially present within the EMBA are most likely to be affiliated with reefs and coastal waters.

A typical behavioural response to an acoustic source is likely to include being startled (McCauley *et al*., 2000); however, studies have shown that squid quickly become habituated (Fewtrell and McCauley, 2012), and this behavioural disturbance does not appear to influence feeding (McCauley *et al*., 2000a). The life history traits of cephalopods (see previous section) mean they are well adapted to disturbance and combined with the above findings that they appear to become habituated to acoustic release and display other behaviour that indicates rapid recovery, suggests that there is no anticipated long-term risk to squid populations presented by the Seismic Survey. Consequently, the residual risk of behavioural impacts to cephalopod species from seismic sound exposure during the Seismic Survey has been assessed as **Low** (*Minor* x *Unlikely*).

7.2.2.2.4 Marine Reptiles

As described in **Section 4.5.5**, two threatened sea snakes and six threatened marine turtles are known or are likely to be present in the OA. An additional 15 non-threatened sea snake species may also have a presence in the OA; indeed, the Timor Sea is regarded as a sea snake biodiversity hotspot (Guinea and Whiting, 2005; Minton and Heatwole, 1975; Smith, 1926).

Nelms *et al*. (2016) conducted a thorough literature review of studies carried out world-wide to investigate the behavioural and physical impacts of seismic surveys on turtles. Compared to cetaceans and fish, research on the impacts of underwater noise on turtles is scarce.

Lenhardt (1994) found that loggerhead turtles managed to minimise exposure to seismic simulations in a confined environment by swimming to and remaining at the water surface. Also, in a confined environment, McCauley *et al*. (2000a) observed an alarm response (rapid swimming) in caged loggerhead and green turtles when acoustic source levels exceeded 166 dB re 1 µPa rms, this level has been widely adopted as 'behavioural response' threshold for marine turtles (NFS, 2011). Swimming behaviour was described as more erratic once acoustic source levels reached 175 dB re 1 µPa rms and this level has subsequently been adopted as the 'behavioural disturbance' threshold (see Connell *et al*., 2022).

As Nelms *et al*. (2016) points out, studies carried out within the confines of a cage or tank are biased by the acoustic properties of the immediate environment, and results may differ in an open ocean environment where behaviour may change because turtles are able to swim away from the acoustic source. Observations of turtle behaviour at sea are difficult because they require calm sea conditions, and it is often difficult to distinguish behavioural response from variables other than the acoustic source sounds, such as the presence of the Seismic Vessel, the towed equipment, and the observation vessel. Nelms *et al*. (2016) also raises the issue of subjective and variable interpretation of turtle behaviour by different observers, giving the example of one study reporting “no signs of panic of distress” during a seismic survey, where “behaviour consisted of either ‘steady swimming’ or ‘diving’ to avoid the vessel” (Pendoley, 1997). Similar studies, according to Nelms *et al*. (2016), categorised diving as a startle response or avoidance behaviour.

See **Section 7.2.2.1.5** for information relating to the ‘Recovery Plan for Marine Turtles in Australia 2017-2027’ (Commonwealth of Australia, 2017b).

The UAM predictions for the Seismic Survey indicate that behavioural responses would be expected at a maximum distance of 7.68 km from the acoustic source, and behavioural disturbance would be expected out to 2.44 km from the active source (**Table 51**). However, as turtles spend substantial periods of time at or near the sea surface, exposure may be avoided to some degree if their heads are out of the water or moderated by the Lloyd Mirror Effect (Carey, 2009). This effect is produced by destructive interference between the direct path of a low-frequency sound and the sea surface reflection of that sound, and results in an area of acoustic shadowing where the sound is attenuated (much quieter) or cancelled in the top 0.5 - 2 m of the water column (Gerstein, 2002 as cited in O’Shea and Poche, 2006).

Table 51 Behavioural Threshold Levels for Individual Turtles – Impulsive Noise Events

Threshold	Zones of impact – maximum horizontal distance from source to impact threshold levels	
	Criteria - RMS SPL (dB re 1µPa)	Maximum threshold distance (m)
Behavioural response	166	7,680
Behavioural disturbance	175	2,440

As identified in **Section 4.4.4**, the OA overlaps with a flatback turtle foraging BIA. Flatback turtles are classified by the EPBC Act as vulnerable and migratory. In addition, loggerhead turtle and olive ridley turtle foraging BIAs have been identified nearby (approximately 9 km to the east of the OA), and both these species are classified by the EPBC Act as endangered and migratory. Alarm responses (rapid swimming) have been observed in caged turtles during acoustic releases within the SEL range overlap for turtles and seismic surveys, although the response in an open ocean environment is unclear and turtles at or near the surface may experience lower levels of exposure than predicted. Consequently, the residual risk of behavioural impacts to marine turtle species from underwater noise exposure during the Seismic Survey has been assessed as **Moderate** (*Moderate* x *Possible*).

The way in which seismic surveys influence the behaviour of sea snakes is virtually unknown. The only study that has attempted to investigate this was conducted by the Australia and Pacific Science Foundation (AP Science, 2015) and involved 10 days of field experiments in the Ningaloo Marine Park (WA) in August 2013. A baited camera system was deployed at a fixed distance from an underwater speaker playing noise from a seismic source. None of the six olive sea snakes assessed showed an observable change in behaviour either when the sound was initiated or during the sound treatment. During the experiments, sea snakes were exposed to a peak sound pressure of 66.3 dB re 1µPA at 1 m with dominant frequencies between 20 and 100 Hz. It is considered that the source was not loud enough to trigger reactions of wild sea snakes to underwater sound, even though nearby reef fish demonstrated a startle response. The level of exposure which would elicit a behavioural response in sea snakes remains unknown; however, Chapuis *et al*. (2019) found that sea snakes demonstrate a relatively low hearing sensitivity compared to other marine vertebrates (i.e. bony fish and marine turtles). On this basis the behavioural threshold for sea snakes is assumed to be lower than that of marine turtles and the residual risk of behavioural impacts from underwater noise exposure during the Seismic Survey has been assessed as **Low** (*Minor* x *Unlikely*).

7.2.2.2.5 Marine Mammals

Noise produced by the Seismic Vessel has the potential to disrupt typical behaviours (e.g. foraging, resting) or cause displacement away from the noise source. Difficulties arise in separating the effects of shipping noise from those of the physical presence of the vessel in eliciting a response, and most studies generally involve smaller vessels (Aguilar Soto *et al*., 2006). While behavioural responses to vessels have been observed in numerous species (for reviews see Senigaglia *et al*., 2016; Machernis *et al*., 2018); it is only recently that the sensory drivers behind these behavioural responses have been linked to vessel noise specifically (Sprogis *et al*., 2020).

Blair *et al.* (2016) found evidence of behavioural responses in humpback whales to increasing vessel noise. Significant effects on foraging such as a reduction in the number of bottom-feeding events per dive, slower descent rate and fewer side-roll feeding events (evidence of a cessation of feeding or a switch to another feeding method) per dive corresponded with increasing ship noise. Such behavioural changes and interruptions to foraging events may impact on foraging rate and efficiency. Explanations presented to explain these behavioural effects include the whales perceiving the vessel as a threat, alterations to prey behaviour, or masking effects reducing foraging efficiency (Blair *et al*., 2016). Blair *et al*. (2016) suggests that although humpback whales show habituation towards vessel noise, they are unable to completely adjust to the disturbance. This is likely to be the case for other cetacean species too.

The behavioural response of Atlantic right whales was experimentally tested to controlled sound exposures; recordings of ship noise, the social sounds of conspecifics, and an 'alert' signal designed to get some form of response from the whales (Nowacek *et al*., 2007). Although the whales reacted strongly to the alert signal, and mildly to the conspecific sounds, no behavioural response was observed when subject to play-back of vessel noise. A lack of measurable response was also found when whales were approached by a vessel (Nowacek *et al*., 2007).

Dyndo *et al*. (2015) experimentally exposed penned harbour porpoises to play-back of noise from vessel passages. The penned animals reacted to vessel noise recordings by porpoising, suggesting a high level of disturbance to low levels of vessel noise (Dyno *et al*., 2015).

Disturbance from vessel noise has recently been linked to reduced foraging time for the endangered southern resident killer whale in the Pacific waters of the Salish Sea (DFO, 2017). To address this, a voluntary vessel speed reduction trial was undertaken, during which both acoustic monitoring and behavioural monitoring were conducted. This trial concluded that vessel speed reductions of 2.1 – 7.7 knots (for general cargo ships and container ships respectively) resulted in vessel noise source level reductions of 5.9 – 11.5 dB which equated to significant benefits to killer whales; reducing the affected foraging time by up to 11.5% (Vancouver Fraser Port Authority, 2018). This clearly demonstrates that reducing vessel speed is an effective way of reducing the underwater noise generated at the vessel source.

Behavioural effects from seismic surveys on marine mammals include avoidance or displacement, and changes in swimming or diving behaviour (Gordon *et al*., 2003; Miller *et al*., 2009) both of which have the potential to lead to significant reductions in sightings rates across large areas of marine ecosystem (Kavanagh et al., 2019). While behavioural responses may not have direct lethal effects on marine mammals, concern has been raised on the potential for sub-lethal effects such as increases in energy expenditure and demand, decreased foraging efficiency, disruption of group dynamics (e.g. group cohesiveness), and lowered reproductive rates leading to population-wide effects (Weilgart, 2007; 2013). Effects may also be harmless (Weilgart, 2007). Studying the behavioural effects of a MSS on marine mammals can be difficult as reactions vary depending on factors such as the species, individual, age, sex, prior experience with noise, and behavioural state (Weilgart, 2007), with studies typically focusing on opportunistic observations of surface behaviours (Verfuss *et al*., 2018). In addition, behavioural responses may be subtle and barely detectable, with the potential to incorrectly suggest an apparent tolerance (Weilgart, 2007). In open seas it is unlikely that temporary displacement would have significant energetic consequences for migrating whales, but displacement could have more significant consequences in confined waterways. An RMS SPL of 160 dB re 1 µPa has been identified for the level at which adverse behavioural disturbance could occur (NOAA, 2019). During the Seismic Survey, the maximum distance at which this threshold could be exceeded varies between 8.79 and 14.3 km from the acoustic source (**Table 52**) (following Connell *et al*., 2022).

An increase in surface behaviour (e.g. breaching or increased time spent at the surface) has been interpreted as a way of reducing exposure to the higher sound's levels from the acoustic source on account of the 'Lloyd mirror effect' (Carey, 2009) which significantly reduces sound intensity in the upper-most part of the water column. Other stress-related behaviours have also been documented for some species in the vicinity of seismic surveys (or under simulated conditions) including changes in respiration rates (Richardson *et al*., 1995), swim speed (Stone and Tasker, 2006), and diving behaviour (Richardson *et al*., 1995). Such changes were observed in bowhead whales up to 54 – 73 km from an active seismic source at received levels as low as 125 dB re 1 µPa (Richardson *et al*., 1995).

McCauley *et al*. (2000) made aerial observations on the response of southern migrating humpback whales off Australia's east coast before, during, and after a 3D MSS. A change in sighting rate from the seismic vessel was observed, with sighting rate considerably higher near the vessel with no active source compared to operational periods, suggesting a localised avoidance during operations. Observations suggest that humpback whales spent extended periods of time in surface waters reducing the received sound loading (McCauley *et al*., 2000). During periods where the acoustic sources were alternated between on and off compared to continuously on or off periods, sighting rates increased suggesting either a startle or investigative response of the whales that brought them to the surface. Active whales consistently undertook avoidance manoeuvres (altered course and speed) at >4 km to pass no closer than 3 km behind an operating seismic vessel, while those engaged in sedentary behaviour avoided the operating vessel at a range of 7 – 12 km (McCauley *et al*., 2000). Approach trials were also carried out using a single operating acoustic source; mean SELs for avoidance behaviours to occur was 140 dB re 1 µPa SPL and startle responses were observed at 112 dB re 1 µ Pa SPL (McCauley *et al*., 2000).

Avoidance responses of humpbacks such as increased distance from a seismic source and reduced travel speed have also been observed in more recent studies such as Dunlop *et al.* (2016), supporting the findings of McCauley *et al*. (2000). Dunlop *et al*. (2015) also surveyed southward migrating humpback whales off Australia's east coast and suggested that the whales show little or no behavioural response to acoustic source emissions; however, as the received levels were low (close to background levels up to 156 dB re 1 µPa), they may not have been high enough to elicit an observable and consistent behavioural response (Dunlop *et al*., 2015). McCauley *et al*. (2000) hypothesised that actively migrating whales are less sensitive to seismic emissions and were at a low risk to seismic activities, while whales engaging in resting behaviours at key habitats (e.g. resting grounds), and cow-calf pairs were particularly sensitive (McCauley *et al*., 2000). This highlights the importance of considering the context of exposure where animals engaged in certain behaviours are likely to disproportionately affected by noise disturbance (Gomez *et al*., 2016).

Following the Dunlop *et al*. (2015) study, Dunlop *et al.* (2017) aimed to further quantify responses of migrating humpback whales and looked at the recovery of whales following the cessation of acoustic emissions. This was then compared to normal behaviours (e.g. dive time, respiration rate, various surface behaviours, and group movement) to assess the biological significance of any response. No abnormal behaviours such as separation of cow-calf pairs or sustained bouts of high energy surface behaviours were observed, and 'typical' behaviours such as singing, surface slapping, conspecific socialising and continuation of general southward migratory travel continued. This led the authors to conclude that the addition of the Seismic Vessel and acoustic emissions had little impact on typical behaviours and there was no evidence the whales were under significant additional stress. Small and temporary changes in typical behaviours were observed; however, these were within the normal behavioural repertoire of migrating groups. Speed of southward movement was slower in trials with active acoustic sources, although this reflected deviance from course instead as opposed to reduction in travel speed. While Dunlop *et al*. (2017) did not determine whether this deviation in migration path would have long-term effects, they did note that migrating whales are only likely to be exposed to a seismic survey for a short period of time before moving away as part of their migration. Dunlop *et al*. (2017) observed that changes in movement behaviour are likely to occur within 4 km from the Seismic Vessel at received levels over 135 dB re 1 µPa. Clear course changes of migrating humpback whales were observed by Dunlop *et al*. (2017) at received levels of 144 – 151 dB re 1 µPa, lower than that of Dunlop *et al*. (2015).

Blue whales are suggested to be more sensitive to emissions from seismic surveys than other baleen whales such as humpback whales (McDonald *et al*., 1995). Tracking data from a blue whale located in an area where an active Seismic Vessel was operating recorded a long-range avoidance response beginning 10 km from the vessel. The whale's track diverged from that of the vessel by approximately 80° and from its original course by approximately 120°. Estimated received levels at the whale's location were 143 dB re 1 µPa peak-to-peak (McDonald *et al*., 1995). This study only tracked a single blue whale, so the sensitivity of this species to seismic surveys remains somewhat unclear, although in the absence of more data this information certainly informative.

Avoidance behaviours of minke (likely Antarctic minke), sei and fin whales have also been reported. In an analysis of reports from Seismic Vessels operating in UK waters from 1998 – 2003, Stone (2003) concluded that ranges of minke, sei and fin whales to Seismic Vessels were higher for sightings made during surveys than at other times, suggesting avoidance of the operating vessel. Avoidance of MSSs by fin whales is supported by the findings of Castellote *et al*. (2012) who observed extended displacement which lasted well beyond the duration of the survey.

Studies into behavioural responses of sperm whales to MSSs have revealed variable results. Mate *et al*. (1994) observed a significant decrease in sperm whale abundance in the Gulf of Mexico, with the closest whales observed at least 50 km away from an active seismic survey. However, results of Jochens *et al.* (2016), Weir (2008), Stone and Tasker (2006) and Madsen *et al*. (2002) contradict those of Mate *et al.* (1994). In Weir (2008), encounter rates did not differ with operational status of the acoustic source array, and although the mean distance to initial sighting was greater during full-operations, this effect was not statistically significant. In Madsen *et al*. (2002), sperm whales receiving sound pressures of 124 dB re 1 µPa did not change behaviours or elicit an observable avoidance of the area, and whales instead remained in the area for at least 13 days of exposure. More recently sperm whale distribution was monitored by satellite tag (n = 51 tagged whales) in relation to seismic survey activity in the Gulf of Mexico. Statistical analysis to determine if whale distribution varied from that expected under spatially random conditions concluded that there was no evidence of horizontal avoidance (Winsor *et al*., 2017).

In a review of over 200 seismic surveys in UK waters, Stone and Tasker (2006) also found no statistically significant behavioural effects of seismic activity on sperm whales. Jochens *et al.* (2016) report on a multi-year (2000 – 2003) sperm whale tagging study in the Gulf of Mexico. Eight sperm whales were tagged and tracked before, during, and after playback of seismic noise. All whales continued on their course of travel and did not avoid the Seismic Vessel throughout the playback; however, two whales showed dive changes indicative of avoidance by deep-diving during full-array exposure, and all whales responded in a fashion expected to result in reduced energetic expenditure (i.e. lowered number of pitching movements); evidence of an effect on foraging behaviour (Jochens *et al*., 2016). Observations of distance response was conclusive with that of Madsen *et al.* (2002) whereby there was no obvious response to pulses at a range of 20 km (Jochens *et al*., 2016). Jochens *et al*. (2016) suggests that conflicting results may reflect a broad spread in sensitivity of sperm whales to sound based on age and sex or history of sound exposure.

During a 3D MSS off Nova Scotia, Moulton and Miller (2005) observed the behaviours of a number of smaller odontocete species: long-finned pilot whales, common dolphins, Risso's dolphins, striped dolphins, and Atlantic spotted dolphins. Except for the long-finned pilot whale and Atlantic spotted dolphins, all these species have been identified within the NWMR (**Section 4.5.6**). Dolphins were consistently observed during periods when acoustic sources were active; however, some dolphins exhibited localised avoidance behaviours on account of distance to initial sighting being significantly less during non-operational periods. Some dolphins were observed riding the bow of the seismic vessel (a distance of 350 m from the active source) and exhibiting feeding behaviours during active operations. Within 700 m of the active source, dolphins would be exposed to sound levels exceeding 180 dB re 1 µPa (rms) (Moulton and Miller, 2005). Goold (1996) also suggests a localised avoidance of common dolphins to a 2D MSS, with dolphins tolerating seismic emissions outside a 1 km radius.

Harbour porpoises were displaced from an active 470 in^3 acoustic source array over ranges of 5 – 10 km during a 2D MSS over a range of 5–10 km at received peak-to-peak sound pressure levels of 165 – 175 dB re 1 µPa and sound exposure levels of 145 – 151 dB re 1 µPas-1 and were temporarily displaced (Thompson *et al*., 2013). However, these animals were detected again at the affected sites within a few hours after exposure (Thompson *et al*., 2013). Thompson *et al*. (2013) concluded that prolonged MSSs did not lead to broad-scale displacement of marine mammals and that impact assessments should focus on sub-lethal effects. However, it is noted that the acoustic source used for this study was far smaller than the source proposed by SLB for the Seismic Survey; hence, the zone of influence around the 3,000 in^3 source is expected to be larger.

The results of Moulton and Miller (2005), Goold (1996) and Thompson *et al.* (2013) studies are inconsistent with the Stone and Tasker (2006) analysis which suggested small odontocetes (i.e. dolphins) exhibit the strongest lateral spatial avoidance of airguns compared to mysticetes, killer whales, and long-finned pilot whales (Stone and Tasker, 2006). As discussed in the EPBC Act Policy Statement 2.1, smaller dolphins and porpoises are less likely to be disturbed by an MSS (and are less vulnerable to acoustic trauma) than baleen and larger toothed whales. This is on account of the frequency produced in an MSS being lower than the high frequency peak sensitivities of the smaller dolphin species.

Killer whales remain further from a seismic source when active indicating some level of spatial avoidance, although no reduction in sighting rate in response to an active acoustic source has been observed (Stone and Tasker, 2006). Long-finned pilot whales also show little response to an active acoustic source; the only observed effect is a change in orientation with more moving away from, and fewer towards a vessel during seismic activity (Stone and Tasker, 2006).

The behavioural impacts of seismic surveys on beaked whales are largely unknown as beaked whales are very difficult to observe whilst at sea but based on their observed responses to mid-frequency active sonar (i.e. increased swim speed, unusual dive behaviours and multiple unusual mass stranding events that have ultimately caused the death of individuals) this group is believed to be particularly sensitive to anthropogenic noise (Stimpert *et al*., 2014). Although sonar represents a vastly different sound source to what is used in an MSS, in the absence of any data on the effects of seismic surveys on beaked whales, their responses to sonar provide a useful indication of what might be expected of other underwater noise sources.

In addition to avoidance responses, there is also anecdotal evidence of marine mammals being attracted to seismic operations. For example, common dolphins have been observed repeatedly approaching an operating Seismic Vessel to bow ride as it entered shallow coastal waters. McCauley *et al*. (2000) observed what were believed to be male humpback whales approaching an operating acoustic source and hypothesised that this was due to the similarity to sounds produced by humpback whale breaching.

Typically, the distribution of marine mammals is closely linked to that of their prey (see Fielder *et al*., 1998), therefore avoidance of the Seismic Vessel could lead to abandonment of valuable feeding grounds (e.g. large aggregations of krill or fish) or reduced foraging effort. Resident marine mammals that consistently use the Timor Sea as a foraging ground (e.g. Bryde’s and Omura’s whales) are of particular note in this regard due to the spatial overlap between foraging areas and the acoustic footprint of the Seismic Survey.

In addition, changes in abundance and distribution of prey species are also well recognised as potential indirect effects of seismic surveys (Simmonds *et al*., 2004) whereby the availability of prey species can change as a result of acoustic disturbance (e.g. fish; Pearson *et al*., 1992; McCauley *et al*., 2000; Colman *et al*., 2008; Handegard *et al*., 2013, and zooplankton; McCauley *et al*., 2017). Such indirect effects could lead to decreased foraging efficiency, higher energetic demands, lower group cohesion, higher predation rates and decreased reproduction rates in marine mammals (Weilgart, 2007). Such indirect effects are much more difficult to detect and measure than direct effects; however, as with direct effects, they are likely to vary with species, individuals, age, sex, past exposure and behavioural state (IWC, 2007). As discussed in **Section 7.2.2.1.1**, acoustic disturbance has been linked to changes in abundance and distribution of zooplankton. Distributional changes in zooplankton (particularly krill) could have flow on effects to foraging baleen whales.

If behavioural impacts do occur during the Seismic Survey, the discussion above highlights that impacts are generally greater for baleen whales than odontocetes and that threatened species that are reliant on biologically important habitat in the proximity of the OA or resident species for which understanding of population and conservation status is unclear are of potential concern. On this basis, the species listed below are of note:

- Pygmy blue whales (endangered/migratory) – potential migratory presence from late Apr to mid-Jan;

- Fin whales (vulnerable/migratory) – potential presence from May to Oct, but at very low densities;
- Sei whales (vulnerable/migratory) – potential presence from Apr to Nov, but at very low densities;
- Humpback whales (migratory) – potential presence from Jun to early Oct, mostly inshore of OA;
- Bryde's whale (migratory) – potential year-round presence in OA; and
- Omura's whale – potential year-round presence in OA.

The underwater noise level at which behavioural disturbance is likely to occur for most marine mammal species is generally accepted to be SPL 160 dB re 1 µPa (NOAA, 2019) (**Table 52**). However, (and as discussed earlier in this section), behavioural effects resulting from seismic operations have been documented in some species at levels lower than this (see McCauley *et al*., 2000; Dunlop *et al*., 2017; 2017a; McDonald *et al*., 1995) indicating substantial variance in behavioural response between species, individuals and sound levels. It is also noteworthy that severe behavioural responses are not consistently associated with higher source levels but are context dependent as well (i.e. influenced by what behaviour an individual is engaged in) (Gomez et al., 2016; Pirotta *et al*., 2021).

Table 52 Behavioural Disruption Threshold for Marine Mammals – Impulsive Noise Events (NOAA, 2019)

Marine mammal hearing group	Zones of impact – maximum horizontal distance from source to impact threshold levels		
	Criteria - SPL (dB re 1µPa)	Water Depth (m)	Range of maximum threshold distance (km)
All hearing groups	160	all	8.79 – 14.3

The following suite of survey design features, mitigations and management procedures are being proposed to minimise potential behavioural impacts to an **Acceptable Level** (see **Table 60** for further detail):

- 'Standard Management Procedures' in accordance with the EPBC Act Policy Statement 2.1. These will be adhered to throughout the OA (observation zones, pre-start-up visual observations, soft start procedures, delayed start-up procedures, continuous daylight observations, stop work procedures, night-time and low visibility procedures). Noting that 24-hour operations will occur where possible;
- 'Additional Management Procedures' in accordance with the EPBC Act Policy Statement 2.1. These will be adhered to throughout the OA (extended shut-down zone for baleen whales, presence of experienced MMOs, use of PAM). These additional measures have been implemented on account of the Seismic Survey having a 'moderate to high likelihood' of encountering whales. These additional procedures are particularly important given the presence of biologically important habitat in the proximity of the OA, in particular the blue whale migratory BIA;
- 'Additional Blue Whale Migratory BIA and Buffer Management Procedures' over and above the requirements of the EPBC Act Policy Statement 2.1. SLB recognises that the potential to encounter whales increases as the OA approaches and overlaps with the migration BIA for blue whales. To address this, a 17 km buffer will be established around the blue whale migratory BIA and a suite of additional mitigations have been developed as follows:
    - The Seismic Vessel will not activate the seismic source within the blue whale migratory BIA or buffer from mid-April (14^{th}) to mid-January (14^{th}) being the period over which this species is predicted to have a presence (see **Table 21**);
    - Outside this period (15 Jan to 13 April), seismic operations inside the blue whale migratory BIA or buffer will:

a) Implement an extended observation zone of 5 km;

b) The extended observation zone in the BIA and buffer will be monitored using the Chase Vessel as an additional observation platform with two MMO's onboard. The Chase Vessel will travel c. 3 km ahead of the Seismic Vessel and will conduct visual surveillance for marine mammals during daylight hours. Trained and experienced MMOs will be required to undertake these observations;

c) Whenever possible, two experienced MMOs will be on the bridge of the Seismic Vessel during daylight hours when the source is active within the blue whale migratory BIA or buffer;

d) Limit soft start procedures to conditions that allow visual inspection of the 5 km Observation Zone; and

e) Cease night-time or low visibility operations in the blue whale migratory BIA or buffer if three or more whale instigated shut-downs or power-downs are made during the preceding 24-hour period. Note that this applies irrespective of shut-down/power-down locations relative to the blue whale migratory BIA or buffer. Night-time and low visibility operations may only resume in the blue whale migratory BIA or buffer after 24 hours of no blue whale instigated shutdowns (again, irrespective of location relative to the blue whale migratory BIA or buffer); and

f) If species identity is uncertain at any location inside the blue whale migratory BIA or buffer, any unidentified whale will be assumed to be a blue whale.

- 'Adaptive Management Procedures' in accordance with the EPBC Act Policy Statement 2.1. Where a survey is proposed in an area that is spatially and temporally on the edge of areas considered to provide biologically important habitat, the following adaptive management procedures to manage the potential increased likelihood of encountering whales will be implemented throughout the OA:
  - For blue whales –

    a) If three or more blue whale instigated shut-downs occur within a 24-hour period, the Seismic Vessel will relocate to another area at least 17 km away (and outside of the blue whale migratory BIA or buffer) before commencing Pre Start-up Visual Observations and Soft Start Procedures. This mitigation will be implemented throughout the entire OA (i.e. shut-downs both inside and outside the blue whale migratory BIA and buffer will contribute to this count); and

    b) If a blue whale mother and calf pair is observed during the Seismic Survey, the acoustic source will be immediately shut-down and the Seismic Vessel will relocate to another area at least 17 km away (and outside of the blue whale migratory BIA or buffer) before commencing Pre Start-up Visual Observations and Soft Start Procedures. This mitigation will be implemented throughout the entire OA (i.e. sightings both inside or outside the blue whale migratory BIA and buffer will trigger this mitigation measure).
  - For other baleen whales –

    a) Night-time or low-visibility operations will cease if there have been three or more whale instigated power-down or shut-down situations during the preceding 24-hour period;

    b) If three or more baleen whale instigated shut-downs occur within a 24-hour period, the Seismic Vessel will relocate at least 10 km away before commencing Pre Start-up Visual Observations and Soft Start Procedures; and

c) If a baleen whale mother and calf pair is observed during the Seismic Survey, the acoustic source will be immediately shut-down and the Seismic Vessel will relocate to another area at least 10 km away before commencing Pre Start-up Visual Observations and Soft Start Procedures.

The survey design also confers a degree of mitigation against disturbance to marine mammals as 1) The OA is located in open ocean; hence, will not impact any confined water body; and 2) The long survey lines with 720 m line spacing will ensure that the Seismic Vessel will not focus in any specific area for a long period of time or expose any marine mammals to potential cumulative effects from acoustic noise being concentrated in one location.

Experienced MMO's will be on watch at all times during daylight hours to monitor 2 km shut-down zone for baleen whales, and while the proposed 2 km shutdown zone will not fully protect whales from behavioural disturbance (which according to UAM results could occur out to 14.3 km), it represents a significant extension on the standard shutdown zone of 500 m for whales as required by the EPBC Policy Statement 2.1.

SLB will also implement both spatial and temporal exclusions to minimise the potential effects of underwater survey noise on blue whale migration, whereby no seismic operations will occur in the BIA or buffer during the period in which blue whales are expected to be migration. Acquisition within this zone will be limited to the period of 15 Jan to 13 Apr when the least number of blue whales are expected to be in the area. This spatio-temporal control represents best international practise for minimising noise disturbance in areas of high density and biological importance during key periods (following Chou *et al*., 2021).

In accordance with the Blue Whale Conservation Management Plan (Action Area A2) "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 implementation of the additional control measures when the acoustic source is active in the BIA and buffer will protect blue whales from both injury and behavioural disturbance (i.e. displacement). Therefore, it is considered that the residual environmental impacts and risks of the proposed Seismic Survey on blue whales are managed to an **Acceptable Level**.

As Conservation Management Plans are not available for all other marine mammal species that have been identified as having a potential presence in and around the OA, the following considerations contribute to the ERA results:

- With the exception of blue whales, behavioural responses (especially displacement) are expected for most marine mammals within 10 - 15 km of the acoustic source and serve to protect marine mammals from hearing injury;
- Most other baleen whales are probably only present in and around the OA at low or very low densities (see **Table 50** and related discussion);
- On account of their different hearing sensitivities, odontocetes are less likely to be disturbed by seismic survey noise; and
- The closest important dugong habitat is well beyond the 14.3 km zone of behavioural impact.

In summary, with the implementation of the extensive control measures that have been specifically developed to take into account all the different marine mammal sensitivities within the OA and surrounds, the residual risk of behavioural impacts to marine mammal species from acoustic disturbance during the Seismic Survey has been assessed as **Moderate** (*Moderate* x *Likel*y).

7.2.2.2.6 Elasmobranchs

Sharks are part of an important commercial fishery within Australian waters and the Gippsland Marine Environmental Monitoring Project (Przeslawski *et al*., 2018; 2018a) found that seismic operations resulted in no evidence of consistent adverse effects on commercial catch rates of sharks, with some species (i.e. elephant fish, broadnose and school sharks) having increased catch rates following the MSS, while others (i.e. gummy shark and saw shark) showed decreased catch rates.

Elasmobranchs detect sound via particle motion and some of the highest sound sensitivity to low frequency sound (~20 Hz to ~1,500 Hz) (Myrberg, 2001; Casper, 2011; Casper *et al*., 2012), which is the largest proportion of sound frequency that is generated during an MSS (Carroll *et al*., 2017). However, given what has been stated above, elasmobranchs will still show a response to noise; where Klimley and Myrberg (1979) found that sharks would withdraw from high intensity sound source that was more than 20 dB re 1 µPa above broadband ambient SPL once within 10 m of the source location.

Many species of shark are predatory and use their 'hearing' to locate prey. Therefore, any interruptions to their ability to find/detect food through excessive noise in the environment could impact on the sharks feeding ability (Popper, 2003). Free-swimming elasmobranchs (such as pelagic shark species) have been found to have more sensitive hearing apparatus (specifically the *Macula neglecta*) than bottom-dwelling species (Corwin, 1978), possibly placing the pelagic species at greater chance of hearing damage if subjected to high intensity noise sources.

Based on the available information presented in this section and the likely physiological effects to elasmobranchs (**Section 7.2.2.1.7**), significant impacts on elasmobranchs, including whale sharks which are a protected species under the EPBC Act, and predicted to be foraging through the southern part of OA and EMBA, from the Seismic Survey are predicted to be unlikely.

As a result, the residual risk of behavioural impacts to elasmobranchs from seismic sound exposure during the Seismic Survey has been assessed as **Low** (*Minor* x *Unlikely*).

7.2.2.2.7 Seabirds

Although there is little information about the behavioural effects of MSSs on seabirds, a number of authors have raised the possibility of disruption to feeding activities. For instance, Goudie and Ankney (1986) suggested that seabird feeding behaviours could possibly be interrupted by acoustic disturbance from the Seismic Vessel passing through feeding grounds; and MacDuff-Duncan and Davies (1995) postulated that birds in the area could be alarmed as the seismic operations pass close-by, causing them to temporarily stop diving. In addition to the potential direct displacement of seabirds, the displacement of bait fish could lead to a reduction in the diving activities and foraging potential for seabirds in the immediate vicinity of the seismic operations.

Lacroix *et al*. (2003) assessed the effect of seismic operations on the foraging behaviour of moulting male long-tailed ducks in the Beaufort Sea. Long-tailed ducks are incapable of flying during the moult and, in order to compensate for this nutritionally costly moult process, increase their foraging time during this period. The findings of Lacroix *et al*. (2003) indicated that the abundance and distribution of ducks in both seismic and control areas changed similarly following the start of seismic operations suggesting that other influencing factors (e.g. wind) were more important for duck distribution than seismic activities, and that seismic activity did not significantly change the diving intensity of ducks. Overall, Lacroix *et al*. (2003) concluded that there was no evidence to suggest any displacement away from active seismic operations.

Pichegru *et al*. (2017) assessed the foraging behaviour of African penguins before, during and after an MSS that occurred within 100 km of breeding colonies. Penguins foraging within 100 km of the active seismic source showed a change in foraging direction, increasing the distance between feeding area and Seismic Vessel. Displaced penguins reverted back to normal foraging behaviours following the cessation of seismic activities, suggesting effects are relatively short-lived. It is worth noting that although the Pichegru *et al*. (2017) study was unable to differentiate between penguins shifting foraging activities in direct response to the survey (i.e. behavioural effect) or indirectly due to a change in prey distribution, a behavioural response was determined as the most likely cause. While the penguins were able to locate alternative feeding grounds, the displacement from traditional grounds resulted in an increase in energy expenditure (Pichegru *et al.,* 2017).

Although the Lacroix *et al.* (2003) and Pichegru *et al*. (2017) studies were not carried out on species potentially present within the OA, and found differing results, their results suggest that at most seabirds will be temporarily displaced from areas of active seismic operations, and displacement effects will be short-lived, with animals able to return to traditional feeding grounds after the Seismic Vessel has moved away. The 720 m line spacing's will assist in minimising the disturbance to seabird's behaviour during the Seismic Survey.

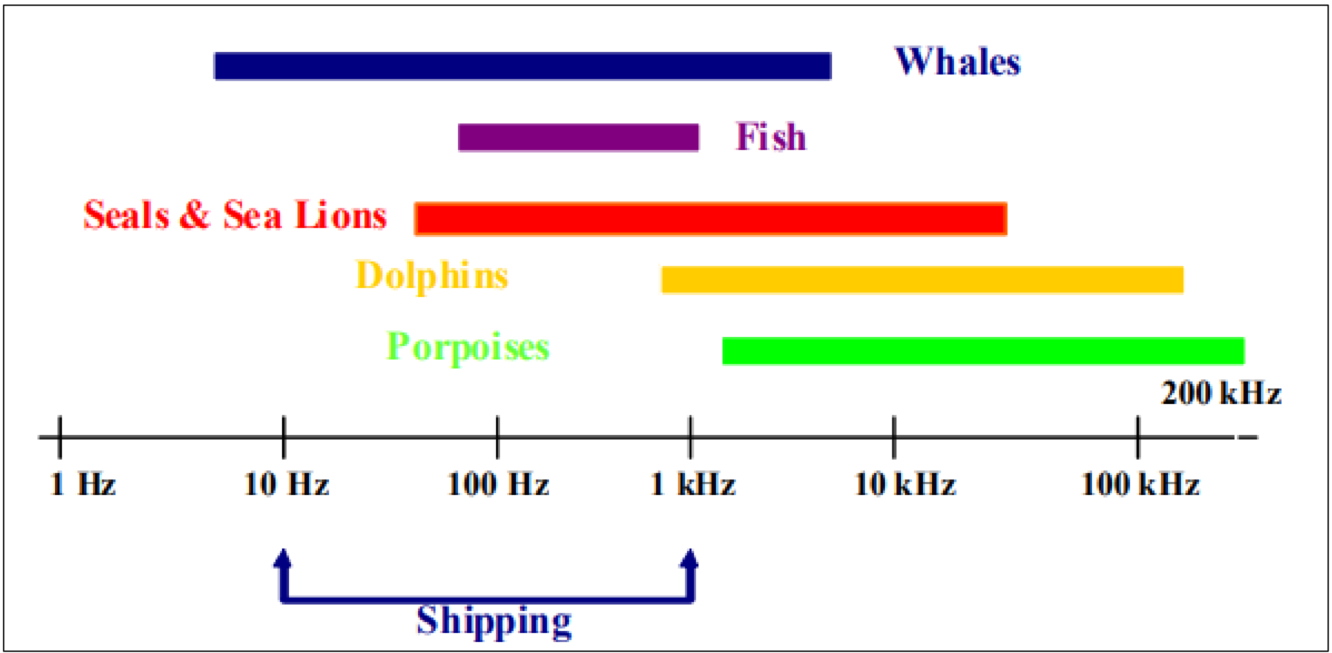
Consequently, the residual risk of behavioural impacts to seabird species from seismic sound exposure during the Seismic Survey has been assessed as **Low** (*Minor* x *Possible*).

7.2.2.3 Potential Perceptual Impacts

Marine animals produce sound for a variety of functions (e.g. navigation, communication, predator and prey detection), and even those that do not produce sound utilise sounds around them to learn about and gain an overall awareness of their environment (Fay and Popper, 2000). The ability to perceive biologically important sounds is therefore crucial to these animals. The addition of anthropogenic noise into the marine environment can disrupt an animal's ability to communicate and/or detect biologically important signals (Dunlop *et al.,* 2010). 'Masking' is an increase in the threshold for detection of discrimination of one sound as a consequence of another (Brumm and Slabbekoorn, 2005) and can be either complete, whereby the signal is not detected at all, or partial, whereby the signal is detected but unable to be properly understood (Clark *et al*., 2009). The effects of masking on an animal's fitness and survival include: blocking/alteration of signals alerting to the presence of predators (Lowry *et al*., 2012), incorrect assessment of the quality of rivals or potential mates lowering reproductive success (Halfwerk *et al.,* 2011), and disruption in group cohesion through a breakdown in communication particularly between parents and offspring (Leonard and Horn, 2012).

The general low frequency band of shipping noise overlaps with the frequencies generated by marine fauna, particularly fish, whales, and pinnipeds (**Figure 44**) (Southall and Hatch, 2008). Masking of biologically significant sounds has been suggested to be the primary effect of vessel noise on marine fauna (Southall, 2005).

Figure 44 Typical Frequency Bands of Sound Produced by Marine Fauna compared to Sounds associated with Commercial Shipping



Source: Southall and Hatch, 2008.

The following provides a discussion on the effects of masking on auditory communication of fish and marine mammals (particularly cetaceans).

7.2.2.3.1 Fish

Vessel noise overlaps with frequencies within the hearing and sound production ranges of many fish, which may mask important biological sounds. For example, vessel noise has been experimentally confirmed to increase detection thresholds for biological sounds in two species of reef fish (brown meagre drums and Mediterranean damselfish), with passing boats reducing detection distances under field conditions by up to 100 times (Codarin *et al*., 2009).

Some fish species produce sounds for communication purposes, with vocalisations typically within a frequency band of 100 Hz to 1 kHz (Ladich *et al*., 2006; Bass and Ladich, 2008). There have been no studies into the effects of MSSs on sound masking in fish, although other anthropogenic sounds (e.g. boat noise) have reportedly caused masking (see Picciulin *et al*., 2012). It is therefore reasonable to assume that sound emissions from an MSS could also result in masking of fish calls. For fish species with good hearing, Popper *et al*. (2014) suggested there is a greater likelihood of masking further from the acoustic source than close to it as masking is more likely for these fish when the animals are far enough away from the source for the sounds to merge and become more or less continuous.

Radford *et al*. (2014) suggest five ways in which fish might adapt to masking:

- Avoidance of noise: This can occur either spatially or temporally. Temporal avoidance involves taking advantage of gaps or fluctuations in competing noise, e.g. silver perch vocalise less frequently when recordings of a predator (bottlenose dolphin) were played (Luczkovich *et al*., 2000);
- Temporal adjustments: Signal detection enhances as signal duration increases as a consequence of an increase in the probability that some of the signal is detected during a quieter period, e.g. male toadfish increase their call rate to compete acoustically in the presence of rival males (Fine and Thorsen, 2008);

- Amplitude shifts: In noisy environments, an increase in amplitude increases signal detection (the Lombard Effect). Although this effect has been demonstrated in a number of vertebrates, it is yet to be demonstrated in fish in response to anthropogenic noise;
- Frequency shifts: Broadband sounds are more difficult to detect in a noisy environment than pure tones, e.g. freshwater gobies in waterfall habitats produce vocalisations in a frequency that differs from that of the waterfall noise; they utilise available 'windows' in the background frequency range (Lugli *et al*., 2003); and
- Change in signalling modality**:** The repertoire of a species usually consists of more than one signal component; hence when one signal type is ineffective, the caller may swap to another signal type to increase the chance of detection, e.g. a change from vocalisations to visual signals.

Little is known about fish vocalisations for marine fishes in the OA; however, in line with the precautionary principle it is reasonable to assume that the Seismic Survey may lead to some masking for some fish species.

As masking of fish communication by anthropogenic sound has been demonstrated; therefore, the residual risk of noise perception by fish species from seismic sound exposure during the Seismic Survey has been assessed as **Low** (*Minor* x *Likely*).

7.2.2.3.2 Marine Mammals

Marine mammals produce sounds that are used to inform a range of behaviours: foraging, navigation, communication, reproduction, parental care, avoidance of predators, and to gain overall awareness of the environment (Thomas *et al*., 1992; Johnson *et al*., 2009). Hence, the ability to perceive biologically important sounds is fundamental to the survival of these animals. Anthropogenic sounds in the same frequency as biological signals can mask biologically important sounds and potentially lead to significant individual effects (Gausland, 2000). Masking is a common effect of underwater noise on marine mammals (Erbe *et al*., 2016) and activities that generate anthropogenic noise are increasing both spatially and temporally in coastal and oceanic environments worldwide (Hatch *et al*., 2016).

The level of masking that will occur depends on several factors other than the noise doing the masking, such as the location of the sender and receiver, source level and spectral characteristics of the signal, and the receiver's auditory capabilities (Erbe *et al*., 2016).

Marine mammals are broadly separated into categories based on hearing capability (Southall *et al*., 2019). The following categories are of relevance to the species potentially present during the Seismic Survey:

- Low frequency cetaceans (auditory bandwidth between c. 0.007 kHz and 22 kHz). Include all mysticete whales, i.e. all baleen whales, Species from this group that could occur in the OA include blue whale, fin whale, sei whale, Bryde's whale, humpback whale, Omura's whale and dwarf minke whale;
- High-frequency cetaceans (auditory bandwidth between c. 0.15 kHz and 160 kHz). Include most dolphins, beaked whales, sperm whales and killer whales. Species from this group that could occur in the OA include sperm whales, Blainville's beaked whale, Cuvier's beaked whale, killer whale, false killer whale, pygmy killer whale, short-finned pilot whale, melon-headed whale, Risso's dolphin, bottlenose dolphins (3 types), spinner dolphin, striped dolphin, spotted dolphin, rough toothed dolphin, common dolphin, Fraser's dolphin, Australian snubfin dolphin, Australian humpback dolphin;
- Very-high frequency cetaceans (auditory bandwidth between 0.2 kHz and 180 kHz). Include true porpoises, most river dolphins, pygmy/dwarf sperm whales, and Commerson's, Chilean, Heaviside's, Hector's hourglass and Peale's dolphins. Pygmy sperm whales and dwarf sperm whales are the only species from this group that could occur in the OA; and

- Sirenians (auditory bandwidth between 5 kHz and 60 kHz with peak sensitivity c. 5 kHz). Include dugongs and manatees. Dugongs are the only species from this group that could occur in the OA.

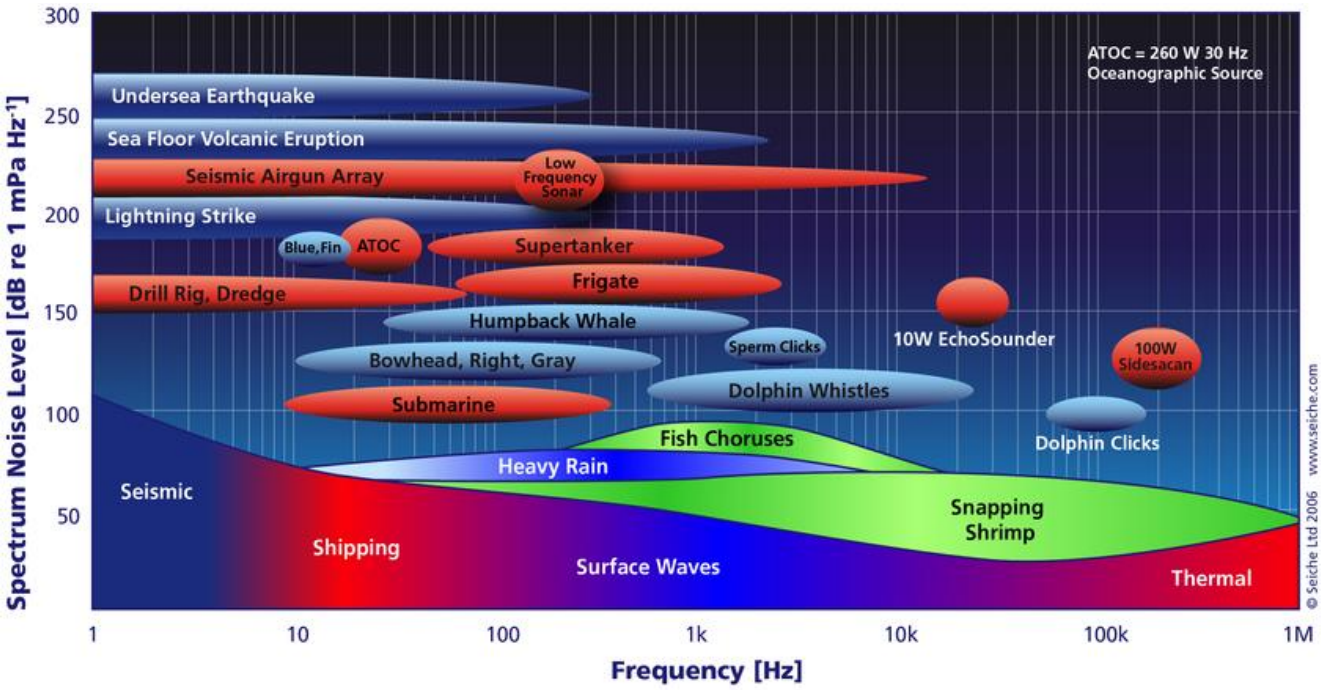
Aguilar Soto *et al*. (2006) reported on preliminary data showing that elevated received noise levels from a passing large ship (with a closest point of approach of 700 m) coincided with an unusual foraging dive in Cuvier's beaked whales, suggesting that elevated noise from shipping may interrupt foraging behaviours by masking echolocation and communication. Evidence suggests that blue whales (McDonald, 2006), killer whales (Holt *et al,* 2008), and North Atlantic right whales (Parks *et al*., 2007) can adjust the frequency and loudness of their calls to compensative for masking by vessel noise, while fin whales alter bandwidth and duration of calls in response to increasing background noise from shipping (Castellote *et al.,* 2012). Communication in two delphinid species (bottlenose dolphin and pilot whales) was also demonstrated to be reduced in the presence of vessel traffic, with communication range reduced by 26% within 50 m of a vessel travelling at 5 knots (Jensen *et al.,* 2009).

The sound frequencies that are emitted by seismic acoustic sources are broadband, but with most of the energy concentrated between 0.1 kHz and 0.25 kHz. The greatest potential for interference with cetacean vocalisations is at the highest end of the seismic spectrum and the lowest end of the cetacean vocalisation spectrum (**Table 53**); i.e. the lowest frequency cetaceans are particularly affected since they have the most overlap with the frequencies of the seismic survey acoustic sources (**Figure 45**). Auditory masking of high- and very-high-frequency cetacean vocalisations is less likely as these species generally operate at higher frequencies than those generated by a seismic survey. The same goes for dugongs that produce sounds for short-range communication in a range much greater than that generated by seismic surveys and have peak hearing sensitivity at around 8 kHz (Southall et al., 2019).

Table 53 Cetacean Communication and Echolocation Frequencies

Species	Communication Frequency (kHz)	Echolocation Frequency (kHz)
Minke whale	0.06 – 6	N/A
Sei whale	1.5 – 3.5	N/A
Blue whale	0.0124 – 0.4	N/A
Fin whale	0.01 – 28	N/A
Humpback whale	0.025 – 10	N/A
Sperm whale	<9	0.1 – 30
Pygmy sperm whale	No data available	60 – 200
Beaked whales*	3 – 16	2 – 26
Common dolphin	0.5 – 18	0.2 – 150
Pilot whale	1 – 18	1 – 18
Killer whale	0.1 – 35	12 – 25
Bottlenose dolphin	0.2 – 24	0.5 – 130
Dugongs	0.15 - 18	NA
* = using the bottlenose whale as an example		

Source: summarised from Simmonds *et al.*, 2004



Source: Professor Rodney Coates, The Advanced *SONAR* Course, Seiche (2002)*; from* www.seiche.com

Figure 45 Ambient and Localised Noise Sources in the Ocean

A number of studies have documented adaptive responses (anti-masking strategies) to anthropogenic underwater noise (Erbe *et al*., 2016). Anti-masking strategies include changes in vocalisation strength, frequency, and timing. For example, blue whales increased their calls (emitted during social encounters and feeding) when a seismic survey is operational in the area (Di lorio and Clark, 2010). Such adaptations have been documented in species such as humpback whales (McCauley *et al*., 1998; 2003b), beluga whales (Lesage *et al*., 1999), right whales (Parks *et al*., 2007, 2011), killer whales (Holt *et al.*, 2008), and bottlenose dolphins (van Ginkel *et al*., 2017) where it is thought that increased calling increases the probability that communication signals will be successfully received by conspecifics by reducing the effects of auditory masking.

Marine mammals may also cease vocalising in response to anthropogenic noise, as has been demonstrated in humpback whales at breeding grounds off Angola in response to an MSS whereby singing activity declined with increasing received levels of the seismic pulses (Cerchio *et al*., 2014). Cessation in singing at a breeding ground was implied to have the potential to affect mating behaviour and success (Cerchio *et al*., 2014). This response is not novel to seismic surveys, with humpbacks also halting vocalisations in response to emissions from acoustic fisheries tools (Risch *et al.,* 2012). Cessation in clicking was also observed in sperm whales by Bowles *et al.* (1994) in response to weak seismic survey pulses (received level of 115 dB re 1 µPa); however, contradictory to the findings of Bowles *et al.* (1994), Madsen *et al*. (2002) did not document any changes in male sperm whale clicks in response to an MSS off Norway. Sperm whales did not cease clicking and did not seem to alter their normal acoustic behaviour during feeding (Madsen *et al*., 2002).

Decreases of three echolocation parameters (number of clicks per minute, minutes with detectable click trains and feeding buzz frequency) were also reported for harbour porpoises in the Danish North Sea within an 8 – 12 km radius of a MSS (Sarnocinska *et al*., 2020). The authors of this study provided evidence to suggest that displacement of porpoises was not the main driver of this effect, but instead that the results instead suggest a change in echolocation behaviour representing a decrease in porpoise foraging efficacy.

The calling rates of bowhead whales near an MSS were found to vary with changes in received SELs (Blackwell *et al*., 2015). In this study, at very low SELs (only just detectable) calling rates increased. As SELs continued to increase, calling rates levelled off (as SELs reached 94 dB re 1 µPa^2-s), then began decreasing (at SELs greater than 127 dB re 1 µPa^2-s), with whales falling virtually silent once SELs exceeded 160 dB re 1 µPa^2-s. Hence adaptations to masking for some species may be limited to circumstances when whales are subject to only low to moderate SELs. Similar results were also reported by Thode *et al*. (2020) where bowhead whale call density increased with exposure to weak SELs from MSS (a 10 – 15 dB increased above ambient noise) and then dropped with increasing cumulative SELs. This study confirmed that whales could completely compensate for MSS noise at low received levels (with whale call volume increasing by nearly 20 dB), but this ability increasingly diminished as MSS noise levels rose; to the point where a 40 dB increase in cumulative SEL (from MSS) prompted call level increases of only a few dB whereby whale communication space was substantially compromised.

Blue whales vocalise at a low frequency (average of 0.01 – 0.110 kHz) (McDonald *et al*., 2001; Miller *et al*., 2014), meaning that their calls can travel hundreds of kilometres underwater. The amplitude of their calls can reach levels of up to 188 dB re 1ɥPa m-1 (Aroyan *et al*., 2000; Cummings and Thompson, 1971). Passive acoustic monitoring has proven to be ineffective at detecting the low frequencies of blue whale calls and some other baleen whales. While SLB will utilise a PAM system during the Seismic Survey (**Appendix J**) this system will be useful for detecting some low-frequency vocalisations and of high- and very-high- frequency cetaceans, (particularly sperm whales). Mitigations for baleen whales have been designed without reliance on PAM detections.

While our understanding of the sound pressure component of whale vocalisations is reasonable, Mooney *et al*. (2016) demonstrated that acoustic fields generated by singing humpback whales include significant particle velocity components as well and these are also detectable over long distances. Further research is warranted with regard to the role that particle motion plays in whale communication and how anthropogenic noise might affect this.

It is likely that marine mammals in the vicinity of the OA during the Seismic Survey may be subject to some masking effects. In particular, the frequency of baleen whale calls overlaps directly with the low frequency seismic operations (**Figure 45**). The long survey lines and the 720 m line spacing of the Seismic Survey will reduce the potential for significant masking effects as underwater noise from the active source will be transitory throughout the OA (i.e. not focused in any one area for an extended period). Several control measures will be implemented during the Seismic Survey to reduce and minimise potential impacts to cetaceans that may arise from the effects of acoustic disturbance (**Table 56**).

Masking levels are difficult to predict, and no auditory thresholds exist for masking effects on marine mammals (Erbe *et al*., 2016); however, as outlined above masking responses (e.g. changes in calling rates) have been documented to occur at relatively low exposure levels (i.e. lower than would elicit any behavioural response). The UAM results for the Seismic Survey clearly predict relatively high cumulative SELs (**Table 48**); hence sound levels sufficient to elicit masking will certainly occur in the OA and surrounding waters. Any masking effects will however cease at the completion of the survey and are highly unlikely to have detectable population level effects on any marine mammal species. On this basis the residual risk of impacts to noise perception by marine mammal species from seismic sound exposure and vessel noise during the Seismic Survey has been assessed as **Moderate** (*Minor* x *Certain*).

Table 54 Summary of Horizontal Distances from 3,000 in^3 Acoustic Array in the Water Column and Seabed at which Potential Impacts to Marine Receptors may occur

Receptor and Source	Behavioural		Impairment						Mortality/ Potential Mortal Injury	
			TTS		PTS		Recoverable Injury			
	Threshold Criteria	Distance (m)	Threshold Criteria	Distance (m)	Threshold Criteria	Distance (m)	Threshold Criteria	Distance (m)	Threshold Criteria	Distance (m)
Fish eggs & larvae (also relevant for plankton)										
Popper *et al.* (2014)									SEL_{24hr} :>210 PK:>207	80 150-200
Benthic Invertebrates										
Crustaceans (Payne *et al.*, 2008) Bivalves (Day *et al.*, 2016a; 2017) Sponges and Corals (Heyward *et al.* 2018)									Crustaceans PK:>202 Bivalves PK:>212 Sponges & corals PK:>226	307-426 10.5 at depth 75m Not reached
Fish (Popper *et al.* (2014)										
No swim bladder			SEL_{24hr}: >>186 dB	6,480 - 10,500			SEL_{24hr}: >216 PK: >213	80 80	SEL_{24hr}: >219 PK: >213	80 80
Swim bladder - not involved with hearing			SEL_{24hr}: >>186	6,480 - 10,500			SEL_{24hr}: 203 PK: >207	100 200	SEL_{24hr}: 210 PK: >207	80 150-200
Swim bladder - that is involved with hearing			SEL_{24hr}: 186	6,480 - 10,500			SEL_{24hr}: 203 PK: >207	100 200	SEL_{24hr}: 207 PK: >207	80 150-200

Marine Reptiles											
Sea Turtles (NSF, 2011; Finneran *et al.*, 2017; McCauley *et al.*, 2000b)	RMS SPL: 166 (response) RMS SPL: 175 (disturbance)	7,680 2,440	SEL_{24hr}: 189 PK: 226	1,820 – 6,110 -	SEL_{24hr}: 204 PK: 232	80 -					
Marine Mammals (NOAA, 2019; Southall *et al.*, 2019)											
Low frequency Cetaceans	RMS SPL: 160	8,790 – 14,300	SEL_{24hr}: 168 PK: 213	38,900 - 47,500 80	SEL_{24hr}: 183 PK: 219	5,750 - 6,840 -					
High frequency Cetaceans	RMS SPL: 160	8,790 – 14,300	SEL_{24hr}: 170 PK: 224	70 – 80 -	SEL_{24hr}: 185 PK: 230	- -					
Very high frequency Cetaceans	RMS SPL: 160	8,790 – 14,300	SEL_{24hr}: 140 PK: 196	180 – 500 790 – 920	SEL_{24hr}: 155 PK: 202	80 290 - 480					
Sirenians (Dugong)	RMS SPL: 160	8,790 – 14,300	SEL_{24hr}: 175 PK: 220	80 -	SEL_{24hr}: 190 PK: 226	- -					

Note: Peak sound pressure levels (PK): dB re 1 µPa;

Cumulative sound exposure level (SEL24hr): dB re 1 µPa2 ·s;

Per-pulse SEL: dB re 1 µPa2 ·s

RMS SPL: dB re 1 µPa

* At a distance of 20 km from the source, distortion and reflection effects will result in smearing of the distinct peak in in the noise pulse that occurs very close to the source. The 20 km distance assumes there is no smearing, i.e. the difference between the noise levels remans 29.6 dB at all distances, an extremely conservative assumption at this distance.

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

7.2.2.4 Potential Impacts on Protected and Sensitive Areas in the Marine Coastal Environment

A number of protected and sensitive environments, species and habitats have been identified in the waters within the EMBA (**Section 4.4**). These include AMPs, State Marine Parks, KEFs, BIAs, the Australian Whale Sanctuary, Ramsar wetlands, National Heritage places and Commonwealth Heritage sites.

The following sections provides an assessment on the values within these protected and sensitive environments from the proposed Seismic Survey. It is worth noting that the following sections have only focused on those sensitive areas that may be impacted by the acoustic disturbance associated with the Seismic Survey, which includes AMPs (specifically the Oceanic Shoals Marine Park), BIAs and KEFs.

7.2.2.4.1 Australian Marine Parks

There are no AMPs located within the OA. However, five AMPs were identified within the EMBA and their associated separation distances from the Seismic Survey are listed below, in order of proximity:

- Oceanic Shoals Marine Park (1.5 km from the OA, 17 km from the Acquisition Area);
- Kimberley Marine Park (69 km from the OA, 79 km from the Acquisition Area);
- Cartier Island Marine Park (100 km from the OA, 122 km from the Acquisition Area);
- Ashmore Reef Marine Park (140 km from the OA, 155 km from the Acquisition Area); and
- Joseph Bonaparte Gulf Marine Park (290 km from the OA, 345 km from the Acquisition Area).

The conservation and management of these AMPs falls under the relevant NWMR and NMR Management Plans, which sets out the management zoning and IUCN categorisation within each AMP and determines the activities allowed within each zone in accordance with the EPBC Act.

The categorisation and zoning consider the purposes for which the reserves were declared, the objectives of the Management Plans, and the requirements of the EPBC Act and associated regulations. The IUCN Category Zones for each of the AMPs is outlined within **Table 11**, and discussion on the key management principles and purpose of each AMP is outlined within **Section 4.4.1**.

Due to the separation distance between the Acquisition Area and the AMPs (listed above), the following discussion focuses on the AMP that is most likely to receive sound levels above which impacts may occur on the conservation values within that AMP; that being the Oceanic Shoals Marine Park. Based on the findings of acoustic modelling conducted by JASCO (Connell *et al*., 2022) and due to their further distance from the OA, noise levels within the Kimberley, Cartier Island, Ashmore Reef, and Joseph Bonaparte Gulf Marine Parks are not expected to elicit behavioural or physiological changes to marine receptors and are, therefore, not considered further within this section.

The Oceanic Shoals Marine Park has multiple IUCN Categories associated within it; however, the most proximate to the Seismic Survey is Multiple Use Zone (IUCN VI) seen in **Figure 14**. The NMR Management Plan allows for seismic surveys to continue within areas classified as IUCN Category VI (Special Purpose Zone and Multiple Use Zone) if effects from such activities allow the following objectives to be met:

- Provide for the protection and conservation of biodiversity and other natural and cultural values of the North-west and North Network; and
- Provide for ecological sustainable use and enjoyment of the natural resources within the North-west and North Network where this is consistent with the above objective.

Activities considered appropriate must be consistent with the Australian IUCN Reserve Management Principles as provided for within Schedule 8 of the EPBC Regulations; those that are relevant to IUCN Category VI are as follows:

- The biological diversity and other natural values of the reserve or zone should be protected and maintained in the long term;
- Management practices should be applied to ensure ecologically sustainable use of the reserve or zone; and
- Management of the reserve or zone should contribute to regional and national development to the extent that this is consistent with these principles.

As outlined within **Section 5**, SLB consulted with DNP about the Seismic Survey in February 2022. This consultation confirmed that as the proposal is not within an AMP, no authorisation requirements from the DNP are required. However, the DNP outlined some of the specific values of the Oceanic Shoals Marine Park that this EP needs to consider, due to the proximity of the proposed activity to the AMP. These values include, but are not limited to, the following:

- Species listed as threatened, migratory, marine or cetacean;
- BIAs including foraging and interesting habitat for marine turtles;
- Carbonate bank and terrace systems of the Van Diemen Rise—an area characterised by terraces, banks, channels and valleys supporting sponges, soft coral, polychaetes, ascidians, turtles, snakes and sharks;
- Carbonate bank and terrace system of the Sahul Shelf—an area characterised by terraces, banks, channels and valleys, supporting sponges, soft corals, sessile filter feeders, polychaetes and ascidians;
- Pinnacles of the Bonaparte Basin—an area that contains the largest concentration of pinnacles along the Australian margin, where local upwellings of nutrient-rich water attract aggregations of fish, seabirds and turtles; and
- Shelf break and slope of the Arafura Shelf—an area characterised by continental slope, patch reefs and hard substrate pinnacles that support over 280 demersal fish species.

Although the Seismic Survey does not specifically overlap the Oceanic Shoals Marine Park itself, it does overlap with some features that are identified values within the Marine Park. To avoid unnecessary duplication in this EP, the values associated with the Oceanic Shoals Marine Park and where the potential impacts on those values are addressed within this EP are outlined in **Table 55.**

Table 55 Conservation Values within the Oceanic Shoals Marine Park that may be affected by Acoustic Disturbance

Conservation Values	Location in EP for full assessment of acoustic effects on conservation values
Carbonate bank and terrace system of the Sahul Shelf KEF	This KEF is regionally important due to its role in enhancing biodiversity and local productivity relative to its surrounds by providing elevated hard substrates to which organisms can adhere and expose filter-feeders to the maximum amount of passing nutrients. As outlined in **Section 7.2.2.1.2**, while there is limited published literature on the potential impacts of seismic noise on sponges and other sessile benthic invertebrates, any impacts are expected to be temporary, localised and restricted to the parent population. However, changes at the community level will unlikely be discernible from the natural variation observed. The potential risk to benthic invertebrates and sponges within the KEF has been assessed as low. Due to the temporary and localised nature of the effects, biodiversity will be protected and maintained in the long-term and the functioning and integrity of these benthic communities will be maintained. The Seismic Survey will not be inconsistent with the IUCN VI principles and the objectives of the Management Plan.
Pygmy blue whale migration BIA	Potential impacts on pygmy blue whales have been assessed in **Section 7.2.2.1.6** (physiological impacts) and **Section 7.2.2.2.5** (behavioural impacts), which in turn directly relates to the potential impact on the BIA. The results of these two sections found that, based on the control measures being in place, the impacts are at worst moderate. Due to this, and the control measures in place to manage any potential impacts on blue whales, it is considered that the Seismic Survey will not be inconsistent with the IUCN VI principles and the objectives of the Management Plan.
Whale shark foraging BIA	The whale shark foraging BIA represents waters where solitary whale sharks may forage during the migration from Ningaloo, which occurs primarily in spring (September to November) and partially overlaps the OA. Potential impacts from the Seismic Survey on whale sharks has been discussed within **Section 7.2.2.1.7** (physiological impacts) and **Section 7.2.2.2.6** (behavioural impacts), which in turn relates to potential impacts on the BIA itself. Based on the assessments within these sections and the control measures to be implemented during the Seismic Survey, it is considered that the Seismic Survey will not be inconsistent with the IUCN VI principles and the objectives of the Management Plan.
Olive Ridley, Loggerhead and Flatback turtle foraging and interesting BIAs	As outlined in **Section 4.5.5** there are several BIAs for marine reptile species, including Olive Ridley, Loggerhead and Flatback turtle, in the region, including within the OA, along the coastline and offshore islands adjacent to the OA, and within or close to the EMBA. Potential impacts from the Seismic Survey on the species associated with the foraging and interesting BIAs are discussed within **Section 7.2.2.1.5** (physiological impacts) and **Section 7.2.2.2.4** (behavioural impacts). The conclusion of both of these sections is that the impacts from the Seismic Survey on marine reptiles is low. Based on this, the Seismic Survey will not be inconsistent with the IUCN VI principles and the objectives of the Management Plan.
Cultural values within the NT northern region and the Kimberley region	As outlined within **Section 4.6**, there are no cultural values located within the OA itself; however, there are values located inshore of the OA, within the EMBA. Due to this separation distance, the potential impacts from the Seismic Survey on cultural values are limited to those unplanned activities (i.e. potential hydrocarbon spill). As such, an assessment of the potential impacts on cultural values is discussed within **Section 8.3.4** in relation to the unlikely event of a hydrocarbon spill. Based on these assessments, the Seismic Survey will not be inconsistent with the IUCN VI principles and the objectives of the Management Plan.

An EP cannot be approved if the activity is likely to result in unacceptable impacts that are inconsistent with the IUCN principles and relevant Management Plan objectives. Based on the discussions within **Table 55**, and the assessments on the various conservation values associated with the Oceanic Shoals Marine Park throughout **Section 7**, along with the implementation of the control measures, it is considered that the Seismic Survey will not be inconsistent with the IUCN principles and the NMR Management Plan objectives when operating within the OA.

7.2.2.4.2 Biologically Important Areas

BIAs are spatially defined areas where aggregations of individuals of a species are known to display biologically important behaviours. These areas have no legal status; however, a number of Conservation Management Plans outline recommendations for MSSs operating within a defined BIA. BIAs for mammals, reptiles and seabirds has been registered within the OA and/or EMBA.

BIAs associated with 21 different threatened and/or migratory species were identified as potentially occurring within the OA (four BIAs for three different species; Pygmy Blue whale, Whale shark and Flatback Turtle) and the EMBA (28), 32 BIAs in total, see summary in **Table 13**. The BIAs are linked to behaviours as; foraging, distribution, migration, resting, breeding, calving and nursing.

There are eleven seabird BIAs represented by nine different threatened and/or migratory species (classified by the EPBC Act) of relevance to the EMBA, none of these overlap with the OA. As discussed in **Sections 7.2.2.1.8** (physiological impacts) and **7.2.2.2.7** (behavioural impacts), the consequence of potential impacts from seismic sound exposure during the Seismic Survey on seabirds have been assessed as **Low** (*Minor* x *Rare*) for all potential impacts.

A foraging BIA for whale shark (classified as vulnerable and migratory) overlaps with the OA. The potential impacts of acoustic disturbances on whale shark have been discussed in detail in **Sections 7.2.2.1.7** (physiological impacts), **7.2.2.2.6** (behavioural impacts), and **7.2.2.3.1** (perceptual impacts). As a result, the residual risk of impacts to elasmobranchs from seismic sound exposure during the Seismic Survey has been assessed as **Low** (*Minor* x *Rare*) for potential physiological impacts and as **Low** (*Minor* x *Unlikely*) for potential behavioural impacts.

The OA overlaps with a flatback turtle foraging BIA. Flatback turtles are classified as vulnerable and migratory. In addition, loggerhead turtle and olive ridley turtle foraging BIAs have been identified nearby (approximately 9 km to the east of the OA), and both these species are classified as endangered and migratory. The potential impacts of acoustic disturbances on these turtles have been discussed in detail in **Sections 7.2.2.1.5** (physiological impacts) and **7.2.2.2.4** (behavioural impacts). As a result, the residual risk to marine reptile physiology arising from acoustic disturbance during the Seismic Survey has been assessed as **Low** (*Minor* x *Possible*) for potential physiological impacts and **Low** (*Minor x Unlikely*) for potential behavioural impacts.

Pygmy blue whale migration and known distribution BIAs overlaps with the northwest part of the OA. The nearest blue whale feeding BIA is located 294 km southwest of the OA. Pygmy blue whales are classified as endangered. There is a high likelihood of encountering pygmy blue whales in and around the migratory BIA for most months of the year. The potential impacts of acoustic disturbances on blue whale have been discussed in detail in **Sections 7.2.2.1.6** (physiological impacts), **7.2.2.2.5** (behavioural impacts), and **7.2.2.3.2** (perceptual impacts).

All Australian marine mammals are fully protected under the EPBC Act, so the potential for causing adverse effects during any MSS is taken extremely seriously. The animat modelling results for cumulative TTS and PTS onset distances shows that the standard shutdown zones recommended in the EPBC Act Policy Statement 2.1 are insufficient to manage the risk of auditory impairment to baleen whales during the Seismic Survey. Based on the findings of the modelling results, additional management procedures and control measures are proposed and will be implemented for blue whales during the seismic survey when the acoustic source is active in the BIA and buffer area (see proposed control measures in **Sections 7.2.2.1.6**, **7.2.2.2.5**, **7.2.2.3.2** and a summary of all control measures for managing acoustic disturbance during the Seismic Survey in **Table 56**).

With specific regards to the objectives of the blue whale recovery plan, the Seismic Survey will be consistent with the objectives within this recovery plan, and it is considered that anthropogenic noise in the blue whale migratory BIA will be managed through the survey design and implementation of the additional control measures so that any blue whale may continue to utilize the area without injuries or behavioural disturbances. Therefore, it is considered that the residual environmental impacts and risks of the proposed Seismic Survey on blue whales are managed to an **Acceptable Level**.

The residual risk of potential physiological impacts on blue whales arising from acoustic disturbance during the Seismic Survey has been assessed as **Low** (*Moderate* x *Rare*). The residual risk of behavioural impacts to blue whales from acoustic disturbance during the Seismic Survey has been assessed as **Moderate** (*Moderate x Likely*) The residual risk of impacts to noise perception on blue whales from seismic sound exposure and vessel noise during the Seismic Survey has been assessed as **Moderate** *(Minor x Certain).*

Based on the risk assessments for all marine receptors, the total residual risk to all BIAs within the EMBA arising from the Seismic Survey has been assessed as **Low** (*Minor x Unlikely*).

7.2.2.4.3 Key Ecological Features

The OA overlaps with one KEF, the Carbonate Bank and Terrace System of the Sahul Shelf. There are five KEFs within the wider EMBA. A summary of the relevant KEFs and area of overlap is described in **Table 12** and displayed in **Figure 15.**

The Carbonate Bank and Terrace System of the Sahul Shelf KEF is recognised for its role in enhancing biodiversity, which values apply to both benthic and pelagic habitats. The banks are also known as a biodiversity hotspot for sponges, in addition to foraging areas for several turtles. Humpback whales and green and freshwater sawfish are also likely to occur in the area (Donovan *et al*., 2008). The KEF does not overlap with the blue whale BIAs.

The known and potential impacts from acoustic disturbances associated with the Seismic Survey on all identified marine receptors supported by this KEF, have been discussed throughout **Sections 7.2.2.1** (potential physiological effects) and **Section 7.2.2.2** (potential behavioural effects), as well as **Section 7.2.2.3** (potential perceptual effects) together with a residual risk assessment for each receptor.

The residual risk of potential impacts on marine receptors, apart from marine mammals, arising from acoustic disturbance during the Seismic Survey has been assessed as **Low.** The residual risk of potential impacts on marine mammals arising from acoustic disturbance during the Seismic Survey has been assessed as **Low** – **Moderate**.

Based on the risk assessments for all marine receptors, the residual risk to Carbonate Bank and Terrace System of the Sahul Shelf KEF arising from the Seismic Survey has been assessed as **Low** (*Minor x Unlikely*).

7.2.3 Known and Potential Impacts on Commercial Fisheries

Effects on commercial fishing from the Seismic Survey may occur via two main mechanisms:

- the physical presence and interaction of the seismic survey vessel and towed equipment has the potential temporarily exclude fishers from their fishing grounds and inconveniences in needing to plan their fishing operations around the planned survey routes (discussed in **Section 7.1.3.1**); and
- underwater sound from the seismic source has the potential to affect fish species which are targeted to be caught.

Changes in the behaviour and physiology of fish and invertebrate species (see **Sections 7.2.2.2.1**, **7.2.2.1.3** and **7.2.2.2.2**) as a result of the Seismic Survey can potentially affect commercial fishing operations (McCauley *et al*., 2000). Although the analysis of catch data does not reveal the underlying mechanisms that may cause changes in catch rates, such data are, understandably, the response type most directly of interest to the fishing industry.

The primary fishery in and around the OA is the NDSMF, with a very minor amount of fishing also being undertaken in the OA under the MMF.

As discussed in **Section 7.2.2.2.2**, acoustic disturbance associated with seismic surveys may modify fish behaviour, and this is often observed as fish moving away from a loud acoustic source to reduce or minimise their exposure. As a result of modified fish behaviour, local abundances, distributions and, consequently, catch rates may be impacted during seismic surveys. This has the potential to manifest as short-term effects on catch rates within and around a survey area. However, fish behavioural responses are often observed to be temporary and short-term, with fish returning to their original area after a short period of time. For example, studies by Engås *et al.* (1996) and Slotte *et al*. (2004) have observed fish species (cod/haddock and blue whiting/herring respectively) moving back to their original areas within five days following the completion of seismic activity.

A number of studies have examined the effects of seismic activities on catch rates of fish species. A recent critical review by Carroll *et al*. (2017) concluded that such studies have found positive, inconsistent, or no effects of seismic surveys on catch rates or abundance of fish.

Bruce *et al*. (2018) examined the impacts of a 2D MSS in Australia's Gippsland Basin using a combination of field studies and analysis of commercial catch rates before and after the seismic survey, with this study representing one of the few studies on the direct effects of seismic discharges on unrestrained fish in the field. The displacement and movement of tiger flathead, gummy sharks, and swell sharks was monitored using acoustically tagged wild caught and released fish. Tags were detected by receivers placed on the seabed, allowing the movement of fish to be tracked. Catch rates were compared within each gear type (i.e. Danish seine and gill-net) before and after the survey (January 2012 – October 2015); three years prior to the survey was taken into account to examine any seasonal and inter-annual variation, and six months post-survey to examine potential impacts. The survey utilised a single 2,530 in^3 acoustic source array, with a highest measured SEL of 146 dB re 1 µPa recorded at 51 m water depth when the acoustic source was operating 1.4 km away. The response of the study species to the seismic survey was found to be species-specific, showing the following results:

- Movement of gummy sharks and swell sharks out of the monitored area largely occurred prior to the commencement of the MSS, although both species moved in and out of the monitored area throughout the study period, with two gummy sharks returning to the experimental zone during seismic operations;

- Of the tiger flathead located within the experimental zone during seismic operations, 50% remained in the area for the entire survey, and 50% departed. None of those that departed returned; however, a degree of residency was suggested for those detected for extended periods, and a possible seasonal movement out of the area was suggested due to all but one individual of this species departing the monitored area by mid-June. The percentage of recorded movements was greater after the survey, with movements during this period more consistently spread throughout a diel cycle;
- An increase in tiger flathead swimming speed was observed during the survey period, suggesting a potential short-term startle response to the MSS activities;
- Catch rate analysis indicated changes in the six-month period following the MSS in nine out of the 15 analysed species; catch rates increased in six species, while three showed reductions in predicted catch rates. The authors note; however, that sawshark catch in the Danish seine sector increased sharply prior to the MSS which is likely to have inflated the predicted catch rate, leading to a greater perceived decrease in catch following the survey than might otherwise have occurred; and
- Changes in catch rate was found to be species and gear specific, with no single species showing a consistent pattern in variation in catch between gear types.

Overall, Bruce *et al*. (2018) concluded that little evidence of consistent behavioural responses (excluding flathead movement) or catch rate changes induced by the seismic survey were found.

Meekan *et al.* (2021) undertook a large-scale experiment that assessed the impacts of a seismic survey on tropical demersal emperors, snappers, and groupers/rock cods on the North West Shelf of WA. The behaviours and movements of fishes were assessed at high, medium, and low exposure sites, as well as at control sites. The results showed there were no short-term or long-term effects on the composition, abundance, size structure, behaviour, or movement of the studied fishes. The study found there to be little evidence that fish were displaced by the exposure to the seismic source – movements of fish occurred over a limited area and there was no evidence for the departure of fish after exposure. There was little evidence to suggest that seismic surveys had impact on demersal fishes in this study.

Also, in Australia, Thomson *et al*. (2014) undertook a desktop study of four fish species (gummy shark, tiger flathead, silver warehou, school whiting) in the Gippsland Basin, Bass Strait and found no consistent relationships between catch rates and effects from 183 seismic surveys undertaken in the area. These authors do however acknowledge that the large historical window of the seismic data may have masked immediate or short-term effects which cannot therefore be excluded. A further desktop study in 2015 targeted a single seismic survey and found that catch rates in the six months post-survey, six of the 15 species examined showed higher catch rates, three species showed reduced catch rates, and five species showed no change (Przeslawski *et al.,* 2016a).

International studies that report no significant effects of seismic activities on catch rates include Pickett *et al*. (1994), who documented the distribution of bass in Lyme Bay (UK) during an MSS (peak source of 202 dB re 1 µPa@1 m) over three and a half months and found no long-term changes in bass distribution or large-scale emigrations from the survey area. In another study, Jakupsstovu *et al*. (2001) undertook a large-scale study on catch rates around the Faroe Islands and found that although the majority of fishers perceived a decrease in catch during seismic operations, analysis of logbook records during periods with and without seismic operations showed no significant effect of seismic activity on catch rates in the area. Furthermore, La Bella *et al*. (1996) found no changes in trawl catches of short-finned squid (*Illex coindetti*) or Norway lobster (*Nephrops norvegicus*) one day after an MSS using an acoustic source at a SPL of 210 dB re 1µPa @ 1 m (corresponding to levels of 149 dB re 1µPa at the animals' location) in the Central Adriatic Sea.

Løkkeborg *et al.* (2012) found that during seismic activities on a Norwegian fishing ground, catch rates changed for all species studied, except for saithe. Gillnet catches for redfish and Greenland halibut increased by 86% and 132% respectively, compared to pre-activity levels. In contrast, longline catch rates fell (16% for Greenland halibut, 25% for haddock). These varied results were explained by greater swimming activity versus lowered food search behaviour in fish exposed to air-gun sound emissions. Acoustic mapping of fish abundance did not suggest displacement from fishing grounds, suggesting strong habitat preference in some species.

Some studies clearly demonstrate a reduction in catch per unit effort in close proximity to seismic operations. Such effects are usually temporary and localised, generally lasting from one to five days following the cessation of seismic activity. For example, Bendell (2011) analysed long-line catches off the coast of Norway during the acquisition of a two-week MSS with a peak source level of 238 dB re 1 µPa@1 m. Catch rates reduced by 55 – 80% within the survey area for distances up to 5 km from the active source; however, these reductions were temporary with catch rates returning to normal within 24 hours of the seismic operations ceasing. There are no studies reporting evidence of long-term displacement in commercially fished species.

In studies where reductions in catch rates occur in conjunction with seismic activities, it can often be difficult to conclusively attribute a change in catch rate to the impacts of such exposure. For example, Engas *et al*. (1996) investigated the abundance and catch rates of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) in the central Barents Sea seven days before, five days during, and five days after seismic acquisition using acoustic sources. They found that trawl catches of cod and haddock and longline catches of haddock declined, on average, by 50% after acquisition started and longline catches of cod reduced by 21%. Catch rates did not return to pre-survey levels during the five-day period after seismic acquisition ended. These authors hypothesised that the reduction in Atlantic cod and haddock catch rates reported from commercial longlines and trawls was most likely due to fish moving away from the seismic area; however, Skalski *et al*. (1992) argued that it may have been due to decreased responsiveness to baited hooks associated with an alarm behavioural response, or impacts related to fishing the same area for over two weeks. Some authors (e.g. Gausland, 2003) also argue that reductions in catch may represent natural fluctuations in fish stocks or long-term negative trends.

Sometimes, apparent increases in catch rates are observed in response to seismic surveys. For example, significant changes to catch rates (both increases and decreases) were reported in response to seismic surveys in Prudhoe Bay, Alaska (Streever *et al*., 2016). These changes were attributed to fish displacement with increased and decreased catch rates occurring depending on the location and timing of fishing efforts in relation to the survey.

Catch rates could also conceivably change in response to flow-on effects associated with changes in the abundance or distribution of zooplankton prey. As discussed in **Section 7.2.2.1.1**, a recent study by McCauley *et al*. (2017) links seismic survey to zooplankton mortality, which could presumably have a negative effect on the prey availability for some pelagic fish species. However, any potential flow-on effects to marine food webs are expected to be spatially restricted to within a few kilometres of the Seismic Vessel with baseline conditions resuming relatively quickly after survey completion (see Richardson *et al*., 2017).

Behavioural changes which may result from seismic activities also have the potential to affect fish spawning activities. This may occur as a result of fish temporarily diverting efforts away from spawning aggregations, egg production and recruitment success. Masking of fish vocalisations may also reduce the amount of spawning activity (Hawkins and Popper 2017).

Due to a lack of data, it is not possible to determine spawning periods and/or locations within the OA for a number of fish species. There is likely to be limited benefit (if any) from trying to implement a survey design based around these restrictions in place as the OA has a large spatial extent.

Based on this, and the fact that any behavioural effects on fish from seismic surveys are likely to be short term and temporary, with literature finding that fish return to normal behaviour and distributions within days of acoustic exposure, it is assessed that the Seismic Survey will have limited impact on fish fecundity, spawning or reproductive potential (assessed in relation to fish behavioural effects).

Section 7.2.2.1.1 provides a discussion and assessment of the potential effects of seismic acoustic disturbance on fish eggs and larvae, where it is also discussed that seismic operations may have some negative effects on zooplankton populations based on recent studies. Consequently, there is the potential for fisheries yield and spawning stock to be adversely affected in subsequent years.

From the literature discussed in this section, it can be summarised that for fish species, studies suggest that in some circumstances behavioural displacement reduces catch rates while in other circumstances catch rates increase. A number of studies also show no change in catch rates. This summary agrees with the conclusion reached by Przeslawski *et al*. (2016a) who concluded that "...[their] *results support previous work in which the effects of seismic surveys on catch seem transitory and vary among studies, species, and gear types*". Although some studies have linked reductions in catch rates to the effects of seismic activities, the body of peer reviewed literature on this topic does not support any long-term abandonment of fishing grounds by commercial fish species. There are a number of studies indicating that post-survey catch levels return to pre-survey levels following the cessation of seismic activities (e.g. Carroll *et al.,* 2017). Also, it is important to note is that although some fish may be temporarily displaced during seismic activities, the total number of fish within the fishery stock will remain unchanged (Przeslawski *et al.,* 2016a).

As discussed in **Section 7.2.2.1.3**, the potential for fish mortality due to peak noise exposure has been identified within 250 m of the active source at full power. However, it is important to note that there are currently no documented cases of fish mortality upon exposure to seismic sound under field operating conditions. Studies show that exposure to seismic sound is considered unlikely to result in direct fish mortality.

To further reduce the potential for any impacts on fish at the population level, SLB have also taken steps to ensure that the Seismic Survey takes place in the shortest time possible (by operating 24 hours per day); and through stakeholder engagement has identified sensitive areas for fisheries, and has made a commitment through the ongoing stakeholder engagement plan to continually engage with the fishers so that any impacts on the fishers and fisheries can be considered as part of the survey design during the acquisition phase if required.

Given the evidence of fish returning to survey areas following the cessation of seismic/acoustic activities, it is highly likely that any effects on fish will be temporary, and fish will return to normal behaviour and distributions within days of any acoustic exposure. There are unlikely to be any population level effects for fish and subsequently, effects on catch rates are considered to be minimal.

Overall, it is considered that the risk of any discernible impacts on catch rates of commercial fisheries targeting fish during and after the Seismic Survey will be **Low** (*Minor* x *Possible)*.

7.2.4 Known and Potential Impacts on Commercial and Recreational Dive Operations

Human ears are most sensitive to waterborne sounds that range in frequencies from 400 Hz to 1 kHz, with a peak sensitivity at 800 Hz (Anthony *et al*., 2009). The sensitivity of the diver to underwater noise is largely influenced by the diving apparatus worn. SCUBA dive masks result in a 'wet' ear where the water floods the external auditory canal. In contrast, enclosed helmets most often used by commercial divers maintain a 'dry' ear. Hearing sensitivity is lower in divers using a 'wet' ear system, and therefore elevated noise levels are more damaging to divers using 'dry' ear systems (Anthony *et al*., 2009). Further hearing protection may be provided by neoprene hoods used by 'wet' ear divers, reducing noise attenuation, particularly in shallower water depths (Anthony *et al*., 2009; Cudahy and Parvin, 2001).

Effects of noise on human divers range from dizziness, disorientation, temporary paralysis of limbs, or TTSs, to PTSs, severe pain, and haemorrhaging of soft tissues (Cudahy and Parvin, 2001). For sounds with frequencies of 500 – 2,500 Hz, Parvin *et al*. (2005) reported temporary dizziness and related symptoms for bareheaded divers exposed to sound levels above 176 dB re 1 µPa, and vibration in forearms and thighs at sound levels above 180 dB re 1 µPa. Sounds were tolerated up to 191 dB re 1 µPa (the maximum used in the trial); however, from these results a threshold exposure level for human divers of 145 dB re 1 µPa was proposed for 100 – 500 Hz frequencies, and 155 dB re 1 µPa for 501 – 2,500 Hz.

In 2020 the Diving Medical Advisory Committee released Rev 2.1 of '*Safe Diving Distance from Seismic Surveying Operations*' Guidance Note which extended the threshold distances stated in previous revisions of the Guidance Note, with the following guidance (among others):

- Plans should be made to avoid overlapping seismic and diving activities; where this is not possible, the activities should be prioritised and a simultaneous operations plan developed;
- Where diving and seismic activity are schedule to occur within a distance of 45 km, it is good practice for all parties to be made aware of the planned activity where practicable, including clients/operators, diving and seismic contractors;
- Where diving and seismic activity will occur within a distance of 30 km a joint risk assessment should be conducted between the clients/operators involved in the seismic and diving contractors in advance of any simultaneous operations;
- The maintenance of effective communication and cooperation between the seismic vessel and the diving vessel is essential;
- Minimum safe distances should not be compromised by either party; and
- Should any diver in the water experience interference with communications, the noise level is considered to exceed acceptable exposure levels, feels sudden discomfort or places the diver at risk in any other way, the diver's exposure should be terminated.

Offshore oil and gas installations are typically noisy above and below water; therefore, commercial divers working around the offshore facilities are already exposed to high levels of noise (Anthony *et al*., 2009; Kirkland *et al.,* 1989). Dive operations at these installations are routinely carried out for inspection and maintenance works and may occur while the Seismic Survey is operating. The closest producing fields from the acquisition area are;

- Northern Endeavour – 55 km; and
- Montara Venture – 60 km.

As outlined within **Section 4.7.2.3**, recreational diving may occur within the EMBA, primarily concentrated around natural features such as reefs, islands and cay (e.g. Ashmore Reef located approximately 170 km from the acquisition area) and around structures such as shipwrecks (e.g. the Ann Millicent shipwreck located approximately 130 km from the acquisition area).

Although the UAM report in **Appendix A** does not provide the horizontal distances from the seismic source for the 145 dB re 1 µPa isopleth as outlined as a threshold in Parvin *et al*. (2005), the results for 140 dB re 1 µPa have been utilised as a conservative value for assessing impacts to divers. Given the large separation distance to those sites utilised by recreational divers (> 130 km) from the acquisition area, the following assessment has focused on potential impacts to any dive operations undertaken at the nearby producing fields.

Interrogating the UAM report in **Appendix A** shows that for those sites modelled in closest proximity to the installations (being Site 25 and 15) the 140 dB re 1 µPa and 150 dB re 1 µPa isopleth do not extend out to the Northern Endeavour or Montara Venture, with ranges from 20 – 50 km. Although both installations are outside of the recommended safe distances under the Diving Medical Advisory Committee Guidance Note, and located further away than thresholds distance, all installation operators will be kept updated throughout the programme with the 48-hour look-ahead so that they may schedule any dive operations as they deem appropriate to ensure the safety of their divers as they undertake their own risk assessment as part of their diving procedures. SLB will be in regular contact with gas installation operators who will be able to schedule dive operations as they deem appropriate.

Consultation has also been conducted with potential dive operators in and around the OA, with no responses to date raising concerns with the proposed Seismic Survey.

Based on the above, and the control measures in place (such as ongoing consultation), the potential risk to divers from noise emissions during the Seismic Survey has been assessed as **Low** (*Rare x Moderate*).

7.2.5 Control Measures

All potential control measures (to manage potential impacts from seismic noise emissions to **ALARP**) that were considered during the planning of the Seismic Survey have been included in **Table 56**. These control measures have been assessed to consider the environmental benefits gained through their implementation, relative to their time and effort with a clear delineation made between which control measures will be implemented during the Seismic Survey and those which won't. Justifications have been provided for each of the decisions against each control measure in **Table 56**.

Table 56 Assessment of Control Measures for Managing the Acoustic Disturbance to the Marine Environment

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Implemented Control Measures:				
Limitation on maximum capacity of the acoustic source	P = Yes E = Effective	Source capacity is reduced to the minimum level possible whilst still enabling survey objectives to be met within OA. This minimises the produced sound levels entering the marine environment. Both smaller and larger arrays were considered but given the water depth and target depths of the geological structures, SLB have determined that the 3.000 in^3 source is the most efficient source size to complete the requirements of the survey objectives. This maximum zero to peak sound pressure level from the 3,000 in^3 acoustic source will be 256.3 dB re 1 µPa @ 1 m.	Yes	Yes
24/7 MSS operations	P = Yes E = Effective	With the exception of periods where the acoustic source is inactive (e.g. marine mammal presence within Exclusion Zone triggering a shut-down or the cessation of night-time operations on the basis of Marine Mammal Adaptive Management Procedures), the MSS will operate 24/7. This reduces the overall duration of the survey to minimise disturbance and displacement.	Yes	Yes
Restrictions on acoustic releases outside of the OA	P = Yes E = Effective	Acoustic release will be limited to within the defined boundaries of the OA, thereby restricting potential effects of acoustic disturbance to within the boundaries of the OA. These effects have been considered within this EP.	Yes	Yes
NOPSEMA website search on activity status and summaries for EP submissions and decisions	P = Yes E = Effective	The NOPSEMA database has been searched for EP submissions and decisions so SLB can identify whether any MSS's may potentially overlap spatially or temporally with the Seismic Survey. This enables the development and implementation of mitigation measures for cumulative effects.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Spatial limitations of operations between multiple MSSs to prevent cumulative effects	P = Yes E = Effective	Multiple MSSs operating simultaneously in close proximity to each other would potentially increase the spatial extent of acoustic energy and the intensity of acoustic energy (if acoustic areas overlap). Ensuring complete spatial separation of each Seismic Vessel (and therefore each acoustic source), will help limit sound source levels to those associated with a single seismic source, which is easier to manage and assess with respect to risks to marine species. SLB will implement a 40 km spatial separation between SLBs Seismic Vessel and any other operating MSS vessel so that they will not acquire data simultaneously within 40 km of each other.	Yes	Yes
Compliance with the EPBC Act Policy Statement 2.1	P = Yes E= Effective	The EPBC Act Policy Statement 2.1 outlines procedures that should be followed by all Seismic Vessels conducting surveys in Australian waters and has a focus on mitigating the effects of MSS on whales. Part A procedures **must** be followed, while Part B procedures are additional measures that **may be required** to further mitigate against any effects. Details of both Part A and Part B procedures that will be implemented are detailed in their respective sections later in this table.	Yes	Yes
Maintenance of vessels	P = Yes E = Effective	Proper maintenance of vessel machinery eliminates excess vibrations which transfer noise into the water column.	Yes	Yes
A 'turtle pause' (or 'shot pause') will be implemented if a marine turtle is seen within 500 m of the active acoustic source. The seismic source will power-up when the turtle is observed to be >500 m from the source, or has not been seen for 15 minutes	P = Yes E = Effective	This will result in a temporary cessation of the acoustic source so that there is no acoustic disturbance when the source array is likely to be closest to the turtle (or the turtle's predicted position).	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Inform relevant commercial fishers and the public about the timing and duration of MSS	P = Yes E = Effective	This will keep all relevant users of the area informed and reduce impacts on fishers and marine users by allowing them to target locations away from the area of active acoustic data acquisition on any given day. This will also minimise any potential interactions between the Seismic Vessel and equipment (i.e. streamers) and other commercial and recreational fishing vessels and gear. 48-hour look-aheads will be provided to those relevant commercial fishers and associations, and relevant fishers will be part of the ongoing stakeholder engagement programme to ensure they have correct and up to date information for the duration of the survey to assist with their planning. They will also have all relevant contact details of who to contact on the water and on the shore should they have any questions or issues about the operations. Public notices will be posted of the commencement of the survey and all local Councils or Government/State departments will be notified of the survey. They will be provided with electronic versions of the Information Pack (including contact details) which can be passed on should they receive any calls or concerns.	Yes	Yes
Detailed marine fauna sighting report (marine mammals and turtles) and any interactions will be recorded and submitted as part of the MMO Report and post-survey Environmental Performance Report. A procedure will be in place so that notification will be provided to the relevant local authorities of any dead or distressed marine mammals as soon as practicably possible.	P = Yes E = Effective	OPGGS Environment Regulation 26(C) requires that "a titleholder undertaking an activity must submit a report to the Regulator in relation to the titleholder's environmental performance for the activity, at intervals provided for in the environment plan." Within two months following the completion of the Seismic Survey, SLB will prepare a Post-survey Environmental Performance Report for submission to NOPSEMA. This report will review the entire programme and have the same scope and objectives as the Annual Report. If possible, these reports may be combined.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
		The OPGGS Environment Regulation 14(2) requires that "the titleholder report to the Regulator in relation to the titleholder's environmental performance for the MSS and provide that the interval between reports will not be more than one (1) year". Accordingly, SLB will submit an annual report to NOPSEMA that reviews the outcomes and achievements for the Seismic Survey. The annual report(s) will be submitted within two months of the anniversary of the acceptance of this EP. Further details of the Annual Reports are in **Section 10.6.** IAGC mitigation measures for cetaceans during Geophysical Operations recommend documenting all observations and report immediately to local authorities any animals in distress.		
EPBC Act Policy Statement 2.1 – Interaction Between Offshore Seismic Exploration and Whales Part A standard measures to be adhered to:				
EPBC Act Policy Statement 2.1: Precaution Zones	P = Yes E= Effective	Precaution Zones are set based on the likely sound levels surrounding the acoustic source as demonstrated by acoustic modelling. The use of Precaution Zones provides the basis for the mitigation measures throughout the EPBC Act Policy Statement 2.1 and defines the zones where certain operational procedures will be implemented (e.g. shut-downs of the acoustic source when a whale enters/is sighted within the Shut-down Zone).	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
		Based on the modelling results, SLB will take a conservative approach and implement an extended 2 km Shut-down Zone for baleen whales and a 3+ km Observation Zone for the duration of the survey; When the acoustic source is active within the blue whale BIA and 17 km buffer, a 5 km observation zone will be implemented. The 3+ km zone will be visually monitored by two MMOs on the Seismic Vessel, and two additional MMOs will be stationed on the Chase Vessel when operations are occurring inside the blue whale BIA and buffer to assist with observations out to 5 km. In addition, SLB will have two PAM Operators on the Seismic Vessel that will be monitoring 24 hours per day while the source is active to assist in locating whales in the vicinity but outside the visual Observation Zone, and during the hours of darkness or periods of poor visibility.		
EPBC Act Policy Statement 2.1: A.1 – Pre-survey Planning	P = Yes E = Effective	Pre-survey planning is a requirement of the EPBC Act Policy Statement 2.1 and requires SLB to identify the key environmental receptors in and around the OA, including identification of important habitats/areas, seasonality, etc. Mitigation measures have been implemented while taking into consideration the findings of the pre-survey planning phase. Extensive pre-survey planning has formed the basis of this EP. Multiple sensitivities in and around the OA have been identified, and control measures have been developed to ensure that a precautionary approach has been adopted for the duration of the survey. Additional mitigations have been implemented to account for the temporal and spatial overlap between the proposed MSS operations and the blue whale migratory BIA. These additional mitigations are presented later in this table.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
EPBC Act Policy Statement 2.1: A.2 – Crew training	P = Yes E = Effective	Vessel crew are required to have sufficient training in order to implement the mitigation procedures of the EPBC Act Policy Statement 2.1. SLB will ensure there is sufficiently trained crew to fulfil the basic requirements outlined below. The trained crew members who are nominated must have proven experience in whale observation, distance estimation and reporting. At the start of the survey a briefing will be provided to all crew on board the survey vessels on environmental matters, including information on the EPBC Act Policy Statement 2.1, whale identification and the environmental legal obligations for companies operating in Australian waters. Reference material will be provided and made available for the duration of the survey onboard the vessel(s), including the EPBC Act Policy Statement 2.1, the Department's Whale and Dolphin sighting report form and the APPEA CD Guide 'Search Australian Whales and Dolphins'. Appropriate visual aids such as binoculars will be available on board the vessel to aid in the identification and reporting of any whales sighted. In addition to trained crew (as required under the standard management procedures), SLB are also required to have two dedicated and experienced MMOs onboard as per EPBC Act Policy Statement 2.1 as a result of the likelihood of encountering whales during the Seismic Survey being moderate to high as assessed within this EP. Two additional MMOs will also be stationed on the Chase Vessel during operations that occur in the blue whale BIA and 17 km buffer. The MMOs will have primary responsibility for whale observation and compliance of the Precautionary Zones; however, trained crew can act as a support role when required to provide additional observations.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
EPBC Act Policy Statement 2.1: A.3.1 – Pre-start-up visual observations	P = Yes E = Effective	Pre-start up visual observations are required under the EPBC Act Policy Statement 2.1. The Observation Zone (3+ km, or 5 km when the acoustic source is active within the blue whale BIA and 17 km buffer) will be monitored for the presence of whales for at least 30 minutes before the commencement of a soft-start procedure during daylight hours. The MMOs participating during the Seismic Survey will have direct responsibility for undertaking pre-start-up visual observations and compliance with the Precautionary Zones, with trained crew (see above) support as required.	Yes	Yes
EPBC Act Policy Statement 2.1: A.3.2 – Soft start procedures	P = Yes E = Effective	Soft start procedures are a gradual increase of power over a set period with the intention of allowing adequate time for whales to leave the area before being exposed to the highest sound levels (Wright and Cosentino, 2015). They will also alert other marine fauna and allow them time to move away from the active source, avoiding potential physiological impacts. Soft starts over a period of 30 minutes are a requirement of the EPBC Act Policy Statement 2.1, where their implementation allows the power of an acoustic source to be gradually increased prior to the survey commencing which ensures that any whales that go undetected during pre-start-up observations have an opportunity to leave the vicinity of the seismic array before full operational power is reached. Throughout the entire OA, soft start procedures will be limited to conditions that allow visual inspection of the Observation Zone.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
EPBC Act Policy Statement 2.1: A.3.3 – Start-up delay procedures	P = Yes E = Effective	During soft start procedures in daylight hours, an MMO will be on the bridge observing for whales. If a whale enters the 3+ km Observation Zone (or the 5 km observation zone when the acoustic source is active within the blue whale BIA and 17 km buffer), another MMO or trained crew member will be called to the bridge to assist in monitoring the whale/s to assess whether it leaves the zone or enters the low power zone (for large, toothed whales only), or a relevant Shut-down Zone. If the whale enters the relevant Shut-down Zone (500 m for large, toothed whales and 2 km for all baleen whales including blue whales), the acoustic source will be immediately shut-down. If a toothed whale enters the low power zone during soft start the source to be powered down to the lowest possible setting. If the acoustic source is shut-down, a soft start procedure will only resume after the whale has been observed to move outside the Shut-down Zone, or when 30 minutes has lapsed since the whale was last sighted. The intention of these delays is to allow sufficient time for any whale/s to exit the Precaution Zones and avoid exposure to the highest sound levels. Start-up delays are a requirement of the EPBC Act Policy Statement 2.1. If an infill line is required, a minimum delay of five hours would occur to allow for repositioning of the Seismic Vessel to repeat data acquisition at a particular location. However, in practice it is anticipated that a 24 hour delay or more would occur between the original pass and the infill pass.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
EPBC Act Policy Statement 2.1: A.3.4 – Operations procedures	P = Yes E = Effective	Operational procedures are a requirement of the EPBC Act Policy Statement 2.1. Operational procedures to minimise acoustic disturbance include the implementation of soft starts and delay procedures (outlined above), and the requirement for the continuous visual monitoring of whales in relation to the Precaution Zones during daylight hours: which in the case of the Seismic Survey will be undertaken by dedicated, trained and experienced MMOs.	Yes	Yes
EPBC Act Policy Statement 2.1: A.3.5 – Stop work procedures	P = Yes E = Effective	Stop work procedures are a requirement of the EPBC Act Policy Statement 2.1. Stop work procedures will be implemented when 1) a baleen whale enters the 2 km Shut-down Zone, or 2) any large, toothed whale enters the 500 m Shut-down Zone; reducing exposure of the whale to the highest sound levels. This control measure will be implemented by independent MMOs that will be onboard the Seismic Vessel, and the Chase Vessel while operation within the blue whale BIA and buffer, at all times. After the whale has been observed to have left the Shut-down Zone for a period of 30 minutes or has not been detected for 30 minutes, the start-up procedures can commence again.	Yes	Yes
EPBC Act Policy Statement 2.1: A.3.6 – Night-time and low visibility procedures	P = Yes E = Effective	Specific night-time and low visibility procedures are a requirement of the EPBC Act Policy Statement 2.1. They allow the MSS to continue throughout periods of reduced/low visibility (e.g. night-time, or periods of rough seas or fog). During these periods, operations may proceed provided there have not been three or more whale instigated power-down or shut-downs during the preceding 24-hour period. However soft start procedures will be limited to conditions that allow visual inspection of the Observation Zone. SLB has adopted the threshold of three or more whales based on what was recommended within the EPBC Act Policy Statement 2.1 Standard Management Procedures.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
		In addition to this, the following notes are applicable to operations occurring inside the blue whale BIA or 17 km buffer: 1) this mitigation will apply irrespective of shut-down locations relative to the blue whale migratory BIA or buffer, and 2) night-time and low visibility operations may only resume in the blue whale migratory BIA or buffer after 24 hours of no blue whale instigated shut-downs (again, irrespective of location relative to the blue whale migratory BIA or buffer). The PAM system will be programmed and tuned to ensure sensitivity within a frequency range of 10 Hz to 200 kHz to detect the species likely to be found in the OA as identified in the development of the EP (in particular the PAM system will theoretically be able to detect the low frequency calls of baleen whales and the high frequency echolocation clicks of sperm whales). The full system specifications of the PAM system are provided in **Appendix J**.		
EPBC Act Policy Statement 2.1: A.4 – Compliance and Sighting Reports	P = Yes E = Effective	A report on the conduct of the survey and any whale interactions will be provided to the DoEE within two months of survey completion following the minimum content recommendations in the EPBC Act Policy Statement 2.1. All cetacean sightings will be recorded in the 'Cetacean Sightings Application' software.	NA	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
EPBC Act Policy Statement 2.1 – Interaction Between Offshore Seismic Exploration and Whales Part B additional measures for whales:				
EPBC Act Policy Statement 2.1: B.1 – Marine Mammal Observers	P = Yes E = Effective	The use of trained, dedicated and experienced MMOs is a recommendation of Part B.1 of the EPBC Act Policy Statement 2.1 when the likelihood of encountering whales is moderate to high. From the assessment undertaken within this EP (**Section 7.2**) it has been determined that the likelihood of encountering whales during the Seismic Survey is moderate-high. Therefore, SLB will have two trained and experienced MMOs onboard the Seismic Vessel for the duration of the Seismic Survey and two trained and experienced MMOs will be stationed on the Chase Vessel for operations that occur in the blue whale BIA and 17 km buffer. The role of MMOs is to undertake all visual observations for whales and to ensure that the appropriate mitigation measures occur in response to any whale sightings in the Precaution Zones in compliance with the mitigation measures outlined in this EP. MMOs will also assist the trained crew in any marine mammal observations and be available to provide advice should whales be encountered. The MMOs used during the Seismic Survey must have logged a minimum of 20 weeks' relevant sea-time engaged in MSS operations in Australian waters as an MMO or MFO and have proven 'at sea' experience in whale identification and behaviour, and distance estimation. The MMOs used must be confident in the identification of those species that the EP predicts will be present in the OA.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
EPBC Act Policy Statement 2.1: B.2 – Night-time/Poor visibility	P = Yes E = Effective	The EPBC Act Policy Statement 2.1 recommends that in areas where whales are expected to be encountered, the proponent should include measures to detect whale presence and apply measures to reduce the likelihood of encounters. Regarding this, PAM will be implemented to assist with whale detection (see below). SLB will also limit the initiation of soft start procedures to conditions that allow visual inspection of the Observation Zone and adaptive management measures (as outlined above) will mean that night-time and low visibility operations will only occur if there have not been three or more whale instigated power-down or shut-down situations during the preceding 24-hour period. The combination of PAM and adaptive management will provide a high level of protection to whales in the OA.	Yes	Yes
EPBC Act Policy Statement 2.1: B.4 – Increased Precaution Zones	P = Yes E = Effective	The EPBC Act Policy Statement 2.1 defines the standard Shut-down Zone as being 500 m from the acoustic source with a Low-power Zone out to 2 km. In keeping with their precautionary approach, SLB have committed to extending the Shut-down Zone out to 2 km from the acoustic source for all baleen whales to provide additional protection for these low-frequency cetaceans. On this basis, with the implementation of the additional controls that SLB has proposed, the Low-power Zone is only required for toothed whales. When species identification is uncertain, a precautionary approach will be taken, and a detection will be assumed to be a baleen whale until identification is otherwise confirmed.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
EPBC Act Policy Statement 2.1: B.5 – Passive Acoustic Monitoring (PAM)	P = Yes E = Effective	Visual methods of scanning for whales are restricted to daylight hours and relatively calm weather conditions. Animal behaviour such as diving further reduces detection probability (Verfuss *et al.*, 2018). PAM detects whale vocalisations in real-time and is useful during night-time, low visibility operations and for submerged animals. The use of PAM is a suggestion under Part B.5 (Additional Measures) of the EPBC Act Policy Statement 2.1 when the likelihood of encountering whales is moderate to high. SLB will run and monitor a PAM system around the clock while the acoustic source is active; hence, detections of cetacean vocalisations will occur both at night and during daylight hours (to augment visual detections). The PAM system will be programmed to cover a frequency range of 10 Hz to 200 kHz to theoretically detect a) low frequency vocalisations of baleen whales, and b) the high frequency echolocation clicks of sperm whales. Two trained, dedicated and experienced PAM Operators will be on the Seismic Vessel for the duration of the survey, with at least one PAM Operator maintaining 'acoustic watch' at all times. PAM Operators must have logged a minimum of 20 weeks' relevant sea-time engaged in MSS operations in Australian waters as a PAM Operator (following the recommendation of the Marine Mammal Observer Association (MMOA, 2019). PAM experience will be a pre-requisite for the recruitment of personnel for these positions. A full replacement PAM system will be kept onboard the Seismic Vessel and will be used as a back-up in the event that the PAM system malfunctions and is unable to be repaired. Frequency sensitivity will be designed into the hardware to remove vessel noise at very low frequencies masking whale vocalisations which may limit the performance of PAM.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
		PAMGuard software will be incorporated into the PAM system to assist with locating and classifying the vocalisations of marine mammals. This sophisticated software allows the trained PAM Operators to make robust decisions during real-time mitigation operations, such as requesting shut-downs based on whales entering the Precaution Zones or based on whales remaining in the vicinity over longer time periods risking TTS. The full PAM specs that will be implemented for the Seismic Survey are provided in **Appendix J**. Where possible, PAM detection distances will be validated against MMO observations early in the survey schedule to determine PAM accuracy. Validations will occur during daylight hours and good sighting conditions. PAM will be considered to be reliable if estimated distances deviate by $\leq$ 20%. Following validation, PAM may be used to trigger shut-downs at night and during periods of low visibility. In the event of a positive PAM whale detection prior to PAM validation, a precautionary approach will be taken whereby a shut-down will occur regardless of species identification or distance estimate.		
EPBC Act Policy Statement 2.1: B.6 – Adaptive Management	P = Yes E = Effective	In accordance with the EPBC Act Policy Statement, adaptive management procedures will be adopted for blue whales and other baleen whales as described below. For any adaptive management procedures outside of the blue whale migratory BIA or 17 km buffer, if species identity is uncertain, any unidentified whale will be assumed to be an 'other baleen' whale; inside the BIA or buffer, unidentified whales will be assumed to be pygmy blue whales. Adaptive management measures for **blue whales** –	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
		• If three or more blue whale instigated shut-downs occur within a 24-hour period, the Seismic Vessel will relocate to another area at least 17 km away (and outside of the blue whale migratory BIA or buffer) before commencing Pre Start-up Visual Observations and Soft Start Procedures. This mitigation will be implemented throughout the entire OA (i.e. shut-downs both inside and outside the blue whale migratory BIA and buffer will contribute to this count); and • If a blue whale mother and calf pair is observed during the Seismic Survey, the acoustic source will be immediately shut-down and the Seismic Vessel will relocate to another area at least 17 km away (and outside of the blue whale migratory BIA or buffer) before commencing Pre Start-up Visual Observations and Soft Start Procedures. This mitigation will be implemented throughout the entire OA (i.e. sightings both inside or outside the blue whale migratory BIA and buffer will trigger this mitigation measure). Adaptive management measures for **other baleen whales** – • If three or more baleen whale instigated shut-downs occur within a 24-hour period, the Seismic Vessel will relocate at least 10 km away before commencing Pre Start-up Visual Observations and Soft Start Procedures; • If a baleen whale mother and calf pair is observed during the Seismic Survey, the acoustic source will be immediately shut-down and the Seismic Vessel will relocate to another area at least 10 km away before commencing Pre Start-up Visual Observations and Soft Start Procedures.		

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Blue whale Biologically Important Area Control Measures				
Additional blue whale BIA control measures	P = Yes E= Effective	SLB recognises that the potential to encounter whales increases as the Seismic Survey OA approaches and overlaps the blue whale migratory BIA. In addition to the above-mentioned Standard and Additional Control Measures, the following control measures are proposed in relation to acquisition within the blue whale migratory BIA to minimise the potential for behavioural disturbance within this sensitive area: • A 17 km buffer will be established around the blue whale migratory BIA where it overlaps with the OA; • The Seismic Vessel will not activate the acoustic source(s) within the blue whale migratory BIA or buffer from mid-April (14th) to mid-January (14th) which represents the period during which most migrations whales are expected to pass through the Timor Sea; • Outside of this period (15 Jan to 13 April), any seismic operations inside the blue whale migratory BIA or buffer will: - Implement an extended observation zone of 5 km;	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
		- The extended observation zone in the BIA and buffer will be monitored using the Chase Vessel as an additional observation platform with two MMO's onboard. The Chase Vessel will travel c. 3 km ahead of the Seismic Vessel and will conduct visual surveillance for marine mammals during daylight hours. Trained and experienced MMOs will be required to undertake these observations. Note: 'ahead of the Seismic Vessel is defined as an 180° arc ahead of the Seismic Vessel, noting that the Chase Vessel should focus on the portion of the arc closest to the blue whale migratory BIA and buffer. - Limit soft start procedures to conditions that allow visual inspection of the 5 km Observation Zone; and - If species identity is uncertain at any location inside the blue whale migratory BIA or buffer, any unidentified whale will be assumed to be a blue whale. • Note, as PAM is not considered to be a particularly reliable method for detecting low-frequency cetaceans. On this basis, the proposed adaptive management approach at night or during periods of low visibility serves to remove the reliance on PAM while still maintaining a high level of protection for low frequency cetaceans, particularly blue whales.		

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Control Measures for Stakeholders and Other Marine Users:				
Pre-survey stakeholder engagement	P = Yes E = Effective	Pre-survey stakeholder engagement allows stakeholder objections, claims, or expectations to be heard and understood and incorporated into the development of the EP (NOPSEMA, 2020). Early identification of issues allows mitigation measures to be developed to reduce the risk to **ALARP** and **Acceptable Levels**. Pre-survey engagement with identified stakeholders is a requirement of the OPGGS Act. • Throughout the development of this EP, an extensive stakeholder engagement programme was undertaken. This was conducted via mail, email and phone contact, face-to-face meetings has not been possible due to COVID-19. Fishing associations were also engaged with as they represent the licence and quota holders and the preference by industry is that the operators deal and engage with the associations rather than directly with the licence holders. This is detailed in **Section 5.4.6.**	Yes	Yes
Ongoing communication with marine users: • Provision of a 48 hr 'look-ahead' plan; • Publication of Notice to Mariners; and Communication with fishers and industry associations throughout the survey period.	P = Yes E = Effective	Communication with marine users allows the opportunity for both parties to work together to understand each other's activities and minimise disturbance and interactions (i.e. commercial fishers can avoid deploying gear in the path of the Seismic Vessel), including daily communication and a week look-ahead in addition to 48 hr look-ahead). Provision of a 48 hr 'look-ahead' plan that will be distributed every 24 hours allows marine users to understand the future movements of the Seismic Vessel over the next 48 hours and plan accordingly to avoid interactions. Under the Navigation Act 2012, the AHO publish and distribute a Notice to Mariners. This Notice outlines potential hazards and restrictions to marine users.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Data acquisition will not occur over recreationally dived waters	P = Yes E = Effective	A large proportion of the OA (approximately 95%) constitutes water depths greater than 60 m, which is beyond the safe diveable depths of recreational divers (i.e. 30 m).	Yes	Yes
Notification of MSS commencement to diving operators (diving charters, dive schools, dive equipment).	P = Yes E = Effective	A large proportion of the OA (approximately 95%) constitutes water depths greater than 60 m, which is beyond the safe diveable depths of recreational divers (i.e. 30 m).	Yes	Partially
Oil and gas operators close to the OA will be contacted prior to the survey commencing. If requested, they will be provided with 48-hour look-aheads so they will know where the vessel will be operating, so they can consider as part any commercial diving operations if required.	P = Yes E = Effective	The nearest production operation, Montara Venture, is located, approximately 12 km south of the OA. This distance is located beyond what is considered to have an effect on divers from acoustic noise based on the UAM results. However, SLB acknowledges commercial diving operations need to consider all potential risks into their job hazard analysis and health and safety plans.	Yes	Yes
Alternative Control Measures:				
Use of an additional vessel for the specific purpose of marine mammal monitoring	P = No E = Very Effective	Having another vessel specifically dedicated to marine mammal monitoring (with MMOs and a PAM system onboard) could provide additional capacity for detecting whales at greater distances than from the Seismic Vessel. In this respect a dedicated marine mammal monitoring vessel would provide a high level of support to the extended mitigation zones outlined in this EP. However, an additional monitoring vessel is not considered to be necessary as the control measures that will be adopted sufficiently address the risks to marine mammals as quantified by underwater noise modelling, particularly the use of the Chase Vessel as an additional platform from which visual observations for marine mammals will occur during acquisition in the extended 5 km observation zone for the blue whale migratory BIA or buffer. The adaptive management measures that will be implemented also serve to manage risk to marine mammals throughout the survey.	Yes	No

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Elimination of noise emissions from the acoustic source	P = No E = Very Effective	Although the most effective way to halt any potential effects on marine organisms, is complete elimination of noise from the acoustic source, which is not practical. Acoustic release of the acoustic source is required to obtain data from below the seabed and the survey cannot be undertaken without noise emissions. The survey is required to provide robust data for the region. Given the precautionary control measures to be implemented, the costs far outweigh the benefits.	Yes	No
Use of alternative seismic sound sources and alternative geological imaging technology	P = No E = Unknown Effectiveness	Alternative technologies are not yet commercially available or have not been proven to meet geophysical data quality objectives, operational safety, and reliability requirements (IOGP, 2017).	Unknown	No
Increase in line spacing	P = No E = Fairly effective	Wider line spacing would serve to reduce the survey duration and therefore reduce the overall amount of underwater noise generated. However, wider line spacing would not allow the objectives of the Seismic Survey to be achieved due to reduced data coverage.	Yes	No
Alternative line sequencing to a 'race track' design to avoid sequential lines	P = No E = Effective	If an alternative line turn sequencing programme was implemented, it could double the line change time. This results in the duration of the survey would be for a lot longer, which has other implications with stakeholder and peak-foraging season. With the duration of the survey increasing, this means that the crew are out on the vessel for longer, which can increase HSE exposure and potential conflict with other water users. In addition, increasing the duration of the survey increases the costs to the programme significantly.	Limited	No

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Geographical and seasonal restrictions for all fish spawning areas (i.e. no acquisition during peak spawning periods)	P = No E = Fairly effective	It is not possible to determine the exact spawning periods and/or locations within the OA for all fish species, or spawning may occur outside the OA, but at some point, the eggs pass through the OA (even if not near the Seismic Vessel). For many species, including the commercially fished species in the OA, spawning periods are known, but spawning locations are often not, nor the distribution of eggs after spawning occurs. There is likely to be limited benefit (if any) from trying to implement a survey design based around these restrictions in place. Fish are likely to be widely distributed and more abundant in the nearshore coastal region during spawning, mostly inshore of the OA. As such, it is considered that it is not reasonable to restrict survey efforts to a more limited area when the entire area is likely to contain spawning fish at some point over the possible survey window. Furthermore, spawning fish are likely to display a behavioural response to the acoustic noise and temporarily avoid the OA while still remaining in their wider spawning region. As such, effects at the population level of fish species from the Seismic Survey from taking place are unlikely and costs from implementing this type of control are considered to be disproportionate to the benefits that would be gained.	Yes	Partially
Seismic activities will be restricted to areas outside key commercial fishing areas/seasons	P = No E = Fairly effective	This would avoid overlap with the commercial fishing operations identified during the stakeholder engagement process. Best efforts have been made to avoid fisheries where possible; however, there will be some overlap, and this will be managed through control measures and ongoing communication for the duration of the survey to minimise conflict and disturbance.	Yes	Partially

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Alternative methods for detecting marine mammals other than PAM and visual observations (i.e. Active Acoustic Monitoring, Thermal Imaging, and Radio Detection and Ranging (**RADAR**))	P = No E = Limited/ Unknown Effectiveness	Visual sightings methods using MMOs are restricted to daylight hours and relatively good weather conditions and can only detect whales at the sea surface. Therefore, any additional method for detecting marine mammals during poor sighting conditions would be beneficial, especially during night-time operations and detection of submerged animals. Alternative detection methods include PAM, Active Acoustic Monitoring, Thermal Imaging, and RADAR. SLB will utilise PAM on the Seismic Vessel during the Seismic Survey. PAM will be operational 24 hours per day while the acoustic source is active and will be continuously monitored by an experienced PAM Operator. Classification to species level from the acoustic detections can only be reliably achieved using PAM, as all other detection methods have not yet been commercially proven or validated (including for detection distance) (Verfuss *et al*., 2018). PAM provides the most cost effective and reliable method to complement visual sightings, despite its limitations for detecting some low frequency vocalisations.	Limited / Unknown	Partially, PAM only
Noise reduction controls for vessels	P = No E = Fairly effective	Noise reduction controls involve significant engineering intervention. Seismic Vessels are already designed to limit noise emissions from the vessel to avoid interference with the acoustic release. As such, it is considered that the costs are disproportionate to any potential benefits gained.	Yes	No

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Prohibition of night-time operations.	P = No E= Effective	Modelling indicates that most whales exposed to a single acoustic pulse will not suffer PTS, but that TTS could occur from a single impulse out to c. 1 km. Cumulative effects of noise exposure over 24 hours would mean onset distances for TTS and PTS are larger; the potential for PTS in baleen whales due to cumulative exposure has been identified out to 7 km. While this is effect could theoretically occur beyond the 2 km Shut-down Zone, TTS is unlikely to occur as; 1) individual animals are expected to move away from the active source and would not remain within this radius for 24 hours; 2) the Seismic Vessel will travel up to 200 km with a 24 hour period. Specific Animat modelling for pygmy blue whales indicate that cumulative TTS will be limited to a radius of 17 km surrounding the acoustic source. The 2 km shutdown zone will provide a very high level of protection to this species. Under the standard management procedures for all whales, night-time operations may occur provided that there have not been three or more whale instigated power-down or shut-down situations during the preceding 24-hour period. Decisions on the requirement for this control will be made daily, i.e. at dusk each day, the MMO on-duty will advise whether the threshold of three whale instigated shut-downs was reached in the preceding 24 hours and will therefore confirm if night-time operations can occur. For blue whales, this control measure also applies, with the addition that when operating in the blue whale BIA and 17 km buffer, night-time operations after 24 hours of no blue whale instigated shut-downs. The same applies for all whales and blue whales respectively for low visibility operations. The control measure of no night-time operations is not considered practicable, as it will result in extending the duration of the overall survey.	Yes	Partial

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Use of drones or unmanned aerial vehicles (**UAV**)	P = No E = Limited	The capability of drones in offshore environments is limited by battery life, the distance they can travel and to low wind conditions (~<20 knots). The battery life of UAV's is longer, and they are capable of travelling longer distances, but are still limited to wind conditions of <25 knots. An experienced pilot is needed to operate an UAV and the costs associated with this in an offshore environment are likely to be c. $700/hr, excluding the cost of drone hire. Therefore, the cost of having a pilot on a Seismic Vessel for c. 100 days would be approximately $70,000. It is considered that there would be limited benefit of using a drone/UAV over visual observation by MMOs as both are best suited to optimal conditions. As such, the costs associated with using drones or UAVs to observe for whales are considered to be disproportionate to the benefits.	Limited	No
Compensation to commercial fishers who fish in or in close proximity to the Seismic Survey OA	P = No E = No	Based on all assessments undertaken within this EP, combined with the results from the UAM, relevant literature, and previous seismic surveys that have been undertaken globally, no significant impacts are expected for commercial fisheries within the OA or surrounding environment. There are also no potential impacts expected on the marine life within the Bonaparte Basin that make up the food web of the commercially fished species.	No	No

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
		There are many different environmental variables at play within the Bonaparte Basin that can contribute to the success and recruitment or the lack there of, the different commercial fisheries and these variables can all contribute towards lower catch rates. As a result, it is extremely difficult to associate poor catch rates or recruitment success of a certain species in a given year solely due to a seismic survey. An example of this is the Bass Strait Scallops where seismic was originally blamed for the mortality; however, recent studies have found there were large increases in water temperatures at the same time as the seismic survey and it is not clear whether the mass mortality event resulted from the thermal spike, which occurred in the same region on almost exactly the same dates as the seismic survey operation, or from the seismic survey (Przeslawski *et al*., 2018; 2018a).		
A Before After Control Impact (**BACI**) study is implemented prior to the Seismic Survey commencing.	P = No E = Yes	Developing and completing a BACI study for the active fisheries within and surrounding the OA is a significant undertaking and would need to occur over a long time period to assure that the methodology was robust. There would also need to be enough replication within the survey design for each of the different species to incorporate variability of results. BACI studies are complex, logistically difficult, and very expensive to undertake. This type of study is something that needs to be developed industry wide and could be put forward for both the petroleum and seafood industry as a shared research programme covering a sufficient period of time to ensure the findings are scientifically robust. For these reasons and given the short duration of the Seismic Survey it is considered that the BACI experiment is not an appropriate undertaking. The costs of such an extensive BACI study would be grossly disproportionate to the environmental benefit gained from implementing such a control measure.	No	No

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
		Many studies have been undertaken on the effects of fish and their response to seismic emissions, where most fish will typically move away from a loud acoustic source if they are uncomfortable with the noise, thereby minimising their exposure and the potential for any physiological effects. Most studies that are undertaken on fish are essentially represented as worst case scenarios, as the fish are not able to move away from the seismic source like they can in the wild.		

7.2.6 Environmental Performance

The EPOs that have been established for the effective management of environmental impacts from underwater acoustic emissions during the Seismic Survey are:

- No excess noise is emitted into the marine environment above what is required to meet survey data objectives;
- No acoustic disturbance to shallow environments;
- No mortality or physical injury to protected marine fauna (i.e. pinnipeds, turtles, sharks) throughout the OA due to acoustic disturbance;
- No mortality or physical injury to marine mammals throughout the OA due to acoustic disturbance;
- No disturbance to migrating pygmy blue whales within the blue whale migratory BIA due to acoustic disturbance;
- No permanent impacts on commercially fished stocks due to acoustic disturbance;
- No noise impacts on other marine users in the Bonaparte Basin from acoustic noise (i.e. scuba divers – both commercial and recreational);
- Noise emissions into the marine environment from sources other than the seismic acoustic source will be minimised; and
- No mortality or physical injury to marine fauna arising from any cumulative impacts will occur from the Seismic Survey.

If the proposed control measures are implemented (**Table 56**), it is considered that the EPOs will a) support the ongoing environmental performance of the Seismic Survey in accordance with the **Acceptable Levels**, and b) ensure that the relevant legislation is complied with in order to avoid, as far as practicable, any health and safety risks or impacts to the marine environment.

The EPSs within **Table 57** have been defined to manage the impacts from acoustic emissions to **ALARP** and an **Acceptable Level**. Compliance with these standards will ensure that the identified EPOs will be achieved for the duration of the Seismic Survey.

Table 57 Environmental Performance Outcomes and Standards for Acoustic Emissions

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
EPO: No excess noise is emitted into the marine environment above what is required to meet survey data objectives.			
Limitation of acoustic source volume	**EPS 54**: The acoustic source will have a maximum source output no greater than 3,000 in^3, with a maximum zero to peak SPL of 256.3 dB re 1 µPa @ 1 m.	UAM will verify the power of acoustic source and model its output. MMOs will record source volumes as part of their daily observations each swing.	SLB Project Manager. MMO.
Operational Procedures 24/7 operations	**EPS 55**: Acquisition will occur under 24/7 operations (where possible).	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 show when operations occurred. Bridge logs.	Vessel Master. MMO.
Directional design of acoustic array	**EPS 56**: The configuration of the acoustic array will be designed to direct sound energy towards the seabed.	UAM report will verify the configuration of the array and directionality of sound propagation. Approval of EP by NOPSEMA	SLB Project Manager.
Restrictions on acoustic releases outside of the designated OA	**EPS 57**: The acoustic source will only be activated within the boundaries of the Seismic Survey OA that is clearly defined as part of the EP application.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 show no breach in operations. Bridge logs. MMO daily and weekly logs.	Vessel Master. MMO.
EPO: No acoustic disturbance to shallow environments.			
Depth limitations to activation of the acoustic source	**EPS 58**: There will be no activation of the acoustic source, including source testing and soft-starts in water depths less than 40 m.	Vessel records show no breach of these requirements. Bridge logs and vessel track records. MMO daily and weekly logs.	Vessel Master. MMO.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
EPO: No mortality or physical injury to protected marine fauna (i.e. pinnipeds, turtles, sharks) throughout the OA due to acoustic disturbance.			
Reporting and notification requirements	**EPS 59**: Reporting of performance against the EP requirements and relevant regulations for the duration of the Seismic Survey for any non-compliance against the Environment Regulations and Industry Best Practice.	Compliance with OPGGS Environment Regulation 26(c), 14(2) and the IAGC recommended mitigation measures. MMO daily and weekly logs. Bridge logs and vessel track records.	SLB Project Manager. Vessel Master. MMO. PAM Operator.
Turtle pause	**EPS 60**: A 'turtle pause' or 'shot pause' will be implemented if a marine turtle is seen within 500 m of the active acoustic source	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of these procedures. MMO daily and weekly logs.	MMO. Seismic Operator.
	EPS 61: The acoustic source will power-up when the turtle is observed to be >500 m from the source or has not been seen for at least 15 minutes.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of these procedures. MMO daily and weekly logs.	MMO. Seismic Operator.
EPO: No mortality or physical injury to cetaceans throughout the OA due to acoustic disturbance.			
Compliance with the EPBC Act Policy Statement 2.1	**EPS 62**: Operations will comply with the EPBC Act Policy Statement 2.1. Part A requirements at all times.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of these procedures.	SLB Project Manager. Vessel Master. MMO.
EPBC Act Policy Statement 2.1: Precaution Zones	**EPS 63**: The following Precaution Zones will be implemented throughout the duration of the survey: • Observation Zone – 3+ km (or 5 km observation zone when the acoustic source is active within the blue whale migratory BIA and 17 km buffer); • Shut-down Zone – 500 m for toothed whales, and 2 km for all baleen whales (including pygmy blue whales); and	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. Bridge logs. MMO daily and weekly logs.	MMO. Seismic Operator.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	• Low Power Zone – 2 km for toothed whales.		
	EPS 64: Whales and their movements within the Observation Zone will be monitored to determine whether they are approaching or entering a Shut-down Zone or Low Power Zone.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. Bridge logs. MMO daily and weekly logs.	Vessel Master. MMO.
	EPS 65: When a whale is sighted or detected via PAM entering the Shut-down Zone, the acoustic source will immediately be shut-down.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. Bridge logs. MMO daily and weekly logs. PAM daily and weekly logs.	Seismic Operator. MMO. PAM Operator.
	EPS 66: MMOs and PAM operators onboard will have the primary responsibility for whale observation and compliance of the Precautionary Zones.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. Bridge Logs. MMO daily and weekly logs. PAM daily and weekly logs.	MMO.
	EPS 67: Trained crew will act as a support role to the MMOs when required to provide additional observation effort.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. Bridge Logs. MMO daily and weekly logs	Vessel Master. MMO. Trained Crew.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
EPBC Act Policy Statement 2.1: A.1 – Pre-survey Planning	**EPS 68**: An EP will be prepared and submitted to NOPSEMA for approval prior to commencement of the survey.	Submission of an EP to NOPSEMA for review and working through the public notification and approval process.	SLB Project Manager.
EPBC Act Policy Statement 2.1: A.2 – Crew training	**EPS 69**: Sufficiently trained crew will be on-board the Seismic Vessel with enough proven experience in whale observation, distance estimation and reporting to fulfil the basic requirements of the EPBC Act Policy Statement 2.1. Trained crew will act in a supporting role to the two experienced MMOs onboard the vessel.	Induction records outline qualifications/training of each observer/trained crew member. A copy of these records will be kept onboard the Seismic Vessel and the SLB Project Manager will also have a copy.	SLB Project Manager. MMO's. Trained Crew.
	EPS 70: MMOs and PAM operators will be inducted in their responsibilities regarding environmental matters (including the EPBC Act Policy Statement 2.1), whale identification, and the environmental legal obligations for companies operating in Australian waters.	Induction records outline the content of vessel inductions and crew present. The experience records of MMO's will be available at the inductions and a copy will be held by the SLB Project Manager to ensure the MMOs comply with the requirement of having a minimum of 20 weeks' relevant sea-time engaged in MSS operations in Australian waters as an MMO or Marine Fauna Observer and have proven 'at sea' experience in whale identification and behaviour.	SLB Project Manager. Vessel Master. MMO's PAM Operators.
	EPS 71: Reference material will be available onboard all vessels, with available materials including the EPBC Act Policy Statement 2.1, the Department's whale and dolphin sighting report form, and the APPEA CD Guide Search Australian Whales and Dolphins, and a copy of this EP.	Audit/inspection records verify the presence of reference materials on board the vessel.	SLB Project Manager. Vessel Master.
	EPS 72: Appropriate visual aids and identification guides will be supplied on board the vessels and made available for all crew to read.	Audit/inspection records verify the presence of reference materials and identification guides for marine mammals/marine fauna on board the vessels.	SLB Project Manager. Vessel Master.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
EPBC Act Policy Statement 2.1: A.3 – Pre-start-up visual observations	**EPS 73**: During daylight hours, visual observations for the presence of whales will be undertaken by two dedicated and experienced MMOs in the 3+ km Observation Zone (or the 5 km observation zone when the acoustic source is active within the blue whale migratory BIA and 17 km buffer) for at least 30 minutes before the commencement of soft-start procedures.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. Bridge logs. MMO daily and weekly logs.	Vessel Master. MMO.
EPBC Act Policy Statement 2.1: A.3.2 – Soft start procedures	**EPS 74**: Soft-start procedures may only commence if no whales have been sighted within the relevant Shut-down Zone of Low Power Zone during the pre-start observation period.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. Bridge logs. MMO daily and weekly logs.	MMO.
	EPS 75: An MMO will be onboard the bridge during soft-start procedures to observe for the presence of any whales entering the Observation Zone, Shut-down Zones or Low Power Zone.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. Bridge Logs. MMO daily and weekly logs.	MMO.
EPBC Act Policy Statement 2.1: A.3.3 – Start-up delay procedures	**EPS 76**: If a whale is sighted within the Observation Zone during soft-start procedures, an additional trained observer will be brought to the bridge to continuously monitor the animal. Two MMOs will be onboard the Seismic Vessel at all times and will be supported by trained crew. Two MMOs will be onboard the Chase Vessel for operations that occur inside the blue whale migratory BIA or buffer. Two PAM Operators will be onboard the Seismic Vessel at all times.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. Bridge logs. MMO daily and weekly logs. PAM Operator daily and weekly logs.	Vessel Party Chief. MMO. PAM Operator.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	EPS 77: If a whale is sighted within or about to enter a relevant Shut-down Zone, the acoustic source will shut-down completely. A soft-start procedure will resume only after the whale has been observed to move outside the Shut-down Zone, or when 30 minutes has lapsed since the whale was last sighted.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. Bridge logs. MMO daily and weekly logs. PAM Operator daily and weekly logs.	Seismic Operator. MMO. PAM Operator.
	EPS 78: If a toothed whale is sighted within or about to enter the Low Power Zone, the acoustic source to be powered down to the lowest possible setting. The soft-start procedure will resume only after the whale has been observed to move outside the Low Power Zone, or when 30 minutes has lapsed since the whale was last sighted.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. Bridge logs. MMO daily and weekly logs. PAM Operator daily and weekly logs.	Seismic Operator. MMO. PAM Operator.
EPBC Act Policy Statement 2.1: A.3.4 – Operations procedures	**EPS 79**: During daylight hours, visual observations by trained MMOs will be maintained continuously, including during pre-start observation period and soft-start operations. PAM will run continuously, 24-hours per day for the duration of the MSS on the Seismic Vessel.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. Bridge logs. MMO daily and weekly logs. PAM Operator daily and weekly logs.	MMO. PAM Operator.
	EPS 80: Visual observations will continue during daylight hours, and PAM will continue under 24 hour operations, within the OA even if the acoustic source is completely shut-down. A re-start will only occur following the pre-start observations and soft-start procedures.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. Bridge logs. MMO daily and weekly logs	MMO. PAM Observer. Party Chief.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
EPBC Act Policy Statement 2.1: A.3.5 – Stop work procedures	**EPS 81**: If a whale is sighted visually or detected acoustically within the Observation Zone, the second MMO will be brought to the bridge to continuously monitor the whale while is in sight (if during daylight hours).	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. Bridge logs. MMO daily and weekly logs. PAM daily and weekly logs.	MMO. PAM Observer.
	EPS 82: If a baleen whale is sighted within/about to enter the 2 km Shut-down Zone, the acoustic source will be shut-down immediately. If a toothed whale is sighted within/about to enter the 500 m Shut-down Zone, the acoustic source will be shut-down immediately. If a toothed whale is sighted within/about to enter the 2 km Low Power Zone, the acoustic source will be powered down to the lowest possible setting immediately.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. Bridge logs. MMO daily and weekly logs. PAM daily and weekly logs.	Seismic Operator. MMO. PAM Operator.
	EPS 83: Power-up of the acoustic source will only occur after the whale has been observed to more outside the Shut-down Zone or Low Power Zone, or when 30 minutes has lapsed since the last sighting. Power-up will follow the soft-start procedure.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. Bridge logs. MMO daily and weekly logs. PAM daily and weekly logs.	Seismic Operator. MMO. PAM Operator.
EPBC Act Policy Statement 2.1: A3.6 – Night-time and low visibility procedures	**EPS 84**: At night or other times of low-visibility (i.e. observations cannot extend to 3+ km from the acoustic source, or the 5 km observation zone when the acoustic source is active within the blue whale migratory BIA and 17 km buffer), operations may continue only if there have not been ≥3 whale instigated shut-down situations during the preceding 24-hour period.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. Bridge logs. MMO daily and weekly logs. PAM daily and weekly logs.	MMO. PAM Operator. Seismic Operator.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	EPS 85: Soft start procedures throughout the OA will be limited to conditions that allow visual inspection of the Observation Zone.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4. Bridge logs. MMO daily and weekly logs. PAM daily and weekly logs.	MMO. PAM Operator. Seismic Operator.
	EPS 86: During low-visibility, continuous observations to spot whales will be maintained where conditions allow, with a focus on the Low power and Shut-down Zones. If whales are detected visually, the Stop-work procedures will apply.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4. Bridge logs. MMO daily and weekly logs.	MMO. Seismic Operator.
	EPS 87: PAM will be implemented on the Seismic Vessel and will operate continuously (i.e. 24 hours/day) while the acoustic source is in the water.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4. Bridge Logs. PAM daily and weekly logs.	PAM Operator.
EPBC Act Policy Statement 2.1: A.4 – Compliance and sighting reports	**EPS 88**: Whale sightings will be reported in accordance with the EPBC Act Policy Statement 2.1 Part A.4 Compliance and Sighting Reports requirements, including submission of a report to the DoEE within two months of the survey completion	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4. Whale Observation Report.	SLB Project Manager. MMO. PAM Operator.
EPBC Act Policy Statement 2.1: B.1 – Marine Mammal Observers	**EPS 89**: Two trained MMOs will be onboard the Seismic Vessel at all times, with at least one MMOs on the bridge of the Seismic Vessel for the visual detection of marine mammals at all times during daylight hours. Two trained MMOs will be onboard the Chase Vessel during operations inside the blue whale migratory BIA and buffer, with at least one MMO on the bridge for the visual detection of marine mammals during daylight hours.	Induction records outline qualifications/training of each MMO. MMO daily and weekly logs.	SLB Project Manager. MMO.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	EPS 90: MMOs will have logged a minimum of 20 weeks' relevant sea-time engaged in MSS operations in Australian waters as an MMO or Marine Fauna Observer and have proven 'at sea' experience in whale identification and behaviour. MMOs will need to be able to demonstrate competency in identifying species likely to be present during the Seismic Survey and in assessing behaviour and estimating distance.	Induction records outline qualifications/training of each MMO.	SLB Project Manager.
EPBC Act Policy Statement 2.1: B.5 – Passive Acoustic Monitoring	**EPS 91**: PAM will be implemented on the Seismic Vessel and will operate continuously while the acoustic source is in the water for the duration of the Seismic Survey.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4. Bridge logs. PAM Logs.	PAM Operator.
	EPS 92: Two trained and experienced PAM Operators will be onboard the Seismic Vessel for the duration of the survey. At least one experience PAM Operator will maintain 'acoustic watch' at all times while the acoustic source is in the water.	Induction records outline qualifications/training of each PAM Operator. PAM daily and weekly logs.	PAM Operator. SLB Project Manager.
	EPS 93: PAM Operators will have logged a minimum of 20 weeks' relevant sea-time engaged in MSS operations in Australian waters as a PAM Operator. PAM operators will need to be able to demonstrate competency in the acoustic identification of the species that are likely to be present during the Seismic Survey, and in interpreting acoustic software and estimating distance to any detected whale calls.	Induction records outline qualifications/training of each PAM Operator. PAM daily and weekly logs.	SLB Project Manager.
	EPS 94: The PAM system will be programmed to receive/recognise vocalisations of whales within the frequencies 10 Hz to 200 kHz. The frequency range will detect both the low frequency vocalisations of baleen whales and the high frequency echolocations of sperm whales.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. PAM daily and weekly logs.	SLB Project Manager. PAM Operator.
	EPS 95: Frequency sensitivity will be designed into the hardware to remove vessel noise at very low frequencies.	PAM daily and weekly logs.	PAM Operator.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	EPS 96: PAMGuard software will be incorporated into the PAM system to assist with locating and classifying the vocalisations of marine mammals, and the PAM operators will be suitably trained in using the PAMGuard software.	PAM daily and weekly logs. PAM Operator training records.	SLB Project Manager. PAM Operator.
	EPS 97: Where possible, PAM detections will be validated and cross-referenced against MMO daylight visual observations and ranges at the start of the Seismic Survey to determine the error (if any) in PAM detections.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4. MMO daily and weekly logs. PAM daily and weekly logs.	PAM Operator. MMO. Party Chief. SLB Project Manager.
	EPS 98: PAM will be considered to be reliable if estimated distances deviate by ≤ 20%.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. PAM daily and weekly logs.	MMO. PAM Operator. Party Chief. SLB Project Manager.
	EPS 99: If PAM records prove reliable in estimating distances, PAM will be used to trigger shut-down procedures at night and during periods of poor visibility.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. MMO daily and weekly logs. PAM daily and weekly logs.	Seismic Operator. PAM Operator.
	EPS 100: In the event that a positive PAM whale detection occurs prior to PAM validation, a precautionary approach will be taken whereby a shut-down will occur regardless of species identification or distance estimate.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. MMO daily and weekly logs. PAM daily and weekly logs.	Seismic Operator. PAM Operator.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	EPS 101: A full replacement PAM system will be onboard the Seismic Vessel. PAM Operators will be competent to firstly assess whether there is an issue, and if not possible to repair, must be able to swap out the PAM system that is not working with the replacement PAM system.	Audit/inspection records verify the presence of a replacement PAM system.	SLB Project Manager. PAM Operator. Party Chief.
EPBC Act Policy Statement 2.1: B.6 – Adaptive Management	**EPS 102**: If high numbers of whale detections result in three or more shut-downs in a 24-hour period, the following adaptive management measures will be applied: • If three or more blue whale instigated shut-downs occur within a 24-hour period, the Seismic Vessel will relocate to another area at least 17 km away (and outside of the blue whale migratory BIA or buffer) before commencing Pre Start-up Visual Observations and Soft Start Procedures. This mitigation will be implemented throughout the entire OA (i.e. shut-downs both inside and outside the blue whale migratory BIA and buffer will contribute to this count; and If three or more other baleen whale instigated shut-downs occur within a 24-hour period, the Seismic Vessel will relocate at least 10 km away before commencing Pre Start-up Visual Observations and Soft Start Procedures.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. MMO daily and weekly logs. PAM daily and weekly logs. Vessel logs.	Vessel Master. MMO. PAM Operator.
	EPS 103: In the event that a baleen whale mother/calf pair is observed during the seismic survey the acoustic source will be immediately shut-down and the Seismic Vessel will relocate to: • Another area at least 10 km away for other baleen whales before commencing Pre Start-up Visual Observations and Soft Start Procedures; and • Another area at least 17 km away (and outside of the blue whale migratory BIA or buffer) before commencing Pre Start-up Visual Observations and Soft Start Procedures. This mitigation will be implemented throughout the entire OA (i.e. sightings both inside or outside the blue whale migratory BIA and buffer will trigger this mitigation measure).	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 verify the implementation of this procedure. MMO daily and weekly logs. PAM daily and weekly logs.	Vessel Master. MMO. PAM Operator.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
EPO: No disturbance to migrating pygmy blue whales within the blue whale migratory BIA due to acoustic disturbance.			
General blue whale migratory BIA and 17 km buffer control measures	**EPS 104**: A 17 km buffer will be established around the blue whale migratory BIA where it overlaps with the OA. Both the BIA and buffer will be subject to additional control measures.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 and MMO/PAM Logs verify the implementation of these procedures. MMO daily and weekly logs PAM daily and weekly logs.	Vessel Master. MMO. PAM Operator.
	EPS 105: The Standard (EPS 62 –35) and Additional Control (EPS 36 – 50) measures will be implemented within the blue whale migratory BIA and 17 km buffer, as well as the additional BIA control measures.	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 and MMO/PAM Logs verify the implementation of these procedures. MMO daily and weekly logs. PAM daily and weekly logs.	SLB Project Manager. MMO. PAM Operator.
	EPS 106: The Seismic Vessel will not activate the acoustic source(s) within the blue whale migratory BIA or buffer from mid-April (14th) to mid-January (14th);	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4. MMO daily and weekly logs. PAM daily and weekly logs. Bridge logs verify the implementation of these procedures.	Vessel Master. MMO. PAM Operator.
	EPS 107: As the likelihood of pygmy blue whales being present in the OA significantly decreases outside the migration season, seismic operations within the blue whale migratory BIA or 17 km buffer will be limited to the period 15 Jan to 13 April. During this period, all seismic operations inside the blue whale migratory BIA or buffer will: • Implement an extended observation zone of 5 km;	Compliance and sighting reports as per the EPBC Act Policy Statement 2.1 Part A.4 and MMO Logs verify the implementation of these procedures. Compliance with MMO Management Plan. MMO daily and weekly logs. Bridge logs.	SLB Project Manager. MMO.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	• The extended observation zone in the BIA and buffer will be monitored using the Chase Vessel as an additional observation platform with two MMO's onboard. The Chase Vessel will travel c. 3 km ahead of the Seismic Vessel (defined as an 180° arc ahead of the Seismic Vessel) and will conduct visual surveillance for marine mammals during daylight hours. Trained and experienced MMOs will be required to undertake these observations; • Whenever possible, two experienced MMOs will be on the bridge of the Seismic Vessel during daylight hours when the source is active within the blue whale migratory BIA or buffer; • Limit soft start procedures to conditions that allow visual inspection of the 5 km Observation Zone; • Cease night-time or low visibility operations in the blue whale migratory BIA or buffer if three or more whale instigated shut-downs or power-downs are made during the preceding 24-hour period. Note that this applies irrespective of shut-down/power-down locations relative to the blue whale migratory BIA or buffer. Night-time and low visibility operations may only resume in the blue whale migratory BIA or buffer after 24 hours of no blue whale instigated shut-downs (again, irrespective of location relative to the blue whale migratory BIA or buffer) and • If species identity is uncertain at any location inside the blue whale migratory BIA or buffer, any unidentified whale will be assumed to be a blue whale.	Vessel records list crew onboard Seismic Vessel and appropriate training.	
EPO: No permanent impacts on commercially fished stocks due to acoustic disturbance.			
Depth limitations to activation of acoustic source	**EPS 108**: There will be no active acoustic source within water depths less than 40 m.	Bridge logs. Vessel track records.	Vessel Master. MMO.
EPO: Survey is conducted in a manner that prevents noise effects on other marine users.			
Pre-survey stakeholder engagement	**EPS 109**: Stakeholder engagement will be conducted with all identified stakeholders prior to the commencement of the Seismic Survey.	EP submitted to NOPSEMA confirms stakeholder engagement.	SLB Project Manager.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
		Ongoing stakeholder consultation register.	
Ongoing communication with marine users	**EPS 110**: A 48-hour 'look-ahead' plan will be provided to marine users detailing the survey activities over the next 48 hours. The 48-hour Look-ahead plans will be updated and issued every 24 hours and distributed to relevant stakeholders via email.	Documentation of consultation and issuing of 48-hour look-ahead plans demonstrate compliance. Forms part of ongoing consultation strategy.	SLB Project Manager.
	EPS 111: A Notice to Mariners will be published and distributed by the AHO under the Navigation Act 2012.	Notice to Mariners will be issued.	Vessel Master. SLB Project Manager.
	EPS 112: All Notices to Mariners will be updated during the survey should changes occur.	An updated Notice to Mariners will be issued if required.	Vessel Master. SLB Project Manager.
	EPS 113: Stakeholder engagement will continue throughout the duration of the Seismic Survey with identified stakeholders. Any additional stakeholders identified during the programme will also be included in the stakeholder engagement communications and process.	Documentation of consultation demonstrates compliance.	SLB Project Manager.
EPO: No permanent impacts on commercially fished stocks due to acoustic disturbance.			
Depth limitations to activation of acoustic source	**EPS 114**: There will be no active acoustic source within water depths less than 40 m.	Bridge logs. Vessel track records.	Vessel Master. MMO.
EPO: Survey is conducted in a manner that prevents noise effects on other marine users.			
Pre-survey stakeholder engagement	**EPS 115**: Stakeholder engagement will be conducted with all identified stakeholders prior to the commencement of the Seismic Survey.	EP submitted to NOPSEMA confirms stakeholder engagement. Ongoing stakeholder consultation register.	SLB Project Manager.
Ongoing communication with marine users	**EPS 116**: A 48-hour 'look-ahead' plan will be provided to marine users detailing the survey activities over the next 48 hours. The 48-hour Look-ahead plans will be updated and issued every 24 hours and distributed to relevant stakeholders via email.	Documentation of consultation and issuing of 48-hour look-ahead plans demonstrate compliance. Forms part of ongoing consultation strategy.	SLB Project Manager.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	EPS 117: A Notice to Mariners will be published and distributed by the AHO under the Navigation Act 2012.	Notice to Mariners will be issued.	Vessel Master. SLB Project Manager.
	EPS 118: All Notices to Mariners will be updated during the survey should changes occur.	An updated Notice to Mariners will be issued if required.	Vessel Master. SLB Project Manager.
	EPS 119: Stakeholder engagement will continue throughout the duration of the Seismic Survey with identified stakeholders. Any additional stakeholders identified during the programme will also be included in the stakeholder engagement communications and process.	Documentation of consultation demonstrates compliance.	SLB Project Manager.
EPO: Noise emissions into the marine environment from sources other than the seismic acoustic source will be minimised.			
Maintenance of vessel machinery	**EPS 120**: Vessel machinery will be properly maintained in accordance with vessel's Planned Maintenance Systems.	Records demonstrate the latest maintenance has occurred.	Vessel Master.
EPO: No mortality or physical injury to marine fauna arising from any cumulative impacts will occur from the Seismic Survey.			
NOPSEMA website search	**EPS 121**: The NOPSEMA database of approvals will be searched to identify the potential for temporal and spatial overlap with other seismic surveys.	Search of the NOPSEMA activity status and summaries website, looking in particular for EP submissions or decisions in the surrounding areas to the SLB OA.	SLB Project Manager.
	EPS 122: All other submitted seismic survey EPs for in the region will be reviewed to determine any spatial or temporal potential overlap.	Documented summary presented in EP.	SLB Project Manager.
Spatial limitations of operations between multiple MSSs	**EPS 123**: In the event that another vessel is acquiring seismic data in the region, the Seismic Vessel will not acquire data simultaneously within 40 km of the other Seismic Vessel.	Vessel records and log will show any breach of these requirements. Bridge logs.	Vessel Master.

7.2.7 Residual Risk of Impact

Following the implementation of the control measures in **Table 56**, the likelihood of noise emissions having any impact on marine fauna varies from *rare* to *certain* depending on the receptor, and the consequence of noise emissions from the Seismic Survey varies from *Negligible* to *Moderate* following the discussions in **Section 7.2.2**.

The following table presents a summary of the residual risk from acoustic disturbance for each receptor (**Table 58**).

Table 58 Residual Risk Summary for Acoustic Disturbance to the Marine Environment

Receptor	Likelihood	Consequence	Residual Risk
Physiological Effects			
Zooplankton	Likely	Negligible	Negligible
Benthic Invertebrates	Unlikely	Minor	Low
Fish	Likely	Minor	Low
Cephalopods	Unlikely	Minor	Low
Marine Reptiles	Possible	Minor	Low
Baleen Whales	Rare	Moderate	Low
High Frequency Cetaceans	Rare	Negligible	Negligible
Dugongs	Rare	Negligible	Negligible
Elasmobranchs	Rare	Minor	Low
Seabirds	Rare	Minor	Low
Behavioural Effects			
Benthic Invertebrates	Unlikely	Minor	Low
Fish	Likely	Minor	Low
Cephalopods	Unlikely	Minor	Low
Marine Turtles	Possible	Moderate	Moderate
Sea snakes	Unlikely	Minor	Low
Marine Mammals	Likely	Moderate	Low
Elasmobranchs	Unlikely	Minor	Low
Seabirds	Possible	Minor	Low
Perceptual Effects			
Fish	Likely	Minor	Low
Marine Mammals	Certain	Minor	Moderate
Other Marine Users			
Commercial Fishers	Possible	Minor	Low
Divers	Rare	Moderate	Low

7.2.8 Demonstration of ALARP

To demonstrate the potential impacts from noise emissions are managed to **ALARP**, SLB has considered a number of control measures to assess the benefits of their implementation towards risk reduction (**Table 56**), based on a Hierarchy of Controls (**Table 59**). The adopted control measures that will be implemented throughout the Seismic Survey are considered appropriate to reduce the environmental impacts of noise emissions from the acoustic source, and any further efforts towards reducing potential risk of impacts (i.e. additional or modified control measures) are considered unfeasible (i.e. they do not provide significant additional environmental benefit or are not reasonable or practicable to implement). In addition, the costs (based on the experience of SLB) of implementing such measures would be disproportionate to the benefits conferred. As a result, the impacts from acoustic emissions have been reduced to **ALARP**, where the residual risk from adoption of these control measures is reduced to **Moderate** at most (**Table 58**).

Table 59 Hierarchy of Controls for Acoustic Disturbance to the Marine Environment

Eliminate	Noise emissions are a fundamental requirement of any MSS in order to produce the detailed geological images and meet survey objectives. As a result, noise emissions cannot be eliminated.
Substitute	While alternative acquisition options for acquiring geological data have been trialled, they are not yet commercially available or proven.
Reduce	The maximum capacity of the acoustic source has been designed to be as low as possible while still maintaining the ability to meet survey objectives. Survey operations will run 24/7 (where possible) in order to reduce the total duration of the survey. During the survey planning stage, several source sizes were investigated, and the 3,000 in^3 acoustic source was selected on the basis of being the lowest power source still capable of achieving the survey objectives.
Mitigate	Control measures have been assessed within **Table 56** in order to mitigate the impacts from noise emissions to **ALARP** levels. Those which are appropriate and are not impracticable or unfeasible (**Table 56**) will be implemented for the duration of the Seismic Survey.

The proposed control measures in **Table 56** to minimise and mitigate the risk of noise emissions to the marine environment are considered appropriate to the nature and scale of potential environmental impacts during the Seismic Survey. These proposed control measures are in accordance with industry best practice and regulatory requirements. No further practicable controls have been identified to effectively reduce the impact and risks to the marine environment, marine organisms, and marine users from noise emissions from the acoustic source over and above what is proposed in **Table 56**.

Based on the information presented throughout this section, including: the UAM results, the survey design, and the ongoing stakeholder engagement process; it is considered that the potential impacts from acoustic disturbance from the Seismic Survey are reduced to **ALARP**.

7.2.9 Risk Acceptability

MSSs are required to map the geologic formations beneath the seabed and there are currently no alternatives to accurately image these to the required resolution. As part of the survey design phase, SLB considered several source sizes to determine the most appropriate size to minimise impacts while still achieving survey objectives. The preferred source size for illumination was an array with a volume of 3,000 in^3. This is in line with source volumes used in recent marine surveys in the area and sufficient to achieve the goals of the survey. In summary, the selected size was found to be sufficient for the required data resolution and achieving the survey objectives, whilst minimising impacts.

The ERA process within this EP has determined that, assuming the implementation of control measures (**Table 56**) the potential impacts to the marine environment and associated receptors (i.e. marine fauna and marine users) from noise emissions are *Negligible* to *Moderate*. The control measures that are proposed are in accordance with the Environment Regulations and based on the acceptability criteria outlined in in **Table 34**, as well as being consistent with relevant legislation, standards and codes.

Due to the transitory nature of the Seismic Vessel, the acoustic noise will be constantly moving at 4 – 5 knots throughout the OA along the pre-determined survey line plan. This will assist in limiting potential impacts to fish and marine mammals as the vessel will not be focused in any particular area for a period of time. The 140 km survey lines, that will take approximately 32 hours to complete, contributes further to the transient nature of the survey. There is expected to be some avoidance behaviour from marine mammals, fish and turtles that may be in the OA based on the underwater noise modelling (**Section 7.2.2.2)**; however, these behavioural effects are expected to cease once the Seismic Vessel has moved further along the sail line and are predicted as worst-case due to all azimuths being modelled away from the acoustic source.

There are no predicted long-term physiological effects (**Section 7.2.2.1**) or behavioural effects (**Section 7.2.2.2**) that could contribute to population level effects on any species that has been identified within the development of this EP as a result of the Seismic Survey, and no adverse effects on the environmental values or the objectives of the management plans associated with the Australia Marine Parks, KEFs, and other protected areas or areas classified as important to marine conservation (**Section 7.2.2.4**).

The control measures (**Table 56**) that will be implemented as part of operational procedures for the duration of the Seismic Survey have been developed in consideration and accordance with the criteria for risk acceptability (**Table 34**). These criteria are further assessed in **Table 60**. Where uncertainty exists around the criteria or the risk, a precautionary approach was taken for the criteria of acceptance.

Table 60 Demonstration of Risk Acceptability for Acoustic Disturbance

Criteria for Acceptance	Acceptability Summary
SLB's internal context	The proposed management of the impact/risks from noise emissions are within **Acceptable Levels** of SLB's Environmental and QHSE Policy.

Industry Best Practice	The proposed control measures follow industry best practice and best practice guidelines, including:
	• Adoption of the EPBC Policy Statement 2.1 which is considered Industry Best Practice for minimising the effects of MSSs on marine mammals. Control measures will be implemented for the duration of the Seismic Survey and these measures have been developed in accordance with the EPBC Act Policy Statement 2.1 (i.e. soft starts, Precaution Zones, MMOs);
	• The IAGC Environmental Manual for Worldwide Geophysical Operations which includes recommended mitigation measures for cetaceans to minimise acoustic disturbance during geophysical operations. These measures include, but are not limited to:
	  ◦ Use of soft-start procedures;
	  ◦ Providing basic awareness training to the entire crew; have them immediately report any cetacean observation to the bridge;
	  ◦ Reporting immediately to local authorities any animals in distress, animal carcasses, etc.; and
	• The APPEA Code of Environmental Practice which includes objectives to reduce the impact on cetaceans and other marine life to **ALARP** and to an **Acceptable Level** by

Criteria for Acceptance	Acceptability Summary
	ensuring operations are in accordance with legislative requirements and demonstrate the implementation of appropriate management measures.
External Context – Commonwealth and State Legislative Criteria	The Seismic Survey will comply with all relevant legislative requirements, in particular the EPBC Policy Statement 2.1 Part A measures. Under Part B of the EPBC Act Policy Statement 2.1, various measures are recommended when the likelihood of encountering whales is moderate to high. Several control measures will be implemented for the duration of Seismic Survey in accordance with Part B of the EPBC Act Policy Statement 2.1.
External Context – Management Plans, Species Recovery Plans and Conservation Advice	The NOPSEMA guidance note for petroleum activities and Australian Marine Parks (NOPSEMA, 2020d) requires that an EP is developed for undertaking activities such as MSSs to evaluate how environmental impacts and risks will be of an **Acceptable Level** and reduced to **ALARP** and demonstrate that the MSS will not be inconsistent with the relevant marine park management plan. The Seismic Survey will be undertaken in accordance with the objectives of the North-west Marine Parks Network Management Plan and the North Marine Parks Network Management Plan. Each of the environmental sensitivities within the Australian Marine Parks have been assessed within this EP, where the management of the Seismic Survey is considered to be consistent with the objectives of the management plans. The relevant measures within the conservation advice and recovery plans have been considered during the development of the control measures that will be implemented during the Seismic Survey and are considered to be consistent with these recovery plans and Conservation Advice as described below. Interim Objective 4 of the 'Conservation Management Plan for the Blue Whale' is to "*ensure anthropogenic threats are demonstrably minimised*" and is to be tested by Target 4-1; "*Robust and adaptive management regimes leading to a reduction in anthropogenic threats to Australian blue whales are in place*". This Conservation Management Plan listed seismic noise as a potential source of anthropogenic noise impacts, which was determined a threat with very high priority for pygmy blue whales. Listed conservation actions to ensure recovery targets are met that are applicable to the Seismic Survey include: • Assessing the effect of anthropogenic noise on blue whale behaviour; • Anthropogenic noise in BIAs will be managed such that any blue whale continues to utilise the area without injury, and is not displaced from a foraging area; and • EPBC Act Policy Statement 2.1 is applied to all MSSs. The effects of anthropogenic noise on pygmy blue whales have been assessed in this EP. Adoption of the EPBC Act Policy Statement 2.1 Part A measures and several Part B measures including the implementation of additional control measures in the blue whale migratory BIA and 17 km buffer will ensure that blue whales will be able to utilise the BIA without injury or significant behavioural impacts whilst the survey takes place, and the control measures that SLB will implement are consistent with the conservation actions for the blue whale. In addition, SLB will apply spatial exclusion measures to the blue whale migratory BIA and 17 km buffer from 14 April to 14 January which is when migrating whales are expected to be present (see **Table 21**).

Criteria for Acceptance	Acceptability Summary
	Animat modelling was undertaken to better understand the risk that the Seismic Survey poses to pygmy blue whales. This modelling incorporated pygmy blue whale movement data to predict exposure ranges that are significantly more realistic than those produced by UAM. Animat modelling predicted that the distance within which 95% of threshold exceedances would occur for pygmy blue whales is 1.4 km for PTS. Therefore, compliance with the extended 2 km Shut-down Zone will prevent PTS impacts on blue whales. The establishment of the 17 km buffer around the blue whale migratory BIA will protect this species from any potential effects of TTS as well. Adaptive management measures will also be implemented to manage night-time/low visibility operations. Based on the 1) proposed control measures (including the temporal and spatial mitigations to be implemented in the blue whale migratory BIA and 17 km buffer and several adaptive management measures), and the species specific Animat modelling to quantify potential impacts, the overall environmental risks from the Seismic Survey are considered to be reduced to **ALARP** and at **Acceptable Levels** with regard to pygmy blue whales and that management of the Seismic Survey aligns with the objective of the blue whale Conservation Management Plan. For all other species of baleen whale, conventional UAM results predicted that 24-hour cumulative PTS could occur out to a maximum of c. 7 km, but that exposure to a single pulse from the active acoustic source would not elicit PTS even if an animal was very close to the source (< 20 m). The maximum onset distance for 24-hour cumulative TTS is predicted to be 48 km while the single pulse onset distance for TTS is 80 m. On the basis that other baleen whales are probably only present in the OA at low or very low densities (see **Table 50**) and that UAM does not account for animal movement or the movement of the Seismic Vessel, the 24-hour cumulative UAM results were considered to be excessively conservative for defining the extent of observation or shutdown zones for other baleen whales. It is noteworthy that over a 24-hour period the Seismic Vessel could travel up to 200 km; hence 24-hour cumulative exposure over the 48 km TTS onset distance and the 7 km PTS onset distance is highly unlikely for baleen whales. As a precaution, an extended 2 km shutdown zone for all baleen whales will be adopted throughout the OA and this will serve to provide complete protection from short-term exposure to underwater noise for these species. In addition, adaptive management measures will be implemented to provide further protection to these other species of baleen whale. Conservation and Management Actions for humpback whales have been outlined in the humpback whale Conservation Advice and include "*assessing and addressing anthropogenic noise: shipping, industrial and seismic surveys*". All mitigation measures listed within the Conservation Advice are included within the proposed control measures and will be implemented throughout the Seismic Survey, this also includes the adoption of all EPBC Act Policy Statement 2.1 Part A measures and certain Part B measures (including spatial and temporal adaptive management procedures where appropriate and use of PAM), and the undertaking of UAM. The mitigation measures in place for the Seismic Survey will adhere to the requirements of the Conservation Advice and will assist with reducing potential noise impacts and risks to **ALARP** so that any potential impacts are managed to an **Acceptable Level** with regard to humpback whales and that the survey will be carried out in a way that will be consistent with the humpback whale Conservation Advice.

<table>
<tr><th>Criteria for Acceptance</th><th>Acceptability Summary</th></tr>
<tr><td></td><td>No further mitigation measures have been provided in the Conservation Advice for sei and fin whales to address anthropogenic noise; however, those mitigations adopted to address potential impacts on blue whales will be of substantial benefit to sei and fin whales as well. Adoption of the EPBC Act Policy Statement 2.1 Part A measures and several Part B measures will be implemented to reduce the potential noise impacts and risks to ALARP and Acceptable Levels with regard to sei and fin whales, and the survey will be consistent with the Conservation Advice for these species.

Although anthropogenic noise has been assessed within the Recovery Plan for Marine Turtles in Australia, there are no specific actions to address effects on turtles other than the recommendation to adhere to the EPBC Act Policy Statement 2.1, particularly the use of soft start procedures, which are incorporated into SLBs control measures. Therefore, the control measures that will be implemented will be consistent with the objectives of the marine turtles Recovery Plan.

Under the Draft Wildlife Conservation Plan for Seabirds 2019, effects of anthropogenic disturbance to seabird breeding and roosting areas are to be managed. Given the open ocean nature of the Seismic Survey no disturbance effects from underwater noise are predicted for breeding or roosting sites therefor no specific additional measures are required to reduce potential noise impacts and risks to ALARP and Acceptable Levels for seabirds.</td></tr>
<tr><td>Social Acceptance – Stakeholder expectations</td><td>Some concerns were raised during the stakeholder engagement programme, in regard to the effects from acoustic disturbance. The main concerns raised and what has been considered within the EP and environmental risk assessment process were:
• Implement notification requirements, as a 48-hour operational look ahead plan.
• Effects upon the values of protected receptors within the Oceanic Shoals Marine Park located adjacent to the OA.
• Implementing protocol to compensate fishers if they are displaced from their fishing grounds during the Seismic Survey.

All concerns raised by stakeholders were considered as part of the EP process and responses were provided to all submissions with further information or feedback as necessary. All submissions and associated response are provided in Appendix I. Detailed literature reviews, UAM and revisions to the survey design and OA were included in the development of the EP and an extensive set of control measures to reduce the overall impacts from the Seismic Survey on the marine environment and those stakeholders that use the marine environment for their economic wellbeing, to ALARP and an Acceptable Level.</td></tr>
<tr><td>Ecologically Sustainable Development</td><td>The management of risk associated with acoustic source emissions for the Seismic Survey shall comply with the five principles of ecologically sustainable development as defined within the EPBC Act. These principles have been considered as part of the development of this EP and risk assessment process, and the assessment has not identified any adverse impacts to the principles of ESD, namely:
• No threats of serious or irreversible environmental damage were identified, particularly in relation to marine mammals, benthic invertebrates, zooplankton, fishes and seabirds;
• Inter-generational equity will not be degraded for future generations as potential acoustic disturbance impacts will be localised and full recovery of all potential receptors is expected;
• The decision-making process has integrated both long-term and short-term economic, environmental, social and equitable considerations and where necessary, appropriate control measures have been proposed;</td></tr>
</table>

Criteria for Acceptance	Acceptability Summary
	• Conservation of biological diversity and ecological integrity have been considered in the decision-making process following the ERA process outlined in **Section 6**; and • The control measures proposed have considered improved valuation, pricing and/or incentive mechanisms – control measures that had environmental benefits that outweighed the costs of their implementation were proposed to be undertaken.
Existing Environmental Context	The OA overlaps or is near (<50 km) to BIAs for the following species: whale sharks, pygmy blue whales, flatback turtles, loggerhead turtles, olive ridley turtles, and lesser frigate birds. While numerous commercially valuable fish stocks occur in the region, in recent years fishing effort in the OA has been limited to the Northern Demersal Scalefish Managed Fishery and the Mackerel Managed Fishery, with by far the majority of fishing effort occurring inshore of the OA. Based on the UAM results, the residual risk ratings for all animal groups (excluding marine mammals and turtles), were assessed as **Low (Table 58**). Marine mammals and turtles had a **Moderate** residual risk rating for behavioural effects; and marine mammals also had a Moderate residual risk rating for perceptual effects. It is considered that the proposed control measures provide appropriate protection to the marine environment from acoustic disturbance associated with the Seismic Survey and the associated effects to marine organisms, marine conservation, stakeholders and other marine users. Further/alternative control measures were considered (see **Table 56**) but would not be practicable and the time and cost required to implement further controls are considered to be disproportionate to the environmental benefit that would be gained. No Australian Marine Parks overlap with the OA and the OA boundaries only approach (<50 km) one AMP, namely the Oceanic Shoals Marine Park Multiple User Zone which is classified IUCN VI. The OA overlaps with one KEF being the Carbonate Bank and Terrace System of the Sahul Shelf. Environmental sensitivities within each AMP and KEF have been individually taken into consideration within the EP. Overall, it is considered that through the implementation of the proposed control measures (including precaution zones, MMOs, temporal and spatial measures and adaptive management measures), and the operational procedures, the impacts from underwater noise emissions from the Seismic Survey will not have any detrimental or long-lasting impact on the marine environment. Lastly, the Seismic Survey will be conducted in accordance with the relevant IUCN principles, EPBC Act Policy Statement 2.1 and other relevant legislation or code, and any adverse impacts to the surrounding marine environment, fauna, protected species, recognised values and sensitivities will be reduced to **ALARP** and **Acceptable Levels**.
ALARP	MSSs are required to identify hydrocarbon reserves and there are currently no alternatives to accurately image these potential reserves under the seabed. As part of the survey design phase, SLB considered a number of different source volumes used in preceding surveys in the area as part of a survey design and modelling exercise in order to determine the most appropriate to minimise impacts while still achieving survey objectives. The preferred source for illumination was an array with volume 3,000 in^3. This is in line with source volumes used in recent marine surveys in the area and sufficient to achieve the goals of the survey. In summary, the selected size was found to be sufficient for the required data resolution and achieving the survey objectives, whilst minimising impacts.

Criteria for Acceptance	Acceptability Summary
	The ERA process within this EP has determined that, assuming the implementation of the proposed control measures the potential impacts to the marine environment and associated receptors (i.e. marine fauna and marine users) from noise emissions are likely to be medium term but would cease when the activity stops (moderate consequence rating). The control measures that are proposed are in accordance with the Environment Regulations and based on the acceptability criteria, as well as being consistent with relevant legislation, standards and codes. Due to the transitory nature of the Seismic Vessel, the acoustic noise will be constantly moving at 4 – 5 knots throughout the OA along the pre-determined survey line plan. This coupled with the survey line length (140 km) largely serves to limit potential impacts to ecological receptors as the vessel will not be focused in any one area for long periods of time. Some avoidance behaviours from marine mammals, fish and turtles are expected; however, these behavioural effects are expected to cease once the Seismic Vessel has moved outside the behavioural onset distance for each receptor, which will quickly occur as the Seismic Vessel proceeds along each sail line. The location of the OA is entirely oceanic and does not approach closer than 100 km to any coastline. There are no predicted long-term physiological effects or behavioural effects that could contribute to population level effects on any species that has been identified within the development of this EP as a result of the Seismic Survey following the implementation of the extensive suite of control measures, and no adverse effects on the environmental values or the objectives of the management plans associated with the Australia Marine Parks, KEFs, and other protected areas or areas classified as important to marine conservation. Based on the findings of this EP, with the implementation of the control measures, underwater noise emitted from the acoustic source is considered to have a **Moderate** impact on the marine environment. This impact is predicted to be a medium scale effect in terms of displacement of some marine mammals, marine turtles and fish species away from the active acoustic source; however, it is envisaged that the proposed temporal and spatial controls will avoid displacement to of migrating pygmy blue whales. However, for any marine mammals or fish which are displaced and move away from the emitted sound levels, the duration that they would move away is likely to be of medium term and any displacement or avoidance of the area would cease as soon as the activity ceases. With the control measures in place, it is considered that the Seismic Survey will be acquired so that the environmental risk and impacts on the marine environment and associated receptors within and surrounding the OA from the acoustic disturbance are reduced to **ALARP**. In accordance with the Risk Ranking Descriptions, where risk cannot be reduced to '**Low**', control measures must be applied to reduce the risk to **ALARP**, as indicated in above. As a result, following the implementation of the extensive control measures, the impacts from acoustic disturbance associated with the Seismic Survey are considered to be at an **Acceptable Level**.

7.2.10 Acoustic Disturbance Impact Summary

Based on the findings of this EP, with the implementation of the control measures, underwater noise emitted from the acoustic source is considered to have (at most) a **Moderate** risk to the marine environment. Consequences of predicted effects will generally be of medium scale and term with regards to displacement of marine mammals, marine turtles and fish away from the acoustic source; however, it is envisaged that any displacement or effects would cease as soon as the activity ceases.

In accordance with the Risk Ranking Descriptions in **Section 6;** where risk cannot be reduced to '**Low**', control measures must be applied to reduce the risk to **ALARP**. Based on the extensive control measures (**Table 56**) that have been proposed in accordance with industry best practice, Environment Regulations and all other relevant regulations, it is considered that the Seismic Survey can be managed such that the environmental risk from acoustic disturbance are reduced to **ALARP**. The impacts from acoustic disturbance associated with the Seismic Survey are therefore considered to be managed to an **Acceptable Level**.

7.3 Routine Permissible Waste Discharges

7.3.1 Source of Discharge

The source of routine permissible waste discharges falls into three categories:

- Biodegradable waste (sewage, greywater and galley waste such as putrescible food waste);
- Deck drainage; and
- Bilge water.

Sewage, greywater and galley waste represent the primary forms of biodegradable waste that are likely to be produced during the Seismic Survey. A typical Seismic Vessel is likely to have a maximum daily sewage discharge capacity of approximately 15 m^3, and the typical discharge capacity for the Support Vessel and Chase Vessel is approximately 4.2 m^3. The actual daily volumes of sewage and greywater generated during the Seismic Survey will be much lower than these capacities and will be directly related to the number of personnel onboard. For the purpose of this assessment, it is estimated that each person onboard a vessel generates approximately 35 L of sewage/greywater per day, originating from processes such as ablution, laundry and gallery activities. Therefore, assuming a vessel capacity of 70 persons, the Seismic Vessel will discharge approximately 2.5 m^3 per day, and the Support Vessel and Chase Vessel each discharging approximately 1.9 m^3 per day, based on the assumption of having up to 54 persons onboard.

The other source of permissible waste discharges are deck drainage and bilge water. Ongoing cleaning and maintenance operations around the vessels, as well as deck drainage from rain or spray will generate deck waters which may contain remnants of spilt materials, detergents, oils and smaller solid materials (garbage). Larger chemical spills would be contained and/or cleaned up prior to entering the deck drainage systems as per the vessels emergency spill/pollution plans. Bilge water is drainage water and other fluids captured in a closed system, often from engine or machinery spaces within the vessel, for treatment prior to discharge at sea, or stored for discharge at port – as per requirements of MARPOL Annex 1. The contaminant profile of bilge water may comprise cleaning chemicals, hydrocarbons and heavy metals.

In addition to the above, non-biodegradable waste will be generated during the Seismic Survey, such as garbage. MARPOL Annex V prohibits the discharge to sea of all types of garbage unless explicitly permitted under the Annex (as detailed in previous sections). Garbage onboard the survey vessels such as plastics, synthetic ropes, cooking oils, paper and cardboards, rags, packaging materials, polystyrenes/foam and wood are prohibited from being discharged into the marine environment, and these materials will be retained onboard the vessels and stored for later disposal onshore at suitable waste facilities.

7.3.2 Known and Potential Impacts to Environmental Receptors

Biodegradable waste disposed at sea is decomposed by bacteria either in the water column or on the seabed. This decomposition process increases the biochemical oxygen demand (**BOD**) in the surrounding area which can potentially limit dissolved oxygen for other marine organisms (particularly in low flow areas where water circulates slowly). Disposal of biodegradable wastes at sea can also lead to areas of artificial nutrient enrichment (particularly phosphorus and nitrogen) which in extreme cases can trigger excessive algae growth (Perić, 2016; Wilewska-Bien *et al.*, 2016). Whilst the waters comprising the OA are considered oligotrophic and stratified (DEWHA, 2008b), strong seasonal currents and internal tides within the OA will likely result in rapid dilution and dispersion of discharged wastes with no discernible elevation in nutrients and/or BOD. Where rapid dilution and dispersion do not occur, localised elevations in nutrients and/or BOD will not likely exceed the nature and scale of natural local upwelling characteristic of the region (Semeniuk *et al*., 1982).

The discharge of food wastes can also lead to increased scavenging behaviour around the vessels by seabirds and fish, sometimes leading to animals following the vessel for significant distances. Sewage and greywater (particularly untreated wastes) may also contain hazardous pathogens (e.g., faecal coliforms and viruses) which can pose risks to those in contact with the wastes and/or the water in which it is discharged, as well as risks to those that might consume seafood collected from the area where discharges of these wastes occurred.

Constituents within the deck drainage and bilge water could have potential environmental impacts including:

- Polluting surface waters and/or benthic sediments; and
- Toxicity to marine organisms; and

The level of impact will be directly related to the volume of the contaminant and the volume of water it is discharged within, their toxicity, the types of organisms present, and the receiving environment itself. Discharged contaminants can cause damage to organisms across all trophic levels. Immediate impacts would mostly affect organisms within the water column but pollutants adsorbing onto particles/sediments within the water column settle to the seabed where benthic organisms may be exposed.

The OA is located within an open ocean environment where over 95% of the depths to seabed are greater than 60 m. Based on the relative depth of the water profile, coupled with the anticipated mixing and dispersion of discharged wastes, it is unlikely any impact to benthic species will occur. Potential receptors therefore include (pelagic) fish and sharks, marine mammals, marine turtles and seabirds.

Based on the control measures that will be implemented during the Seismic Survey (**Section 7.3.3**), it is considered that the consequence of impact is *Negligible*, with a likelihood of seeing a measurable impact being *Unlikely* which results in an overall risk ranking of **Negligible**.

7.3.3 Control Measures

The control measures that will be implemented during the Seismic Survey to manage the impacts from routine permissible waste discharges to **ALARP** have been included in **Table 61**. These control measures have been assessed to consider the environmental benefits gained through implementing these controls relative to their time, effort and monetary cost. SLB will make a clear delineation of those measures which will be implemented during the Seismic Survey and those which won't, in particular where SLB considers their implementation is disproportionate to the environmental benefit gained. Justifications have been provided for each of these decisions.

Table 61 Assessment of Control Measures for Routine Permissible Waste Discharges

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Implemented Control Measures:				
Compliance with MARPOL Annex I (Regulations for the Prevention of Pollution by Oil) Marine Order 91 (Marine Pollution Prevention – Oil) Protection of the Sea (Prevention of Pollution from Ships) Act 1983	P = Yes E = Effective	It is a legislative requirement to meet the relevant aspects of MARPOL Annex I, Marine Order 91 and the PSPPS Act.	Yes	Yes
Compliance with MARPOL Annex IV (Regulations for the Prevention of Pollution by Sewage from Ships) Marine Order 96 (Marine Pollution Prevention – Sewage)	P = Yes E = Effective	It is a legislative requirement to meet the relevant aspects of MARPOL Annex IV and Marine Order 96.	Yes	Yes
Compliance with MARPOL Annex V (Regulations for the Prevention of Pollution by Garbage from Ships) Marine Order 95 (Marine Pollution Prevention - Garbage)	P = Yes E = Effective	It is a legislative requirement to meet the relevant aspects of MARPOL Annex V and Marine Order 95.	Yes	Yes
No permissible discharge of wastes in Australian Marine Parks.	P = Yes E = Effective	Oceanic Shoals Marine Parks is situated immediately beyond the eastern boundary of the OA. Restricting release of discharges within the Australian Marine Parks will avoid any potential adverse effects from discharges on the sensitivities within the parks.	Yes	Yes
Equipment/machinery involved in the treatment of wastes will be routinely maintained	P = Yes E = Effective	Routine maintenance ensures that the requirements of MARPOL are able to be met.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
All crew will participate in the vessel and environmental induction prior to the commencement of operations	P = Yes E = Effective	It is a standard industry practice to hold inductions for all onboard the vessels, with participation in induction meetings compulsory. During inductions, crew will be made aware of their responsibilities with regard to effects of the discharge of wastes to the marine environment and restrictions around the overboard discharge of waste materials.	Yes	Yes
Secondary containment measures	P = Yes E = Effective	Areas used to store hazardous substances (e.g. hydrocarbons and cleaning chemicals) will be fully bunded with drains leading to the bilge water tank treatment system in order to stop the release of any untreated hazardous substances into the marine environment. Spill kits will be located nearby for use in the event of a hazardous substance spill. These measures are standard industry practice.	Yes	Yes
Alternative Control Measures:				
Eliminate the discharge of sewage, greywater and galley waste	P = No E = Very Effective	As the vessels is required to be manned, the generation of sewage, greywater and galley waste is unavoidable. Although this would reduce the impact of discharges, the storage of this waste on board the vessels and subsequent transfer to shore will add significant operational costs (fuel etc.), and also increase the environmental risk and impact due to the additional journeys to port. It is considered that the costs associated with this control measure are disproportionate to the benefits gained as additional risks and impacts could also occur from the implementation of this measure.	No	No

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Eliminate the discharge of deck drainage and bilge water	P = No E = Very Effective	Similar to above, the storage of deck drainage and bilge water on board the vessels for transfer and disposal to shore is not considered practicable due to vessel stability. This operation would add significant costs (i.e. fuel use and vessel down time) and additional environmental risk and potential impacts to the project if a voyage back to port was made during the Seismic Survey. Therefore, it is considered the costs associated with implementing this control measure are disproportionate to the benefits gained, as additional risks and impacts could also occur from the implementation of this measure.	No	No

7.3.4 Environmental Performance

The EPO for the effective management of environmental impacts from routine permissible waste discharges is listed below:

- All routine permissible waste discharges will comply with legislated discharge requirements for permissible waste.

It is considered that the above EPO, as a result of the control measures (**Table 61**), will enable the ongoing environmental performance of the Seismic Survey in accordance with the **Acceptable Levels** described within **Section 7.3.7**, while ensuring that the relevant legislation is complied with in order to avoid any health and safety risks or impacts on the marine environment as far as reasonably practicable.

The EPSs within **Table 62** have been defined to manage impacts from routine permissible waste discharges to **ALARP** and an **Acceptable Level**. Compliance with these standards will ensure that the identified EPO will be achieved for the duration of the Seismic Survey.

Table 62 Environmental Performance Outcomes and Standards for Routine Permissible Waste Discharges

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
EPO: All routine permissible waste discharges will comply with legislated discharge requirements for permissible waste.			
Compliance with: MARPOL Annex I; Marine Order 91; and Protection of the Sea (Prevention of Pollution from Ships) Act 1983	**EPS 124**: An International Oil Pollution Prevention Certificate (**IOPP Certificate**) will be held by every ship of 400 gross tonnage and above involved in the Seismic Survey as per division 3 of Marine Order 91, and MARPOL Annex I.	IOPP Certificate is valid.	Vessel Master.
	EPS 125: Oil filtering equipment (of an approved design) processes oily water to meet the 15 ppm requirement of MARPOL Annex I, Marine Order 91 and the PSPPS Act. Any discharge of processed oily water will be undertaken while the vessel is underway in accordance with the above concentration requirements. Any separated oil will be retained/stored onboard and transported to shore for disposal at an approved facility.	Vessel audit confirms it is in survey and equipment is operational. Discharge logs.	Vessel Master.
Compliance with: MARPOL Annex IV; and Marine Order 96	**EPS 126**: An International Sewage Pollution Prevention Certificate (**ISPP Certificate**) will be held by every ship of 400 gross tonnage and above involved in the Seismic Survey, and any vessel certified to carry more than 15 persons as per division 3 of Marine Order 96, and Regulation 4 of MARPOL Annex IV.	ISPP Certificate is valid. Vessel audit.	Vessel Master.
	EPS 127: When sewage is comminuted and disinfected using an approved system (as per Marine Order 96), the discharge to sea will only occur at a moderate rate when the vessel is travelling at greater than 4 knots, and when further than 3 NM from the nearest land as per MARPOL Annex IV.	Discharge logs.	Vessel Master.
	EPS 128: When sewage is not comminuted or disinfected using an approved system, the discharge to sea will only occur at a moderate rate when the vessel is travelling at greater than 4 knots, and when further than 12 NM from the nearest land as per MARPOL Annex IV.	Discharge logs.	Vessel Master.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	EPS 129: When operating vessels within 12 NM of the coast, any sewage that is not comminuted or disinfected through an approved system will be stored within holding tanks. This sewage will then either: be transferred ashore for appropriate treatment; or, discharged to sea once further than 12 NM from the coast as per the standards above.	Waste Transfer Certificate issued by licensed facility of carrier for onshore transfers. Discharge logs.	Vessel Master.
Compliance with: MARPOL Annex V; and Marine Order 95	**EPS 130**: When food wastes have been comminuted or ground down to less than 25 mm, the discharge of this waste can occur when further than 3 NM from the nearest land as per MARPOL Annex V.	Visual inspection records confirm that macerator is functional and in use. Discharge logs.	Vessel Master.
	EPS 131: When food wastes have not been comminuted or ground down to less than 25 mm, the discharge of this waste can occur when further than 12 NM from the nearest land as per MARPOL Annex V.	Discharge logs.	Vessel Master.
	EPS 132: Any vessel used for the Seismic Survey over 100 gross tonnes or certified to carry 15 or more persons will hold and maintain a Garbage Management Plan for minimising, collecting, storing, processing and disposing of garbage, including the use of equipment on board, as per MARPOL Annex V and Marine Order 95.	Garbage Management Plan is valid. Garbage logs.	Vessel Master.
	EPS 133: All permissible waste discharges will be recorded within the vessel's Garbage Logbook.	Garbage logs.	Vessel Master.
Restriction of permissible discharges to outside of Australian Marine Park boundaries	**EPS 134**: Permissible discharges will not occur within Australian Marine Parks.	Discharge logs confirm that discharges have occurred outside of Australian Marine Parks. Garbage logs.	Vessel Master.
Participation of all crew in vessel induction	**EPS 135**: All crew will participate in a vessel induction prior to the commencement of the survey, outlining their roles and responsibilities while onboard the vessels.	Induction records show content of induction meeting and participation of crew.	Vessel Master.
Routine maintenance of waste disposal machinery	**EPS 136**: Equipment/machinery involved in the treatment of sewage, galley waste, deck drainage and bilge water will be routinely maintained and will be fully operational prior to survey commencement.	Maintenance records confirm that equipment/machinery is functioning correctly.	Vessel Master.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
Secondary containment measures	**EPS 137**: Hazardous materials (e.g., hydrocarbons and cleaning chemicals) storage areas will be fully bunded and drain to the bilge water tank treatment system. Spill response kits will be stored nearby the storage location of these hazardous substances if a spill does occur for clean-up purposes.	Audit records confirm location of stored hazardous substances and appropriate bunding.	Vessel Master.
Maintenance of drainage control measures	**EPS 138**: Scupper plugs, or equivalent drainage control measures, will be readily available to allow drains to be blocked in the event of a hydrocarbon or cleaning chemicals spill to deck (i.e., outside bunded area).	Audit records confirm location of drainage control measures.	Vessel Master.

7.3.5 Residual Risk of Impact

Following the implementation of the control measures within **Table 61**, the likelihood of a measurable impact on environmental receptors from routine permissible discharges is *Unlikely*. The consequence from routine permissible waste discharges is considered *Negligible*, based on the assessment within **Section 7.3.2.**

Therefore, using the risk matrix outlined in **Table 31**, the residual risk from routine permissible waste discharges, following the implementation of control measures (**Table 61**) is considered to be **Negligible** (**Table 63**).

Table 63 Residual Risk Summary for Routine Permissible Waste Discharges

Likelihood	Consequence	Residual Risk
Unlikely	Negligible	Negligible

7.3.6 Demonstration of ALARP

To demonstrate the potential impacts from routine permissible waste discharges are managed to **ALARP**, SLB has considered a number of control measures to assess the benefits of their implementation towards risk reduction (**Table 61**), based on a Hierarchy of Controls (**Table 64**). The adopted control measures that will be implemented throughout the Seismic Survey are considered appropriate to reduce the environmental impacts from routine permissible waste discharges from vessels (i.e., bilge water, deck drainage, sewage and food wastes) and assessments have been undertaken to ensure that all reasonable and practicable control measures or solutions have not been overlooked. As a result, through application of industry best practice and/or comparable standards to further control risk reduction, it is considered that any impacts from routine discharges have been reduced to **ALARP**, where the residual risk from adoption of the control measures is **Negligible** (**Table 63**).

Additional control measures were considered as part of the assessment process towards further risk reduction; however, it was considered that they did not provide any further environmental benefit or were not reasonably practicable to implement. In addition, the costs (based on the experience of SLB) of implementing such measures would be disproportionate to the benefits that would be gained through their implementation.

Table 64 Hierarchy of Controls for Routine Permissible Waste Discharges

Eliminate	As discussed within **Table 61**, the vessels are required to be manned at all times which means the generation of sewage, greywater and galley waste cannot be eliminated. In order to eliminate the discharge of waste, it would need to be stored onboard the vessels and transported to shore, adding significant operational costs, time, and additional health and safety risks. Therefore, it was considered that elimination of this permissible discharge was not practicable.
Substitute	Similar to the discussion above, the only option to substitute the discharge of this waste is the storage and transfer for disposal onshore which is not considered practicable, given the safety, hygiene and health risks involved.
Reduce	The impact from the discharge of routine permissible waste discharges will be reduced by the implementation of the control measures within **Table 61;** specifically, the fact that the oil content within oily water discharge will be reduced to 15 ppm through an approved oily water separator, an approved comminuting and disinfecting system will be used to treat sewage and a grinder/comminuter will be utilised where required to reduce the potential impacts from the discharge of food waste is considered appropriate means of minimising effects on the marine environment and is in accordance with the regulations and guidelines.
Mitigate	Control measures have been assessed within **Table 61** in order to mitigate the impacts from the discharge of routine permissible wastes to **ALARP** and **Acceptable Levels**. These measures have also included separation distances to the nearest point of land for the discharge of certain aspects of the waste, so the more sensitive nearshore coastal margins are not exposed to any nutrient enrichment of any form. To this end, no untreated sewage and putrescible wastes will be discharged within 12 NM from land and no treated sewage and putrescible wastes will be discharged within 3 NM from land.

The proposed control measures described in **Table 61** to minimise and mitigate the impact from routine permissible waste discharges are considered appropriate to the localised nature and scale of potential environmental impacts during the Seismic Survey. These proposed control measures are in accordance with industry best practice and guidelines. No further practicable controls have been identified that can be implemented to effectively reduce the impact and risks to the marine environment and/or marine organisms from routine permissible waste discharges over and above what is proposed in **Table 61**.

Based on the information presented throughout this section, the relatively localised nature of effects from routine permissible waste discharges around the survey vessels, combined with the scale of the Seismic Survey, it is considered that the potential impacts from routine permissible waste discharges are reduced to **ALARP** and the residual risk is **Negligible** (**Table 63**).

7.3.7 Risk Acceptability

MSSs are required to map the geologic formations beneath the seabed and there are currently no alternatives to accurately image these to the required resolution. At the moment, there is no alternative to having the survey vessels manned, and with that comes the generation of daily waste associated with a number of personnel living on the vessel 24 hours per day.

Total elimination of all impacts associated with routine permissible waste discharges cannot be achieved, as the generation of sewage, greywater and galley waste is unavoidable and will be discharged to sea daily in relatively small volumes, with no practicable alternatives. However, these discharges will be in accordance with the requirements of the MARPOL 73/78 Convention (as implemented in Commonwealth waters by the Protection of the Sea (Prevention of Pollution from Ships) Act 1983). Additionally, the survey vessels may have to discharge bilge water and deck drainage during the Seismic Survey if required.

Routine discharges, such as the discharge of deck drainage, bilge water, sewage and food waste from the vessels used during the Seismic Survey have the potential to cause a localised reduction in water quality. However, following the implementation of the nominated control measures (**Table 61**) the potential impacts to the marine environment and associated receptors from routine permissible waste discharges are likely to be short-term, highly localised and restricted to the pelagic zone.

Planned discharges will be small and intermittent, with volumes dependant on a range of variables. Additionally, the discharge point will be moving as the vessel is continuously moving at 4 – 5 knots throughout the OA under 24-hour operations. Therefore, any discharged waste will not be concentrated in any particular area.

There are no predicted long-term effects at a population level on any species identified in this EP, and no adverse effects on the environmental values of protected areas as a result of permissible waste discharges are expected.

The control measures (**Table 61**) that will be implemented for the duration of the Seismic Survey have been developed in accordance with the criteria for risk acceptability which are detailed in **Table 34** and defined further within **Table 65**. Where uncertainty exists around the criteria or the risk, a precautionary approach was taken.

Table 65 Demonstration of Risk Acceptability for Routine Permissible Waste Discharges

Criteria for Acceptance	Acceptability Summary
SLB's internal context	The proposed management of routine permissible waste discharges is consistent with SLB's QHSE Policy.

Industry Best Practice	The proposed control measures follow industry best practice and best practice guidelines, including:
	• The IAGC Environmental Manual for Worldwide Geophysical Operations which provides guidance on waste management, including, but not limited to:
	    • Vessels having a Waste or Garbage Management Plan to effectively manage waste in line with MARPOL regulations as well as local legislation;
	    • Waste that cannot be incinerated will be segregated and stored for disposal ashore;
	    • Prior to discharge, oily water is processed to remove oil to less than 15 ppm;
	    • Greywater and sewage are dealt with according to MARPOL; and
	• The APPEA Code of Environmental Practice includes an objective to reduce the impact of routine waste discharges on the marine environment to **ALARP** and to an **Acceptable Level** by ensuring discharges are in accordance with legislative requirements and predicted levels.

External Context – Commonwealth and State Legislative Criteria	SLB will ensure that the routine permissible waste discharges (i.e. sewage, food waste, deck drainage and bilge water) will be undertaken in accordance with international conventions and relevant legislation, including: • MARPOL Annex I, Annex IV and Annex V; • Protection of the Sea (Prevention of Pollution from Ships) Act 1983; • Marine Order 91 (Marine Pollution Prevention – Oil), 2014; • Marine Order 95 (Marine Pollution Prevention – Garbage), 2013; • Marine Order 96 (Marine Pollution Prevention – Sewage), 2013; and • Marine Notices 09/2015 Guidance document for the recording operations in the Oil Record Book Part I.

Criteria for Acceptance	Acceptability Summary
External Context – Management Plans, Species Recovery Plans and Conservation Advice	Routine permissible waste discharges are not expected to impact significantly on environmental values or sensitivities at a local or regional level. Routine permissible waste discharges are not considered as a threat requiring additional management under the relevant Management Plans, Species Recovery Plans or Conservation Advices.
Social Acceptance – Stakeholder expectations	No concerns were raised in regard to possible impacts from routine permissible waste discharges, and as such no additional control/mitigation measures were expected or put in place following stakeholder engagement. The environmental impacts relating to routine permissible waste discharges from the survey vessels in accordance with industry best practice were considered to be at a socially **Acceptable Level**.
Ecologically Sustainable Development	The management of the impacts associated with the Seismic Survey as a result of the discharge of routine permissible discharges can be carried out in compliance with the five principles of ecologically sustainable development as defined within the EPBC Act. The assessment has not identified any adverse impacts to the principles of ESD, with no threats of serious or irreversible damage, no impacts to biological diversity and ecological integrity, no degradation of inter-generational equity, or negative effects on the social and economic integrity in the short or long-term.
Existing Environmental Context	It is considered that the routine discharge of permissible wastes will not result in any significant impact on environmental values or sensitivities within the OA, including protected and non-protected species which inhabit the water column, such as pelagic fish, sharks, marine mammals, marine turtles and seabirds. Given the expected mixing and dispersion of discharged waste, it is unlikely that routine permissible waste discharges will impact upon benthic species. By extension, the discharge of routine permissible wastes are not expected to impact significantly on the environmental values and sensitivities, including significant benthic habitats and communities, which comprise the KEF (Carbonate bank and terrace system of the Sahul Shelf) within the OA or the adjacent Oceanic Shoals Marine Park. No impacts to commercial fisheries or other marine users are predicted to occur as a result of the discharge of routine permissible wastes. It is considered that the proposed control measures provide appropriate protection to marine fauna and existing marine users from the potential effects associated with the routine discharge of permissible waste. A number of control measures were considered as part of the assessment process and it was concluded that the addition of any further control measures not already considered would provide little or no additional protection.
ALARP	Total elimination of all impacts associated with routine permissible waste discharges cannot be achieved, as the generation of sewage, greywater and galley waste is unavoidable and will be discharged to sea daily in relatively small volumes, with no practicable alternatives. However, these discharges will be in accordance with the requirements of the MARPOL 73/78 Convention (as implemented in Commonwealth waters by the Protection of the Sea (Prevention of Pollution from Ships) Act 1983). Additionally, the survey vessels may have to discharge bilge water and deck drainage during the survey if required. There are no predicted long-term effects at a population level on any species identified in this EP, and no adverse effects on the environmental values of protected areas or KEFs as a result of permissible waste discharges are expected.

Criteria for Acceptance	Acceptability Summary
	Based on the discussions above, including the potential impacts on the environment and the associated control measures to be implemented, the residual risk from routine permissible waste discharges from the survey vessels is considered **Negligible** and to **ALARP**. Therefore, the impacts from this activity associated with the Seismic Survey are considered to be at an **Acceptable Level**.

7.3.8 Routine Permissible Waste Discharge Impact Summary

Based on the discussions above, including the potential impacts on the environment and the associated control measures to be implemented, the residual risk from routine permissible waste discharges from the survey vessels is considered **Negligible** and to **ALARP**. Therefore, the impacts from this activity associated with the Seismic Survey are considered to be at an **Acceptable Level**.

7.4 Atmospheric Emissions

7.4.1 Description of Source of the Impact

The combustion of exhaust gasses from mechanical equipment (engines, generators, winches, power-units, plant machinery etc.) and incineration of wastes represent the principal sources of potential atmospheric emissions during the Seismic Survey. Most of these gaseous emissions will be in the form of carbon dioxide (**CO_2**) and carbon monoxide (**CO**); however, smaller quantities of other gasses such as methane (CH_4), nitric oxide (**NO**), nitrogen dioxide (**NO_2**) and sulphur dioxide (SO_2) may be emitted particularly during any incomplete combustion.

Fugitive gas emissions comprise both greenhouse gases (**GHG**) such as CO_2 and CH_4 and non-GHG such as CO, NO, NO_2, SO_2.

Vessels used during the Seismic Survey may have Ozone Depleting Substances (**ODS**) onboard. However, if these ODSs are onboard the vessel, they will be within closed loop systems, such as rechargeable refrigeration systems, and will not be discharged deliberately.

7.4.2 Known and Potential Impacts to Environmental Receptors

The known and potential impacts on air quality from atmospheric emissions will be a minor deterioration of local air quality due to the emissions of pollutants from the burning of hydrocarbons. Atmospheric emissions from the vessels, onboard equipment and incineration of wastes can cause a reduction in air quality in the localised area around the vessels. GHG emissions such as these are linked to climate change, and atmospheric emissions are also related to a reduction in ambient air quality; leading to human health issues in populated areas such as pulmonary disease, cardiovascular disease and cancer (Steiner *et al.*, 2016).

The volume of the emissions associated with this Seismic Survey will centre around the vessels and be relatively small in terms of the wider environment (which could be up to 30 m^3 per day of fuel usage as per **Section 3.4.4**). Due to the open ocean nature of the OA and the variable, moderate wind conditions the emissions from the vessels are likely to be quickly dispersed into the atmosphere and will not impact on the onshore/nearshore interests/communities. In addition, the constant movement of the vessels will ensure that the discharge is not occurring in a single location for any significant period of time.

Potential receptors therefore include seabirds and migratory shorebirds which may traverse the OA whilst foraging or on route between staging sites and foraging grounds, and humans in the immediate vicinity of the vessel during discharge events.

The main control measures (detailed below in **Section 7.4.3**) relate to the compliance with MARPOL Annex VI, and the use of MGO instead of Heavy Fuel Oil (**HFO**). It is considered that the consequence of this activity occurring is *Negligible*, with the likelihood of this consequence occurring being *Likely*. This results in a residual risk of **Negligible**.

7.4.3 Control Measures

The control measures that will be implemented during the Seismic Survey to manage the impacts from atmospheric emissions to **ALARP** have been included in **Table 66**. These control measures have been assessed to consider the environmental benefits gained through implementing the controls relative to their time, effort and monetary cost. SLB will make a clear delineation of those which will be implemented during the Seismic Survey and those which won’t, in particular where SLB considers their implementation is disproportionate to the environmental benefit gained. Justifications have been provided for each of these decisions.

Table 66 Assessment of Control Measures for Atmospheric Emissions

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Implemented Control Measures:				
Compliance with: MARPOL Annex VI (Regulations for the Prevention of Air Pollution from Ships). Protection of the Sea (Prevention of Pollution from Ships) Act 1983. Marine Order 97 (Air Pollution): • Vessels >400 tonnes require a certificate to demonstrate that they comply with the requirement to prevent unnecessary air pollution; • The vessel engines do not emit excess NOx emissions; • Incinerators used are of an approved standard and it is operated correctly; • Vessels must comply with a plan for energy efficiency and implement a Ship Energy Efficiency Management Plan (**SEEMP**); • Vessels shall not emit excess sulphur emissions; • Noxious and toxic substances shall not be emitted through combustion of illegal substances; and • ODS shall not be deliberately released.	P = Yes E = Effective	It is a legislative requirement to meet the relevant aspects of MARPOL Annex VI, the PSPPS Act and Marine Order 97.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Vessels will not utilise HFO.	P = Yes E = Effective	The vessels associated with the Seismic Survey will be utilising MGO in order to reduce the pollutants from the combustion engines. MGO usually has less than 0.2% sulphur which aids in meeting the requirements of the legislation outlined in the control measure above.	Yes	Yes
Fuel consumption will be recorded and monitored for abnormal consumption, with corrective action taken if necessary	P = Yes E = Effective	While fuel consumption throughout the Seismic Survey is inevitable, abnormal consumption results in additional atmospheric emissions as well as additional costs.	Yes	Yes
All combustion and incineration machinery will be appropriately maintained as per the manufacturer's guidelines.	P = Yes E = Effective	Routine maintenance ensures that machinery is running in accordance with the manufacturer's specifications, reducing excess emissions.	Yes	Yes
Only wastes approved by the vessel's Garbage Management Plan will be incinerated and no oil or other noxious substances will be incinerated	P = Yes E = Effective	Incineration of materials not approved by the Garbage Management Plan may lead to the release of toxic emissions and will not be compliant with MARPOL.	Yes	Yes
Incineration will only occur when the vessel is a distance greater than 12 NM from shore	P = Yes E = Effective	Incineration of wastes beyond 12 NM from shore will not result in any emissions that will make their way to shore, nor will any emissions be visible from shore.	Yes	Yes
ODS handling procedures will be in place.	P = Yes E = Effective	No ODS will be deliberately discharged during the MSS, however, the implementation of a suitable ODS handling procedure will mitigate the risk of an accidental release of ODS to air.	Yes	Yes
Alternative Control Measures:				
No incineration on vessels	P = No E = Effective	Incineration of wastes on vessels is a standard industry practice and negates the need for additional visits from supply vessels to remove waste. The storage of wastes onboard the survey vessels have added risks to human health.	Yes	No

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Alternative fuels will be used to power vessels	P = No E = Effective	Alternative fuel sources include solar, wind, and biofuels. Such fuel sources have not been commercially proven for vessels and helicopters such as those that will be used during the Seismic Survey.	Yes	No
Non-essential machinery will be routinely shut-down on survey vessels	P = Yes E = Limited	Due to the limited benefit gained from shutting-down non-essential machinery, and the limited risk associated with atmospheric emissions, this control was determined to be unnecessary.	Yes	No
Eliminate atmospheric emissions during operation	P = No E = Effective	Vessels are required for the Seismic Survey to collect data. Without vessels, the survey would not be able to occur.	Yes	No
Use of incinerators and engines with higher environmental efficiency	P = No E = Effective	There are significant costs associated with modifying vessel equipment such as incinerators and engines. The costs are grossly disproportionate to the low environmental benefit gained from limited improvements in air quality that may result.	Yes	No

7.4.4 Environmental Performance

The EPO for the effective management of environmental impacts from atmospheric emissions are:

- All discharges of emissions to the atmosphere that are produced during the survey (including GHG, NO_x, SO_x, CO, and particulates) are complaint with relevant legislation.

It is considered that the above EPO, as a result of the implementation of the control measures (**Table 66**), will allow the ongoing environmental performance of the Seismic Survey in accordance with the **Acceptable Levels** described within **Section 7.4.7**, while ensuring that the relevant legislation is complied with in order avoid any health and safety risks or impacts on the environment as far as practicable.

The EPSs within **Table 67** have been defined to manage the impacts from atmospheric emissions to **ALARP** and an **Acceptable Level**. Compliance with these standards will ensure that the identified EPO will be achieved for the duration of the Seismic Survey.

Table 67 Environmental Performance Outcomes and Standards for Atmospheric Discharges

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
EPO: All discharges of emissions that are produced during the survey (including GHG, NOx, SOx, CO, CO2 and particulates) are compliant with relevant legislation.			
Compliance with MARPOL Annex VI (Regulations for the Prevention of Air Pollution from Ships), the Protection of the Sea (Prevention of Pollution from Ships) Act 1983 and Marine Order 97 (Air Pollution).	**EPS 139**: All vessels used in the Seismic Survey over 400 gross tonnage will hold an International Air Pollution Prevention Certificate (**IAPP Certificate**) as per the requirements of Marine Order 97 and MARPOL Annex VI.	IAPP Certificate is valid.	Vessel Master.
	EPS 140: The engines in the vessels used for the Seismic Survey will meet the prescribed NOx emission levels set within Marine Order 97 and MARPOL Annex VI.	Vessel audit and/or inspection.	Vessel Master.
	EPS 141: The SOx content of the fuel used within the survey vessels will not exceed the limits set within Marine Order 97, the PSPSS Act and MARPOL Annex VI.	Bunker note or other evidence.	Vessel Master.
	EPS 142: All vessels used during the Seismic Survey over 400 gross tonnage will have, and comply with, a SEEMP as per Marine Order 97 and MARPOL Annex VI.	SEEMP in place.	Vessel Master.
	EPS 143: Any Incineration onboard the vessels will be undertaken in accordance with Marine Order 97 and MARPOL Annex VI, including the prohibition of incinerating noxious and hazardous substances.	Vessel audit and/or inspection, Incineration Log.	Vessel Master.
	EPS 144: An ODS Record Book will be maintained if the Seismic Vessel has a rechargeable system that contains ODS as per the PSPPS Act.	ODS Record Book.	Vessel Master.
	EPS 145: No ODS will be deliberately discharged during the Seismic Survey, as per Marine Order 97, the PSPPS Act and MARPOL Annex XI.	ODS Record Book.	Vessel Master.
Vessels will not utilise HFO	**EPS 146**: MGO is the primary fuel for vessels associated with the Seismic Survey.	Bunker note.	Vessel Master.
	EPS 147: No HFO powered vessels will be used.	Bunker note.	Vessel Master.
Fuel consumption will be recorded and monitored	**EPS 148**: Fuel use will be recorded and monitored for excessive fuel consumption, with corrective action taken if necessary.	Daily report log.	Vessel Master.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
Machinery will be regularly maintained	**EPS 149**: All combustion and incineration machinery will be appropriately maintained as per the manufacturer's guidelines.	Maintenance records confirm.	Chief Engineer.
Incineration of approved substances only	**EPS 150**: Only wastes approved by the vessel's Garbage Management Plan will be incinerated and no oil or other noxious substances will be incinerated.	Incineration Log.	Vessel Master.
Incineration will occur at distances greater than 12 NM from shore	**EPS 151**: Incineration will only occur when the vessel is a distance greater than 12 NM from shore.	Incineration Log.	Vessel Master.

7.4.5 Residual Risk of Impact

Following the implementation of the control measures within **Table 66**, the likelihood of a measurable impact on local air quality from atmospheric emissions generated as a result of the Seismic Survey is considered *Likely*. The consequence from atmospheric emissions is considered *Negligible*, based on the assessment within **Section 7.4.2**.

Therefore using the risk matrix outlined in **Table 31**, the residual risk from atmospheric emissions, following the implementation of control measures (**Table 66**) is considered to be **Negligible** (**Table 68**).

Table 68 Residual Risk Summary for Atmospheric Emissions

Likelihood	Consequence	Residual Risk
Likely	Negligible	Negligible

7.4.6 Demonstration of ALARP

To demonstrate that the potential impacts from atmospheric emissions are managed to **ALARP**, SLB has considered a number of control measures to assess the benefits of their implementation towards risk reduction (**Table 66**), based on a Hierarchy of Controls (**Table 69**). The adopted control measures that will be implemented throughout the Seismic Survey are considered appropriate to reduce the environmental impacts from atmospheric emissions from the vessel's machinery and incineration of any wastes generated and to ensure that all reasonable and practicable control measures or solutions have not been overlooked. As a result, through the application of industry best practice and/or comparable standards to further control risk reduction, it is considered that any impacts from atmospheric emissions will be reduced to **ALARP**, where the residual risk from adoption of these control measures is **Negligible** (**Table 68**).

Additional control measures were considered as part of the assessment process towards further risk reduction; however, it was considered that they did not provide any further environmental benefit or were not reasonably practicable to implement. In addition, the costs (based on the experience of SLB) of implementing such measures would be disproportionate to the benefits that would be gained through their implementation.

Table 69 Hierarchy of Controls for Atmospheric Emissions

Eliminate	Fuel use and its associated atmospheric emissions cannot be eliminated as fuel is a fundamental requirement for the operation of the survey vessels. Deliberate discharge of ODS will be eliminated during the Seismic Survey as outlined in **Table 66**.
Substitute	As outlined within **Table 66**, the survey vessels will use MGO to power their engines, rather than other fuels such as HFO. Although the cost of using MGO is higher than that of HFO, the reduction in sulphur content is considered an important step in managing impacts to **ALARP**. No other alternative fuel sources are currently commercially viable for larger vessels.
Reduce	Similar to the discussion around substitution above, the use of MGO will reduce the contaminants discharged from the combustion engines on the vessels in order to meet the requirements of Marine Order 97, the PSPPS Act and MARPOL Annex VI.
Mitigate	The control measures within **Table 66** have been assessed to ensure that they mitigate the impacts from atmospheric emissions to **ALARP**. This is primarily done through the implementation of measures required under Marine Order 97, the PSPPS Act and MARPOL Annex VI.

The proposed control measures in **Table 66** to minimise the impact from atmospheric emissions are considered appropriate to the localised nature and scale of the potential environmental impacts during the Seismic Survey. The proposed control measures are in accordance with industry best practice and relevant regulations. No further practicable controls have been identified that can be implemented that will effectively reduce the impact and risks to the atmosphere over and above what is proposed in **Table 66**.

As the impacts from the atmospheric emissions will be localised in nature, in combination with the scale of the Seismic Survey, it is considered that the potential impacts from these atmospheric emissions have been reduced to **ALARP** and the residual risk is **Negligible** (**Table 68**).

7.4.7 Risk Acceptability

Total elimination of all impacts associated with atmospheric emissions cannot be achieved, as engines must be used onboard the vessels and there are no practicable alternatives. Following the implementation of the control measures (**Table 66**) the potential impacts to the environment from atmospheric emissions generated from fuel combustion and waste incineration are likely to be localised in nature and short-term given the relative spatial extent of the vessel's trajectory across the total OA.

The criteria for risk acceptability are provided in **Table 34** and the survey compliance with these criteria is assessed in **Table 70**. The control measures that will be implemented during the Seismic Survey have been developed in accordance with these criteria. Where uncertainty exists around the criteria or the risk, SLB have taken a precautionary approach.

Table 70 Demonstration of Risk Acceptability for Atmospheric Emissions

Criteria for Acceptance	Acceptability Summary
SLB's internal context	The proposed management of atmospheric emissions is consistent with SLB's QHSE Policy.

Industry Best Practice	The control measures are based on industry best practice and best practice guidelines, including:
	• The IAGC Environmental Manual for Worldwide Geophysical Operations which provides guidance on engine emissions, including:
	  • Ensuring vessels are fitted with appropriate emission monitoring and control systems to meet applicable flag state and vessel design class requirements;
	  • Servicing of exhaust systems occurs on a regular basis to ensure that noise and emissions are kept to appropriate levels (no unburned fuels and exhaust gases to create localised pollution);
	  • Require low-sulphur MGO; and
	• The APPEA Code of Environmental Practice includes an objective to reduce greenhouse gas emissions to an **Acceptable Level** and reduce the risk of impacts to **ALARP**.

External Context – Commonwealth and State Legislative Criteria	SLB will ensure the Seismic Survey air emissions will comply with the relevant legislative requirements and applicable international conventions, including: • MARPOL 73/78 Annex VI Prevention of Air Pollution by Ships; • PSPPS Act, 1983 (Part IIID Prevention of Air Pollution); • Maritime Legislation Amendment (Prevention of Air Pollution from Ships) Act 2007; • Marine Orders Part 97 (Marine Pollution Prevention – air pollution); and • Marine Notice 11/2015 Measure to Reduce Greenhouse Gas Emissions from International Shipping. • Marine Notice 05/2017 Regulations for Air Emissions from Ships
External Context – Management Plans, Species Recovery Plans and Conservation Advice	Atmospheric emissions are not expected to pose a risk to the management objectives or conservation values for any protected species potentially found within the OA.
Social Acceptance – Stakeholder expectations	During consultation with interested stakeholders no concerns were raised in regard to possible impacts from atmospheric emissions, and as such no additional control/mitigation measures were expected or put in place as a result. Consequently, the environmental impacts relating to atmospheric emissions from the survey vessels were considered to be at a socially **Acceptable Level**.
Ecologically Sustainable Development	The management of the risk and impacts associated with atmospheric emissions proposed by SLB can be carried out in compliance with the five principles of ecologically sustainable development as defined within the EPBC Act. These principles have been considered as part of the development of this EP and risk assessment process. The assessment has not identified any adverse impacts to the principles of ESD, with no threats of serious or irreversible damage, no impacts to biological diversity and ecological integrity, no degradation of inter-generational equity, or negative effects on the social and economic integrity in the short or long-term.

Criteria for Acceptance	Acceptability Summary
Existing Environmental Context	Based on the proposed control measures to be implemented, it is considered that atmospheric emissions will not result in a significant impact on environmental values or sensitivities within the OA, including seabird species and migratory shorebirds which may traverse the OA and be temporarily exposed to atmospheric emissions. It is considered that the proposed control measures provide appropriate protection to marine fauna and existing marine users from the potential effects associated with atmospheric emissions. A number of control measures were considered as part of the assessment process, and it was concluded that the addition of any further control measures not already considered would provide little or no additional protection.
ALARP	Total elimination of all impacts associated with atmospheric emissions cannot be achieved, as engines must be used onboard the vessel and there are no practicable alternatives. Following the implementation of the control measures the potential impacts to the environment from atmospheric emissions are likely to be localised in nature and short-term given the relative spatial extent of the vessel's trajectory across the total OA and the duration of the Seismic Survey. Based on the discussions within the EP, including the potential impacts on the environment and the associated control measures to be implemented, the residual risk from atmospheric emissions from the survey vessels is considered **Negligible** and to **ALARP**. Therefore, the impacts and residual risk from this activity associated with the Seismic Survey are considered to be at an **Acceptable Level**.

7.4.8 Atmospheric Emissions Impact Summary

Based on the discussions above, including the potential impacts on the environment and the associated control measures to be implemented, the residual risk from atmospheric emissions generated from the survey vessels and on-board waste incineration is considered **Negligible** and to **ALARP**. Therefore, the impacts and residual risk from this activity associated with the Seismic Survey are considered to be at an **Acceptable Level**.

7.5 Artificial Light Emissions

7.5.1 Description of Source of the Impact

Suitable artificial lighting is required for the health and safety of crew onboard the survey vessels (e.g.. while operating at night) and is also mandatory for safe navigation of vessels underway at sea from sunset to sunrise in accordance with the COLREGS, Marine Order 21 and Marine Order 30. A number of different navigation lights are required that are specific to that particular vessel and size, as well as whether the vessel is engaged in towing and restricted in its ability to manoeuvre.

The primary sources of artificial lighting in the offshore marine environment during the Seismic Survey will result from the deck and navigational lights onboard the survey vessels. These vessels will be making way at all times during the survey travelling at approximately 4.5 knots; therefore, the source of artificial lighting which may impact marine organisms will be relatively transient in nature and will result in comparably less disturbance to these organisms than fixed lighting sources.

7.5.2 Known and Potential Impacts to Environmental Receptors

Artificial light at night (**ALAN**) is a recently acknowledged form of anthropogenic pollution and there are two main modes through which ALAN is known to affect marine fauna: disorientation and behaviour modifications. These potential effects are detailed in the following sections in relation to the groups of fauna that are known to occur within or surrounding the OA.

Artificial lighting on vessels at sea can attract and disorientate marine animals and affect their physiology (Davies *et al.,* 2014; Poot *et al*., 2008). The effects of artificial light can be particularly high for juvenile animals such as turtles and fledgling seabirds/novice flyers in coastal locations (Telfer *et al*., 1987), and artificial lighting has been linked to an increased risk of bird collision with vessels (particularly their rigging) (Black, 2005).

The potential adverse impacts on marine fauna associated with artificial light emissions is well understood, as is reflected in the development of State and Commonwealth guidelines designed to mitigate the effects from these activities (WA EPA 2010; Commonwealth of Australia 2020). According to the National Light Pollution Guidelines for Wildlife (Commonwealth of Australia 2020), a 20 km distance threshold provides a precautionary limit based on observed effects of sky glow on marine turtle hatchlings demonstrated to occur at 15 – 18 km and grounding behaviour of fledgling seabirds in response to artificial light 15 km away. Although, the effect of light glow may occur at distances greater than 20 km for some species and under certain environmental conditions (Commonwealth of Australia, 2020).

Artificial lights that are fixed or stationary in the marine environment have been shown to attract aggregations of zooplankton and then baitfish and/or squid, which are prey for higher trophic order species that take advantage of these aggregations for feeding (Golder, 2007). Increased amounts of light at night in the marine environment can also possibly be detrimental to marine mammals by allowing predators to see the mammals more easily during normally dark night times.

Potential receptors therefore include fish, sharks and rays, marine turtles, seabirds and migratory shorebirds. As cetaceans predominantly utilise acoustic senses to monitor and navigate their environment, impacts are considered to be unlikely. However, an assessment of potential impacts to marine mammals has been undertaken in **Section 7.5.2.2**, below.

Potential impacts are more likely in instances where the light source is stationary, which is not the case during the Seismic Survey when the vessels are constantly moving. The combination of colour, intensity, closeness, direction and persistence of light source are key factors in determining the magnitude of environmental impact (WA EPA, 2010; Commonwealth of Australia, 2020).

7.5.2.1 Fish, Sharks and Rays

The correct functioning of most natural systems fundamentally relies on light days and dark nights. But the presence of ALAN can mask these natural light rhythms, and interfere with the behaviour and physiology of fish, sharks and rays. The response to light emissions varies according to species and habitat; for example, it can throw off fine-tuned nocturnal behaviours such as navigation, hunting patterns or the ability to forage while evading predators. Experiments using light traps have found that some fish species are attracted to light sources (Meekan *et al*., 2001), with traps drawing catches from up to 90 m away (Milicich *et al*., 1992). Lindquist *et al*. (2005) concluded from a study that artificial lighting associated with offshore oil and gas activities resulted in an increased abundance of clupeids (herring and sardines) and engraulids (anchovies) around lighted structures; these species are known to be highly photopositive. Attraction of fish to light may result in an increase in predation from larger fish and sharks on prey species, or exclusion of nocturnal foragers/predators aggregating in the immediate vicinity of the vessels at night (Marchesan *et al*., 2006).

Overall, a short-term localised increase in fish activity as a result of vessel lighting is expected to occur, however, it will not be stationary and be limited to night-time operations. Sound emissions from the Seismic Vessel, Support Vessel and from the seismic source, are also expected to act as a localised and temporary deterrent to fish (refer to **Section 7.2.2.1** and **7.2.2.2**).

The residual risk of artificial light emissions on fish, sharks and rays from vessels associated with the Seismic Survey has been assessed as **Low** (*Minor x Unlikely*).

7.5.2.2 Marine Mammals

Many marine mammals have evolved specialised sight or acoustic techniques to enable successful hunting/prey capture in low light, while others are reliant on suitable levels of light and clear water to enable capture. Cetaceans for example use echolocation as their primary sense for locating and hunting prey, followed by visual means at close range (Simmonds *et al.*, 2004). Artificial lights that are fixed or stationary in the marine environment often attract aggregations of zooplankton and then baitfish and/or squid which are prey for species of pinnipeds and dolphins that take advantage of these aggregations for feeding (Golder, 2007). Increased amounts of light at night in the marine environment can also possibly be detrimental to marine mammals by allowing predators to see the mammals more easily during normally dark night times. However, a number of studies have been undertaken on the effects of artificial lighting from oil and gas exploration activities in the Great Australian Bight Marine Park on sea lions and cetaceans and concluded that any impacts would be insignificant (Pidcock *et al*., 2003), and similar studies in NW Australia and Canada have found no evidence that cetacean feeding and breeding was being impacted from offshore installations (BHP Billiton, 2005).

The residual risk of artificial light emissions on marine mammals from vessels associated with the Seismic Survey has been assessed as **Negligible** (*Negligible* x U*nlikely*).

7.5.2.3 Marine Reptiles

As discussed in **Section 4.5.5**, the flatback turtle, green turtle, hawksbill turtle, olive ridley turtle and loggerhead turtle are known to occur within the NWMR, each of which are listed species under the EPBC Act as either endangered or vulnerable. Of these species, two are known to nest along emergent land within the EMBA. The nearest marine turtle nesting habitat, and therefore critical habitat, includes Cartier Island and Ashmore Reef Island, located between 100 and 140 km to the west of the OA. Here, green turtles' nest year-round but predominantly between November to March (**Section 4.5.5**).

Light cues from natural sources are used by both juvenile and adult turtles for navigation. Adult turtles prefer to nest in areas well away from human habitation, where the beaches are darkened, thus artificial lighting can deter turtles from approaching an area where they may have previously nested reducing the number of nests (Davies *et al*., 2014; Deda *et al.*, 2007; EPA, 2010) and beyond this the number of juveniles in such areas. Post hatching juvenile turtles need to make their way to the ocean and use visual cues to do so.

Artificial lighting can disorientate the juveniles sending them in the wrong direction which could lead to delays or even failure to reach the water, risking greater chances of predation or desiccation (Davies *et al*., 2014; Deda *et al*., 2007). However, offshore light sources will influence newly hatched juvenile turtles less than sources onshore, as offshore sources will attract the juveniles towards the ocean post hatching (Pendoley, 2005). Once at sea, juveniles continue to follow visual clues to navigate away from land and remain in the surface waters. Here, artificial light emissions can distract/disorientate the juveniles and lead them to follow false clues that limit dispersion, and the same artificial lighting can make them more visible to predators in the water (Salmon *et al.*, 1992).

The Environmental Protection Authority (**EPA**) *Environmental Assessment Guide No. 5 – Protecting Marine Turtles from Light Impacts* (EPA, 2010); the *Recovery Plan for Marine Turtles in Australia 2017-2027* (Commonwealth of Australia, 2017b) and the DoEE Species Profile and Threats Database have been considered as part of the preparation of this EP, and do not identify artificial light from vessels underway in the offshore marine environment as creating a risk for turtles. The EPA recommends that a darkness zone of at least 1.5 km from all significant rookeries be maintained in order to mitigate against any potential effects from lighting. Given no known breeding/nesting areas for turtles exist along the coastline inshore of the OA, and the fact that the OA is located beyond 1.5 km from the coastline, it is considered there are no further requirements to be placed on seismic operations to minimise any potential impacts on turtles.

As the OA does not lie in a marine reptile nesting area, and therefore is not of particular importance for more sensitive juveniles, the residual risk of artificial light emissions on marine reptiles from the vessels associated with the Seismic Survey has been assessed as **Low** (*Minor* x *Unlikely*).

7.5.2.4 Seabirds

There are ten seabird species with BIAs reported to overlap the EMBA; however, none of which are located within the OA (see **Section 4.5.7**). Seabirds are known to commonly strike vessels lit with artificial light at night, particularly vessels with significant exposed rigging/lines. Artificially lit installations, vessels or structures also act to attract seabirds, particularly in otherwise dark areas and for migratory birds travelling at night (Poot *et al.*, 2008). From SLB's previous offshore MSSs in New Zealand and Australia, there have been no bird strikes during night-time.

As stated in the previous section on marine mammals, marine organisms such as zooplankton and small fish are often attracted to artificial light sources and these aggregations can create an enhanced food source for seabirds (Rich and Longcore, 2006). However, as the vessels will be continuously moving during the survey the attraction of zooplankton and baitfish will be highly unlikely to occur, particularly in comparison to fixed lighting sources (e.g., lighthouse, platforms, bridges, etc.).

The residual risk of artificial light emissions on seabirds from vessels associated with the Seismic Survey has been assessed as **Low** (*Minor* x *Unlikely*).

7.5.3 Control Measures

The control measures that will be implemented during the Seismic Survey to manage the impacts from artificial light emissions to **ALARP** have been included in **Table 71**. These control measures have been assessed to consider the environmental benefits gained through implementing the controls relative to their time, effort and monetary cost. SLB will make a clear delineation of those which will be implemented during the Seismic Survey and those which won't, in particular where SLB considers their implementation is disproportionate to the environmental benefit gained. Justifications have been provided for each of the decisions.

Table 71 Assessment of Control Measures for Artificial Light Emissions

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Implemented Control Measures:				
Compliance with: • COLREGs Part A (General) • COLREGs Part B (Sound and Light Signals) • COLREGs Part C (Lights and Shapes) • COLREGS Annex I (Positioning and technical details of lights and shapes) • Marine Order 21 (Safety of Navigation and Emergency Procedures) • Marine Order 30 (Prevention of Collisions)	P = Yes E = Effective	It is a legislative requirement to meet the relevant aspects of COLREGs, Marine Order 21 and Marine Order 30.	Yes	Yes
Directional Lighting: Outwards facing lighting reduced to minimum levels as required. Navigation lighting to be compliant with relevant guidance for safe passage at sea and specific to each vessel and the activities it is conducting. Deck/work lighting aimed inboard/downwards wherever possible, amount of lighting and duration lighting operating reduced to minimum level to safely allow deck operations to occur. Exceptional cases in event of an emergency.	P = Yes E = Effective	Outward facing lighting is required for navigation/safety/visibility at sea. Work lighting (e.g., in deck areas) will be directed inward as much as possible but still needs to supply minimum adequate lighting for safe working conditions for all areas where crew are operating on deck.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Separation Distances: The Seismic Survey will be undertaken outside of Coastal Waters (i.e., a minimum distance of 3 NM (5.5 km) offshore will be maintained) to reduce potential impacts on seabird breeding/nesting sites and marine turtle rookeries.	P = Yes E = Effective	During the operational phase of the survey, the vessel will be located offshore. Remaining offshore away from the coastline, particularly areas where known seabird and marine turtle sites exist, reduces the potential for vessel lighting to attract, distract or disorientate which could result in incidences of vessel strike or limited dispersion of juveniles. The nearest seabird breeding/nesting site and marine turtle rookery is located at Cartier Island, approximately 80 km from the OA. No seismic acquisition will take place within 3NM of the coastline. This control measure does not apply for the passage to and from port for crew changes, resupplies or sheltering from adverse weather as the Seismic Survey vessels are no different to any other commercial maritime vessel working at sea.	Yes	Yes
Alternative Control Measures:				
Eliminate lighting	P = No E = Very Effective	Adequate lighting is required for safe work of all crew onboard the vessels and navigation lighting is required for collision avoidance and visibility at sea. Safety costs are disproportionate to benefits.	Yes	No
Inward/downward facing lighting only	P = Partial E = Effective	Outward facing lighting is required for navigation/safety/visibility at sea, in accordance with the COLREGS, Marine Order 21 and Marine Order 30. It is a regulatory requirement to have appropriate navigation lighting on all vessels from sunset to sun rise. However, there are benefits to ensuring deck/workspace lighting is inward/downward facing to reduce light spill as far as reasonably practicable, see directional lighting control measure above.	Yes	Partially See directional lighting above.

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
No acquisition during darkness hours	P = No E = Partial	This measure would effectively double the time to acquire the Seismic Survey. By extension, this would extend the duration of disturbance to sensitive environmental receptors and would increase potential conflict and displacement with commercial and recreational fishers. Additionally, vessels would remain at sea necessitating they display navigation lighting and provide safe amounts of deck lighting for crew even if not acquiring data (e.g., during darkness hours). Consequently, costs are considered disproportionate to benefits.	Yes	No
Data acquisition only occurring outside of turtle nesting periods	P = No E = Partial	As outlined in **Section 7.5.2.3**, the OA is located 80 km from any known turtle nesting or mating areas. Therefore, whilst the wider NWMR is an important breeding and foraging area for flatback turtles, green turtles, hawksbill turtles, olive ridley turtles, and loggerhead turtles, it is considered that any individuals encountered are likely to be transiting the area and should not be significantly affected from the survey given the relatively short duration and localised nature of acquisition across a given survey line and the transient nature of the Seismic Vessel as it moves throughout the OA. As discussed within **Section 7.5.1**, the light source will constantly be moving; any attraction, distraction or disorientation of marine organisms would be highly unlikely, particularly in comparison to a fixed light source. Therefore, any minor environmental gains from limiting data acquisition periods to outside of key nesting periods are considered to be at a disproportionally increased cost to the survey.	Yes	No

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Data acquisition only occurring outside of seabird breeding/nesting periods	P = No E = Partial	The constraints associated with and potential impacts of artificial lighting on seabird breeding/nesting are broadly comparable to those described above for marine turtles. Additionally, seabird breeding at sites such as Ashmore Reef occurs throughout the calendar year with species such as the Wedge-tailed shearwater breeding during spring and summer whereas the White-tailed Tropicbird has been reported to breed during May and October (DoEE, 2022). Therefore, this control measure is considered to provide limited overall benefit.	Yes	No
Use lighting sources with wavelengths that are less disruptive to marine organisms	P = No E = No	Given the large variety of marine organisms that may be present, and that their varying sensitives to different light wavelengths, this control measure is not regarded as being practical and is likely to be of minimal overall benefit.	Minimal	No

7.5.4 Environmental Performance

The EPO for the management of environmental impacts from artificial light emissions is:

- No adverse impacts from artificial light emissions on marine fauna.

It is considered that the above EPO, as a result of the implementation of the control measures (**Table 71**), will allow the ongoing environmental performance of the Seismic Survey in accordance with the **Acceptable Levels** described within **Section 7.5.7**, while ensuring that the relevant legislation is complied with in order to avoid any health and safety risks or impacts on marine fauna as far as practicable.

The EPSs within **Table 72** have been defined to manage the impacts from artificial light emissions to **ALARP** and an **Acceptable Level**. Compliance with these standards will ensure that the identified EPO will be achieved for the duration of the Seismic Survey.

Table 72 Environmental Performance Outcome and Standards for Artificial Light Emissions

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
EPO: No adverse impacts from light emissions on marine fauna.			
Meet the relevant aspects of COLREGs, Marine Order 21 and Marine Order 30	**EPS 152**: Vessel navigational lighting and equipment is compliant with COLREGs and Marine Orders 21 and 30.	Vessel certification confirms compliance with applicable regulations.	Vessel Master
Directional lighting	**EPS 153**: Non-essential lighting will be switched off when not in use.	Pre-mobilisation audit and inspection prior to operations beginning, along with crew inductions.	Vessel Master.
	EPS 154: External lighting will be directed inboard and onto the deck where possible.	Pre-mobilisation audit and inspection prior to operations beginning, along with crew inductions.	Vessel Master.
	EPS 155: Essential navigation lighting to maintain compliance with COLREGS, Marine Order 21 and Marine Order 30 is required.	Pre-mobilisation audit and inspection prior to operations beginning, along with crew inductions.	Vessel Master.
Separation distances	**EPS 156**: Seismic Vessel will go no closer than 3 NM (5.5 km) from shoreline during the operational/acquisition phase of survey (i.e., does not apply to the vessels steaming into/out of port).	Digital records such as AIS tracking show survey vessels remain greater than 3 NM (5.5 km) from the shoreline. Vessel logs.	Vessel Master.

7.5.5 Residual Risk of Impact

Following the implementation of the control measures in **Table 71**, the likelihood of artificial light emissions having any impact on marine organisms and seabirds is *Unlikely*. The consequence from artificial light being emitted from the survey vessels is considered *Minor*, based on the assessment within **Section 7.5.2**.

Therefore, using the risk matrix outlined in **Table 31** the residual risk of an impact occurring from artificial lights onboard the survey vessels, following the implementation of control measures (**Table 71**), is considered to be **Low** (**Table 73**).

Table 73 Residual Risk Summary for Artificial Light Emissions

Likelihood	Consequence	Residual Risk
Unlikely	Minor	Low

7.5.6 Demonstration of ALARP

To demonstrate the potential impacts from artificial light emissions are managed to **ALARP**, SLB has considered a number of control measures to assess the benefits of their implementation towards risk reduction (**Table 71**), based on a Hierarchy of Controls (**Table 74**). The adopted control measures that will be implemented throughout the Seismic Survey are considered appropriate to reduce the environmental impacts from artificial light emissions from the vessels and assessments have been undertaken to ensure that all reasonable and practicable control measures or solutions have not been overlooked. As a result, through the application of industry best practice and/or comparable standards to further control risk reduction, it is considered that any impacts from artificial light emissions will have been reduced to **ALARP**, where the residual risk of an impact from adoption of these control measures is **Low** (**Table 73**).

Additional control measures were considered as part of the assessment process towards further risk reduction; however, it was considered that they did not provide any further environmental benefit or were not reasonably practicable to implement. In addition, the costs (based on the experience of SLB) of implementing such measures would be disproportionate to the benefits that would be gained through their implementation.

Table 74 Hierarchy of Controls for Artificial Light Emissions

Eliminate	Collision prevention and maritime regulations require specific navigation lighting to be implemented. Likewise, provision of safe working conditions at night achieved through employing suitable deck lighting is required to minimise any health and safety incidents. As a result, artificial light emissions cannot be completely eliminated.
Substitute	Navigation lighting cannot be substituted given the requirements cited within the COLGREGs, Marine Order 21 and Marine order 30. Sufficient work lighting cannot be substituted either.
Reduce	Work lighting will be extinguished wherever possible when not required, and as far as practicable work lighting will be focused inwards.
Mitigate	Control measures have been assessed within **Table 71** in order to mitigate the impacts from artificial light emissions to **ALARP** levels. Those which are appropriate and are not impracticable or unfeasible due to disproportionately large costs will be implemented during the Seismic Survey. Likewise, those which do not diminish the safety of on-board operations and navigation will be implemented during the Seismic Survey.

The proposed control measures minimise the risk of impact from artificial light emissions and are considered appropriate to the localised nature and scale of potential environmental impacts generated during the Seismic Survey. The proposed control measures are in accordance with industry best practice. No further practicable controls have been identified to reduce the impact and risks to the marine environment and/or marine organisms from artificial lighting.

Given the relatively localised nature of effects from artificial light emissions around the survey vessels, combined with the location of the OA with respect to biologically important area, receptors and the coastline, it is considered that the potential impacts from artificial light emissions are reduced to **ALARP**.

7.5.7 Risk Acceptability

Total elimination of all impacts associated with artificial lighting emissions cannot be achieved, as lighting must be used onboard the vessel and there are no practicable alternatives. Following the implementation of the control measures (**Table 71**), the potential impacts to the marine environment and associated receptors from artificial light emissions generated by the Seismic Vessel are likely to be localised in nature and scale, given the footprint of the vessels trajectory across the total OA, and short-term.

The criteria for risk acceptability are provided in **Table 34** and assessed in **Table 75**. The control measures that will be implemented throughout the Seismic Survey have been developed in accordance with these criteria. Where uncertainty exists around the criteria or the risk, SLB have taken a precautionary approach.

Table 75 Demonstration of Risk Acceptability for Artificial Light Emissions

Criteria for Acceptance	Acceptability Summary
SLB's internal context	The proposed management of artificial light emissions is consistent with SLB's QHSE Policy.
Industry Best Practice	The control measures to decrease artificial light emissions are based on industry best practice and best practice guidelines, including: • The IAGC Environmental Manual for Worldwide Geophysical Operations. Geophysical vessels must ensure that their emissions are kept to appropriate levels; and

Criteria for Acceptance	Acceptability Summary
	• The APPEA Code of Environmental Practice. Details within this document relate mainly to offshore operations such and offshore exploration/drilling and production facilities where light emissions are recommended to be reduced to **ALARP** and **Acceptable Levels**. A similar approach could feasibly be expected of survey vessels operating in offshore areas.
External Context – Commonwealth and State Legislative Criteria	Lighting requirements for the Seismic Survey are determined by relevant legislative requirements (i.e., COLREGS, Marine Order 21 and Marine Order 30). Legislated requirements for safe working conditions will be met.
External Context – Management Plans, Species Recovery Plans and Conservation Advice	The following Management Plans, Species Recovery Plans and Conservation Advices have been taken into consideration when determining the acceptability of effects of artificial light emissions: • The recovery plan for marine turtles recommends that best practice light management is undertaken to minimise light impacts to marine turtles, so their behaviours are not changed, and they do not become displaced from important habitats. The closest marine turtle breeding/nesting BIA is Cartier Island, located approximately 80 km west of the OA. The lighting control measures proposed herein, and transient nature of the light source generated from the moving Seismic Vessel means that the planned survey approach is compliant with the objectives of the marine turtle recovery plan. The proximity of the OA to marine turtle foraging BIAs is not of concern, given that foraging is constrained to daylight hours when artificial light generated by the Seismic Vessel will be minimal; • A darkness zone of at least 1.5 km from all significant rookeries is stated within the EPA Guideline #5 - Environmental Assessment Guideline for Protecting Marine Turtles from Light Impacts (EPA, 2010). Additionally, a 20 km distance threshold between light source and important sites is recommended to be maintained, according to the National Light Pollution Guidelines for Wildlife (Commonwealth of Australia 2020). Given that the closest marine turtle breeding/nesting BIA is Cartier Island, located approximately 80 km west of the OA, the Seismic Survey is compliant with the relevant EPA guidelines and Commonwealth Guidelines; • The Draft Wildlife Conservation Plan for Seabirds objectives seek to manage and minimise the adverse impacts of anthropogenic disturbance to breeding and roosting seabirds and enhance contingency plans to prevent, respond to or remediate environmental emergencies that have an impact on seabirds and their habitats. Given there is no emergent land within the OA and the closest known seabird breeding/nesting site is Ashmore Reef, approximately 140 km west of the OA, the lighting control measures proposed herein, and transient nature of the light source generated from the moving Seismic Vessel means that the planned survey approach is compliant with the objectives of the conservation plan. The proximity of the OA to seabird foraging BIAs is not of concern, given that foraging is constrained to daylight hours when artificial light generated by the Seismic Vessel will be minimal. • As is the case for marine turtles, a 20 km distance threshold between light source and important seabird habitat is recommended to be maintained, according to the National Light Pollution Guidelines for Wildlife (Commonwealth of Australia 2020). Given that the closest seabird breeding/nesting site is Ashmore Reef, located approximately 140 km west of the OA, the Seismic Survey is compliant with the relevant Commonwealth guidelines.

Criteria for Acceptance	Acceptability Summary
Social Acceptance – Stakeholder expectations	No concerns were raised in regard to possible impacts from artificial light emissions, and, therefore, no additional control/mitigation measures were expected or put in place. As such the environmental impacts relating to light emissions from survey vessels were considered to be at a socially **Acceptable Level**.
Ecologically Sustainable Development	The management of the risk and impacts associated with artificial light emissions proposed by SLB can be carried out in compliance with the five principles of ecologically sustainable development as defined within the EPBC Act. These principles have been considered as part of the development of this EP and risk assessment process. The assessment has not identified any adverse impacts to the principles of ESD, with no threats of serious or irreversible damage, no impacts to biological diversity and ecological integrity, no degradation of inter-generational equity, or negative effects on the social and economic integrity in the short or long-term.
Existing Environmental Context	Given that the survey vessels, and ultimately artificial light source, involved in the Seismic Survey will be constantly moving and the relatively low amounts of artificial light that will be emitted from the vessels, the impacts to the marine environment from artificial light emissions are likely to be short term, highly localised, and quickly recoverable. While the OA is located close to BIAs of several important marine turtle and seabird species, the levels of artificial light emission will be similar or less (with mitigation measures in place) to those generated from maritime traffic in the area associated with coastal shipping and fishing activity. The proposed control measures provide appropriate protection to the marine environment from artificial light emissions. Further/alternative control measures (such as no night-time acquisition) are considered to provide little or no further protection from artificial light emissions, while greatly increasing the duration and cost of the survey. Increases to the duration of the survey are particularly prohibitive as the increase the time environmental receptors are exposed to disturbance and also increase the potential for conflict and displacement with the fishing industry. As a result, no further/alternative control measures have been adopted.
ALARP	Total elimination of all impacts associated with artificial lighting emissions cannot be achieved, as lighting must be used onboard the vessels to maintain safe operations and navigation and there are no practicable alternatives. Following the implementation of the control measures, the potential impacts to the marine environment and associated receptors from artificial light emissions are likely to be short term and localised. Based on the assessment within this EP, including the potential impacts on the environment and the associated controls measures to be implemented, the impact of artificial light emitted from the survey vessels is considered to be **Low** and reduced to **ALARP**. Therefore, the impacts and associated residual risk from this activity are considered to be at an **Acceptable Level**.

7.5.8 Artificial Light Emission Impact Summary

Based on the assessment above, including the identification of potential impacts on the environment and the associated controls measures to be implemented, the impact of artificial lights emissions generated from the survey vessels is considered to be **Low** and reduced to **ALARP**. Therefore, the impacts and associated residual risk from this activity are considered to be at an **Acceptable Level**.

8 Environmental Risks from Unplanned Activities

Unplanned activities are those that are non-routine and are rare during MSS operations. However, the potential risks associated with any unplanned events must be given serious consideration as their consequences can be severe. The potential unplanned activities associated with the Seismic Survey include:

- Introduction of invasive marine species (**Section 8.1**);
- Streamer loss (**Section 8.2**);
- Vessel collision or sinking and associated hydrocarbon spill (**Section 8.3**);
- Hydrocarbon response options (**Section 8.4**); and
- Accidental release of hazardous and non-hazardous materials (**Section 8.5**).

This section of the EP goes through the impact and risk evaluation for each of the unplanned activities listed above that could potentially be associated with the Seismic Survey, for each of the receptors of relevance within the OA and wider environment should such an incident occur, using the methodology described within **Section 6**. This evaluation will demonstrate that the impacts and risks associated with the Seismic Survey will be reduced to **ALARP** and will be of an **Acceptable Level**. This will be achieved largely through the implementation of control measures, operational procedures and operating to industry best practice.

8.1 Invasive Marine Species

8.1.1 Description of Source of the Risk

Invasive marine species (**IMS**) are foreign marine aquatic plants and animals that have managed to colonise and establish new populations in areas beyond their natural range. IMS are typically carried as larvae or juveniles on international vessels, either in niche areas on vessel hulls or in their ballast and/or bilge water. Not all introduced species successfully colonise new environments since most species have well defined tolerances to environmental conditions, such as water temperature, salinity and light. However, if the source environment and the destination environment are sufficiently similar, larvae may successfully establish new colonies which may outcompete and/or predate on native species, causing environmental impacts that are often difficult to control. Likewise, incursions of highly adaptable species, able to successfully proliferate under dynamic environmental constraints, pose similar risk to native species ecology and persistence.

Importantly, an introduced species is only considered ‘invasive’ once it begins to cause negative consequences on its new environment (Bax *et al.*, 2003) and once established, marine pests are usually difficult to manage or eradicate (Fletcher *et al.*, 2017).

For an IMS to become established, there are various conditions which must be met, including surviving the introduction process, ability to overcome abiotic factors and adapt to a new trophic niche and the ability of the recipient environment to facilitate survival and establishment (Streftaris *et al.*, 2005). Gebuzri and McCarthy (2018) suggest that there are several ecological and life-history traits which regularly occur in IMS from different taxa and can, therefore, be associated with their success and many of which are associated with reproduction. These include having the ability to form resting stages, a life-history strategy consisting of pelagic larval dispersal or direct development, having a high reproductive rate and plasticity in resource utilisation (Gebuzri and McCarthy 2018).

The introduction and spread of marine pests or invasive species to Australian waters during MSSs could occur due to international movements of the Seismic Vessel and/or the Support Vessel, and inter-regionally when the vessels operate between different Australian ports or marine regions. Consequently, shallow coastal marine environments surrounding key maritime infrastructure are particularly susceptible to the colonisation of IMS.

8.1.2 Known and Potential Risk to Environmental Receptors

Once introduced, IMS can have significant and irreversible impacts on the marine ecosystem. Due to a lack of natural competitors or predators, the following adverse effects on the receiving environment may occur:

- Out-competing and/or displacing native species;
- Increase in predation and possible depletion of native flora and fauna; and
- Changing the nature of the environment through altering the abundance and diversity of native species, resulting in a change to the functioning of the communities.

The establishment of IMS can have consequences which cascade through the trophic structure, affect commercially important species and aquaculture, or which impact other marine users, as discussed in **Section 8.1.3**.

Should an IMS population establish, the management options available to regulatory agencies are limited primarily to continual monitoring and control of the IMS population, or to mitigating the impacts from its establishment. These measures are commonly associated with a high economic or labour encumbrance. Due to this, and the high social and environmental impacts resulting from the introduction of an IMS, regulatory agencies, such as the WA Department of Primary Industries and Regional Development (**DPIRD**) have implemented increased management requirements.

The risk of an IMS establishing itself as result of the Seismic Survey is no different than the various shipping operations (e.g., commercial shipping and cruise ships) that occur within the wider Bonaparte Basin. The biosecurity of these vessel movements is regulated by a number of legislative requirements which are considered to be industry best practice. These requirements have been utilised to form the basis of the control measures outlined in **Section 8.1.4**, below.

Based on the control measures that will be implemented, it is considered that the risk of introducing IMS as part of this proposal is **Moderate** (*severe x rare).*

8.1.3 Known and Potential Risk to Stakeholders and Other Marine Users

Potential risks from the establishment of an IMS to stakeholders and other marine users include:

- Impacts on human health through presence and/or release of toxins or toxic tissues;
- Predation (leading to depletion) of and competition with commercial stocks, including wild fisheries and aquaculture, and/or impacts to their associated habitats;
- Nuisance biofouling causing damage to and/or smothering of industrial marine equipment or local infrastructure;
- Impacts to shipping logistics, efficiency and feasibility; and
- Reduction of aesthetics in coastal environment and/or water column.

A number of identified stakeholders associated with the OA rely on the presence and use of healthy native flora and fauna and ecologically sustainable populations. As outlined above, in the unlikely event of the establishment of an IMS, these native flora and fauna could be displaced either through direct establishment of the IMS, through increased predation and competition or as a result of changes in environmental conditions driven by the IMS ecology.

The residual risk of introducing IMS during the Seismic Survey has been assessed as **Moderate** (*severe* x *rare*).

8.1.4 Control Measures

Control measures that will be put in place during the Seismic Survey to manage the potential risks associated with IMS have been listed in **Table 76**. These control measures have been assessed to consider the environmental benefits gained through implementing the controls relative to their time, effort and monetary cost. SLB will make a clear delineation of those which will be implemented during the Seismic Survey and those which won’t, in particular where SLB considers their implementation is disproportionate to the environmental benefit gained. Justifications have been provided for each of the decisions

Table 76 Assessment of control measures for IMS

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Implemented Control Measures:				
Adherence to the Ballast Water Management Requirements 2017. Internationally sourced ballast water will not be discharged within 12 NM of emergent land or in water <50 m deep and preferably beyond 200 NM from nearest land in water >200 m deep. Ballast waters sourced from Australian waters may be discharged within 12 NM of emergent land or in water <50 m deep (including ports/harbours)	P = Yes E = Effective	Compliance with these requirements will reduce the risk of potential IMS from establishing within the Bonaparte Basin from the discharge of ballast water.	Yes	Yes
Ballast Water Management Plan in place. This is in accordance with Regulation B-1 of the International Convention for the Control and Management of Ships' Ballast Water and Sediments	P = Yes E = Effective	As each ship is different, so are ballast water management practices. As such, having a Ballast Water Management Plan appropriately maintained for each relevant vessel is important so that the potential for the introduction and establishment of IMS is reduced to **ALARP**.	Yes	Yes
Effective anti-fouling systems and management practices are adopted for each vessel	P = Yes E = Effective	Anti-fouling paint systems are one of the primary methods for preventing the establishment and translocation of fouling species. Therefore, having an effective anti-fouling system in place onboard the survey vessels will reduce the potential for IMS to attach to the vessels, and subsequently establish in new areas. Each vessel is to have documented anti-fouling management procedures, involving periodic in-water and/or dry-dock inspections.	Yes	Yes
All vessels will have 'clean' hull and niche areas upon arrival	P = Yes E = Effective	Checking or evidence of recent inspection that the vessel hulls and niche areas are clean prior to arrival within the OA will reduce the	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
		likelihood of any IMS travelling with the vessel en-route to the area. Due to this fact, the ability for an IMS to establish itself due to the proposed activities will be reduced to **ALARP**.		
Survey equipment to be cleaned and dried prior to use in the OA	P = Yes E = Effective	As per the above, checking that equipment proposed to be used for the Seismic Survey is clean prior to use will reduce the potential for IMS to be transferred into the area and ensure the management of these risks are **ALARP**.	Yes	Yes
Implementing a Biofouling Risk Assessment tool (similar to that required by Western Australia Department of Primary Industries and Regional Development (**DPIRD**)	P = Yes E = Effective	Similar MSSs conducted in WA used the DPIRD biofouling risk assessment tool (https://vesselcheck.fish.wa.gov.au/) to demonstrate that all reasonable measures to minimise IMS transfer had been undertaken. The costs associated with developing and implementing such a tool is low, particularly compared to cost of a potential IMS introduction/establishment.	Yes	Yes
Reporting sighting or suspicion of any IMS on vessel(s), in niche areas or in ports/harbours	P = Yes E = Effective	Reporting of any sighted or suspected IMS will allow an effective response to the presence of IMS and reduce the risk of further establishment of that species. Therefore, if an IMS is sighted or suspected, SLB will report this within 24 hours by email (biosecurity@fish.gov.au) or telephone (Fishwatch tel. 1800 815 507).	Yes	Yes
Alternative Control Measures:				
Mandatory dry docking of the Seismic Vessel prior to entering the OA	P = No E = Effective	Although this control measure would eliminate IMS, the substantial costs associated with this occurring, in addition to the significant delays in the scheduling, make this control measure unsustainable; especially considering the other controls in place are expected to effectively reduce the risks associated with IMS. The cost associated with this measure would outweigh the reduction in risk.	Yes	No
Ballast the vessel using only finely filtered water or freshwater	P = No E = Partly Effective	Ballast water requirements change frequently and supplying the required large volumes of finely filtered seawater, or freshwater is either not possible quickly enough, or would require large redesign	Yes	No

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
		of vessel(s) to create enough storage. Making freshwater, and/or filtering seawater requires a large amount of energy, decreasing efficiency and sustainability. Therefore, the costs are disproportionate to benefits. Additionally, the allocation of freshwater, which likely has many other beneficial uses, to a commercial industrial application is not sustainable and should be minimised wherever possible. Using 'local' water as ballast provides an effective means of reducing IMS introductions to **ALARP**.		
Treatment of ballast water, either through heat treatment or chemical dosage	P = No E = Partly Effective	This control measure would reduce the potential for IMS to establish within the ballast water; however, the high cost involved in completing this control outweighs the reduction in risk, considering the other controls in place already reducing the risks associated with IMS. This type of control also includes detrimental effects to the marine environment, either through additional chemicals being released which are toxic to marine species, or high temperature water being added to the marine environment that may cause death of native marine species.	No	No
Source Seismic Vessel within Australia	P = No E = Partly Effective	There is still a risk of an undetected IMS being present on/near the vessel at its Australian Port, as ports and marinas within the coastal nearshore marine environment are highly susceptible to IMS incursion and establishment. Additional time and resources would be required to find and assess suitable vessels within Australia, if any are present and available. Therefore, the costs are disproportionate to benefits.	No	No
Niche areas and deployed equipment built/redesigned to reduce IMS attachment or stowage	P = No E = Effective	Design of vessels, niche areas and the seismic equipment make them as efficient as possible at their task. Additional redesign adds significant cost and may decrease the efficiency of equipment for its intended purpose, such as affecting the performance of sensitive equipment. Therefore, costs are disproportionate to benefits.	Minor	No

8.1.5 Environmental Performance

The EPO for the management of IMS is:

- No introduction and establishment of any IMS.

It is considered that the above EPO, as a result of the implementation of the control measures (**Table 76**), will allow the ongoing environmental performance of the Seismic Survey in accordance with the **Acceptable Levels** described within **Section 8.1.7**, while ensuring that the relevant legislation is complied with in order to avoid any health and safety risks or impacts on the marine environment and stakeholders as far as practicable.

The EPSs within **Table 77** have been defined to manage the impacts from IMS to **ALARP** and an **Acceptable Level**. Compliance with these standards will ensure that the identified EPO above will be achieved for the duration of the Seismic Survey.

Table 77 Environmental Performance Outcome and Environmental Performance Standards for IMS

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
EPO: No introduction or establishment of any Invasive Marine Species.			
Ballast water discharge restrictions	**EPS 157**: Ballast water discharges must comply with the relevant requirements of the Biosecurity Act 2015 and Australian Ballast Water Management Requirements (Department of Agriculture and Water Resources 2017). **EPS 158**: Internationally sourced ballast water will not be discharged within 12 NM of emergent land or in water <50 m deep and preferably beyond 200 NM from nearest land in water >200 m deep. **EPS 159**: Internationally sourced ballast water will be replaced with 'local' ballast water prior to the Seismic Vessel arriving within the OA. **EPS 160**: Ballast water exchange will be conducted offshore in accordance with the distance and water depth limits indicated in EPS 158. **EPS 161**: Ballast waters sourced from Australian waters may be discharged within 12 NM of emergent land or in water <50 m deep (including ports/harbours).	All Ballast Water exchanges recorded in Ballast Water Logbook. Approved Ballast Water Treatment system onboard and certification of approval held on vessel. Biosecurity Clearance attained from Department of Agriculture and Water Resources using the Maritime Arrivals Reporting System.	Vessel Master.
Ballast Water Management Plan	**EPS 162**: A Ballast Water Management Plan will be maintained in accordance with Regulation B-1 of the International Convention for the Control and Management of Ships' Ballast Water and Sediments	Copy of Approved Ballast Water Management Plan onboard each vessel.	Vessel Master.
Anti-fouling system	**EPS 163**: Vessel anti-fouling systems are maintained in compliance with the Protection of the Sea (Harmful Anti-fouling Systems) Act 2006 and Anti-fouling and In-Water Cleaning Guidelines which implements the International Convention on the Control of Harmful Anti-fouling Systems on Ships.	Vessel Pre-mobilisation inspection/audit checks for current International Anti-fouling System Certificate.	Vessel Master.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	EPS 164: All vessels will comply with the requirements of the National Biofouling Management Guidance for the Petroleum Production and Exploration Industry (Commonwealth of Australia, 2009) which requires: • Maintenance of biofouling electronic records outlining marine fouling management actions • Completion of an IMS risk assessment prior to vessel entry into Australian waters and which concludes a low risk of IMS presence • In-water equipment free of marine fouling prior to the commencement of the survey	Vessel Pre-mobilisation inspection/audit checks are conducted and recorded electronically, prior to vessel entry into Australian waters and which concludes a low risk of IMS presence.	Vessel Master.
All vessels will have 'clean' hull and niche areas upon arrival	**EPS 165**: Vessel will have had recent dry-docking or IMS hull inspection and show certification.	Vessel Pre-mobilisation inspection/ audit for IMS Inspection certificate and dry-dock and/or anti-fouling application certification.	Vessel Master.
In-water cleaning	**EPS 166**: Where required, in-water cleaning will occur in accordance with the requirements of the Anti-fouling and In-Water Cleaning Guidelines, which implements the Guidelines for The Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species.	Onboard records of equipment maintenance and cleaning.	Vessel Master.
Survey equipment to be cleaned and dried prior to use in the OA	**EPS 167**: All equipment deployed from vessel (e.g. streamers, birds, tail-floats, etc.) must be thoroughly cleaned, and then dried for at least 24 hours prior to being deployed in the OA for the first time. This is consistent with the requirements of the National Biofouling Guidelines for the Petroleum Production and Exploration Industry.	Onboard records of equipment maintenance and cleaning.	Vessel Master.
Biofouling Risk Assessment tool	**EPS 168**: Completion of the Department of Fisheries Vessel Check biofouling risk assessment tool: https://vesselcheck.fish.wa.gov.au/ with any actions required from this assessment being completed.	Biofouling Risk Assessment Report received once Vessel Check completed.	Vessel Master.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
Report sighting or suspicion of any IMS on vessel(s), in niche areas, and in ports/harbours	**EPS 169**: Suspected or confirmed presence of any marine pests or disease must be reported to authorities within 24 hours by email (biosecurity@fish.gov.au) or telephone (Fishwatch tel. 1800 815 507).	Incident reporting form, records of communication	Vessel Master.

8.1.6 Residual Risk

Following the implementation of the control measures in **Table 76**, the likelihood of the establishment of an IMS is *Rare*. The consequence from the establishment of an IMS is considered *Severe*, based on the discussions within **Section 8.1.2** and **8.1.3**. Therefore, the residual risk of an impact occurring from the establishment of an IMS following the implementation of control measures, is considered to be **Moderate** (**Table 78**).

Table 78 Residual risk summary for IMS

Likelihood	Consequence	Residual Risk
Rare	Severe	Moderate

8.1.7 Demonstration of ALARP

To demonstrate that any potential risks from the establishment of an IMS are managed to **ALARP**, a number of control measures have been considered to determine the benefits of their implementation and towards risk reduction (**Table 76**), based on a Hierarchy of Controls methodology (**Table 79)**. The adopted control measures that will be implemented throughout the Seismic Survey are considered appropriate to reduce the environmental risks from the establishment of an IMS arriving on one of the survey vessels and assessments have been undertaken to ensure that all reasonable and practicable control measures or solutions have not been overlooked. As a result, through the application of industry best practice and/or comparable standards to further control risk reduction, it is considered that any impacts from an IMS establishing or being introduced to Australian waters are reduced to **ALARP**, where the residual risk is **Moderate** (**Table 78**).

Additional control measures were considered as part of the assessment process towards further risk reduction; however, it was considered that they did not provide any further environmental benefit or were not reasonably practicable to implement. In addition, the costs (based on the experience of SLB) of implementing such measures would be disproportionate to the benefits that would be gained through their implementation.

Table 79 Hierarchy of controls for IMS

Eliminate	To completely eliminate the risk of the establishment of any IMS, the transport of vessels into Australian waters would need to be eliminated. However, the Seismic Survey cannot be conducted without the use of a Seismic Vessel.
Substitute	As per the above, and at this point in time, there are no validated approaches which could be adopted to gather information on geologic formations below the seabed at the required resolution. Therefore, there is no substitute to the Seismic Vessel undertaking the Seismic Survey.
Reduce	Control measures to reduce the risk of the establishment of IMS have been detailed within **Table 76**. These include restriction to the discharge of ballast water, maintenance of adequate anti-fouling systems and cleanliness of the vessels undertaking the Seismic Survey.
Mitigate	Control measures have been assessed within **Table 76** in order to mitigate the risks of an IMS establishing within the OA or connected marine environments. Generally speaking, the risks of unplanned activities should be eliminated, substituted or reduced, with mitigation primarily used for those activities in which impacts will occur. However, SLB will report any sighting or suspicion of IMS as per the measure outlined in **Table 76** in order to mitigate the potential impacts to **ALARP**.

The proposed control measures minimise the risk of establishment of an IMS and are considered appropriate to the nature and scale of potential environmental impacts during the Seismic Survey. The proposed control measures have been developed in accordance with industry best practice. No further practicable controls have been identified to reduce the impact and risks to the marine environment and/or marine organisms from establishment of an IMS.

Based on the assessment and implementation of control measures outlined within **Table 76**, the likelihood of the establishment of an IMS is considered rare and it is considered that the potential risk of the establishment of an IMS has been reduced to **ALARP**.

8.1.8 Risk Acceptability

Complete elimination of the risk of IMS is not possible as the Seismic Survey will require the use of vessels and deployed equipment which could be subject to biofouling, and ballast water will be required for each vessel to operate safely and efficiently.

Following the implementation of the control measures detailed in this assessment (**Table 76**), the residual risks to the marine environment and associated receptors from the establishment of IMS is **Moderate** (**Table 78**).

The criteria for risk acceptability are defined in **Table 34** and assessed in **Table 80**. The control measures that will be implemented throughout the Seismic Survey have been developed in accordance with these criteria. Where uncertainty exists around the criteria or the risk, SLB have taken a precautionary approach.

Table 80 Demonstration of risk acceptability for IMS

Criteria for Acceptance	Acceptability Summary
SLB's internal context	The proposed management of the risks associated with the establishment of IMS is consistent with SLB's QHSE Policy.
Industry Best Practice	The control measures are based on industry best practice to decrease the risk of IMS introduction/establishment, including: • The IAGC Environmental Manual for Worldwide Geophysical Operations. This manual recommends ballast water management plans need to be in place and

Criteria for Acceptance	Acceptability Summary
	followed to ensure IMS are not translocated between regions/countries, including recommendations to regularly exchange ballast water, clean ballast tanks, etc.; and • The APPEA Code of Environmental Practice, which recommends that geophysical surveys should have an environmental objective to reduce the risk of IMS introduction to **ALARP** and **Acceptable Levels**, including having evidence of appropriate quarantine management measures
External Context – Commonwealth and State Legislative Criteria	The proposed control measures for IMS introduction and establishment during the Seismic Survey are consistent with the following relevant standards/documents: • Biosecurity Act 2015; • Australian Ballast Water Management Requirements 2017; • International Convention for Control & Management of Ship Ballast Water & Sediments 2004; • Protection of Sea (Harmful Anti-Fouling Systems) Act 2006 • National Biofouling Management Guidance for the Petroleum Production and Exploration Industry • National System for the Prevention and Management of Marine Pest Incursions; • IMO Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species; and • Anti-fouling and In-Water Cleaning Guidelines.
External Context – Management Plans, Species Recovery Plans and Conservation Advice	The North-west Marine Parks Management Plan allows for ballast water to be discharged or exchanged, except for within areas characterised as Sanctuary Zone (1A), subject to compliance with: • The Australian ballast water management requirements and relevant state ballast water management arrangements; and • Relevant Commonwealth and state legislation or international agreements (if any) relating to ballast water management. The control measures that will be implemented during the Seismic Survey are consistent with the North-west Marine Parks Management Plan. Review and assessment of the species recovery plans, and conservation advice did not identify threats associated with the establishment of IMS for the species of relevance to the OA (**Section 4.5.8**). As such, no additional control measures are required with regard to the establishment of IMS.
Social Acceptance – Stakeholder expectations	No concerns were raised in regard to the establishment of IMS, therefore no additional control/mitigation measures were expected or put in place. As such the environmental impacts relating to IMS and biosecurity during the Seismic Survey were considered to be at a socially **Acceptable Level**.
Ecologically Sustainable Development	The management of the risk proposed by SLB associated with the introduction of IMS can be carried out in compliance with the five principles of ecologically sustainable development as defined within the EPBC Act. These principles have been considered as part of the development of this EP and risk assessment process. The assessment has not identified any adverse impacts to the principles of ESD, with no threats of serious or irreversible damage, no impacts to biological diversity and ecological integrity, no degradation of inter-generational equity, or negative effects on the social and economic integrity in the short or long-term.

Criteria for Acceptance	Acceptability Summary
Existing Environmental Context	As described in **Section 8.1.2** and **8.1.3**, the greatest potential for an IMS introduction occurs due the movement and docking of vessels, transporting material between contrasting source and receiving environments. With regard to the Seismic Survey, this would be limited to occurrences when the survey vessels visit ports/harbours at the beginning and conclusion of the campaign (noting that refuelling and re-supply will be conducted at sea). During acquisition of the survey, the vessels will be continually moving in offshore areas which make the potential attachment or translocation of IMS less likely. It is considered that the control measures in place will provide appropriate protection to the existing marine environment, and that the potential for any impacts and associated risks from the introduction of IMS are at an **Acceptable Level**.
ALARP	Complete elimination of the risk of IMS is not possible as the Seismic Survey will require the use of vessels and deployed equipment which could be subject to biofouling, and ballast water will be required for each vessel to operate safely and efficiently. Following the implementation of the control measures detailed in this assessment, the residual risks to the marine environment and associated receptors from establishment of IMS is **Moderate**. In accordance with the Risk Ranking Descriptions, where risk cannot be reduced to 'Low', control measures must be applied to reduce the risk to **ALARP**. These actions require continued tracking and recorded action plans. With respect to IMS, the control measures include effective and documented anti-fouling, cleaning and ballast water management processes for each vessel. It is considered that through the implementation of control measures, the potential for impacts and associated risks from the introduction of IMS, as a result of the Seismic Survey, are at an **Acceptable Level**.

8.1.9 Invasive Species Risk Summary

Based on the assessment above, including the identification of potential impacts on the environment and the associated controls measures to be implemented, the residual risk of the introduction/establishment of an IMS from the Seismic Survey is considered to be **Moderate** and **ALARP**.

In accordance with the Risk Ranking Descriptions (**Table 32**), where risk cannot be reduced to 'Low', control measures must be applied to reduce the risk to **ALARP**. These actions require continued tracking and recorded action plans. With respect to IMS, the control measures include effective and documented anti-fouling, cleaning and ballast water management processes for each vessel.

The residual risk and impacts from IMS associated with the Seismic Survey are considered to be at an **Acceptable Level**.

8.2 Streamer Loss

8.2.1 Description of Source of the Risk

There are a number of ways in which potential damage to and resultant loss of streamers could occur; these include snagging with floating debris, rupture from abrasions or shark bites, or loss from severance during a collision (e.g. if another vessel were to accidentally cross the streamer). Solid streamers, such as those proposed to be used during the Seismic Survey, are negatively buoyant and would sink if severed.

8.2.2 Known and Potential Risks to Environmental Receptors

Direct contact between the streamer and the seabed as a result of damage or loss would result in physical damage to the benthic habitat and any sensitive communities in the area. Should this equipment be irretrievably lost and persist on the seabed as debris, it has the potential to entangle with marine fauna or fishing equipment.

A number of control measures will be implemented during the Seismic Survey (**Table 81**), including, but not limited to, the utilisation of solid streamers, integration of self-recovery devices and recording real-time positioning of the streamers, all of which are implemented to prevent the loss of streamer should it break free and stop it from reaching the seabed for recovery. The 'streamer recovery devices' are pressure activated self-inflating buoys, that activate if a streamer is severed and sinks to a certain depth. This system provides sufficient positive buoyancy to return the damaged streamer to the sea surface, enabling recovery by the Support Vessel. Only solid streamers will be used during the MSS. In contrast to oil-filled streamers and other alternatives, solid streamers do not contain fluids which could leak into the marine environment following damage or loss.

In the unlikely event that a streamer does make contact with the seabed, it is useful to note that areas of archaeological interest or cultural significance are typically associated with intertidal and shallow subtidal environments of the nearshore and costal marine environment. The nature of the OA, which is located offshore, affords low potential for impacts on such values. Additionally, it is considered that should the control measures fail, and a streamer is lost to the seabed, it would sink relatively quickly, before travelling any great distance. Therefore, if a streamer reached the seabed, it would be unlikely to drift beyond the boundary of the OA.

The seabed is composed of soft sediments comprising varying proportions of silt and sand, and sparse areas of hard substrate inhabited by sponges, soft corals and filter feeders. A lost streamer is likely to marginally disturb the seabed as it lands, through direct physical damage or driving potential resuspension of fine-grained sediments. Therefore, benthic faunal communities may be affected in the landing area and immediate surrounds. Where possible, recovery would occur over time as the disturbed sediments naturally settle and redistribute under the local conditions. These impacts, both direct and indirect, would be spatially constrained and relative to the size of one or, in the worst-case, all streamers. Such habitats are also well represented throughout the region. Consequently, no lasting impacts are expected.

The residual risk to environmental receptors arising from the use of streamers during the Seismic Survey has been assessed as **Low** (*Minor x Remote*). Overall, it is considered that the risk of streamer loss occurring is minimised to **ALARP**, with the ability for immediate recovery if it does occur reducing the potential impacts to an **Acceptable Level**.

8.2.3 Control Measures

The control measures that have been considered during the Seismic Survey to manage any potential impacts from the loss of a seismic streamer to **ALARP** have been included in **Table 81**. These control measures have been assessed to consider the environmental benefits gained through implementing the controls relative to their time, effort and monetary cost. SLB will make a clear delineation of those which will be implemented during the Seismic Survey and those which won't, in particular where SLB considers their implementation is disproportionate to the environmental benefit gained. Justifications have been provided for each of the decisions.

Table 81 Assessment of Control Measures for Streamer Loss

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Implemented Control Measures:				
Solid Streamers	P = Yes E = Effective	The utilisation of solid streamers which contain no fluids eliminates the risk that release of hazardous substances into the marine environment following damage or loss.	Yes	Yes
Streamer-recovery devices	P = Yes E = Effective	Streamer recovery devices will be fitted at nominated intervals along the streamer and programmed to automatically deploy at water depths that are shallower than the depth of the ocean where seismic data acquisition is occurring. Under typical conditions, this will allow a damaged and/or severed streamer to return to the sea surface, and be retrieved, before impacting the seabed.	Yes	Yes
Depth control 'birds'	P = Yes E = Effective	Depth control birds will allow the Seismic Vessel to control the depth of the streamers. This will ensure streamers do not sink too low in the water column and potentially impact the seabed, or migrate too deep and activate streamer recovery devices, which could add additional strain on the streamer while underway and making way.	Yes	Yes
Real time positioning of streamers	P = Yes E = Effective	The exact position of the streamers will be monitored at all times utilising Intrinsic Ranging by Modulated Acoustics, allowing their positions to be seen relative to any potential hazards.	Yes	Yes
Adherence to vessel Standard Operation Procedure (**SOP**) for streamer deployment and retrieval	P = Yes E = Effective	All crew will be suitably familiar with and adhere to SOP documents relating to the preparation, deployment, operation and recovery of the seismic equipment to reduce risk of streamer damage and potential loss.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Inspections and maintenance of streamers and associated equipment	P = Yes E = Effective	Regular inspections and maintenance of streamers and associated equipment (e.g., cables and attachment points) ensures that any 'wear-and-tear' is identified and fixed, reducing the potential for the breaking (and subsequent loss) of equipment.	Yes	Yes
Recovery of lost streamer	P = Partially E = Somewhat effective	Lost equipment will be located and recovered where safe and practicable to do so, in accordance with SLB's Non-Routine Equipment Recovery Procedures.	Yes	Yes
Avoid areas < 20 m depth	P = Yes E = Effective	The minimum depth to seabed in the area of the proposed survey lines is 20 m, though approximately 95% of the survey will be completed in water depths greater than 60 m. In both cases, there will be ample separation distance given the proposed tow depth (7.5 m below sea surface) to ensure that the streamer does not contact the seabed.	Yes	Yes
Reporting of all incidents of lost equipment	P = Yes E = Effective	The recording and reporting of incidents, including those associated with lost equipment is standard in the industry.	Yes	Yes
Alternative Control Measures				
Alternative data acquisition method	P = No E = Effective	The Seismic Survey cannot acquire seismic data without the use of streamers and its associated equipment. Implementation of this control measure would render the survey inoperable.	Yes	No

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Laying the streamers on the sea floor, also known as ocean bottom cable, as opposed to towing the streamers.	P = No E = Effective	Using this methodology for the Seismic Survey would effectively eliminate the risk associated with the potential loss of a streamer, but it still requires an acoustic source to be towed behind a Seismic Vessel. The towed recording device will not pose a significant risk to marine life within the water column and would require less source locations to deliver an equivalent data set and achieve the survey objectives. Deploying the recording array on the seabed takes significantly more time and will introduce additional health and safety risks. It will also cause temporary disturbance to the seabed. The costs would be prohibitively expensive and impracticable for a survey of this size. The proposed methodology is the most efficient way of conducting the survey in the shortest amount of time and will reduce the time that the Seismic Vessel is in the area.	Yes	No

8.2.4 Environmental Performance

The EPO for the management of risks from the loss of the streamer is:

- No contact with the seabed by any towed equipment.

It is considered that the above EPO, as a result of the implementation of the control measures (**Table 81**), will allow the ongoing environmental performance of the Seismic Survey in accordance with the **Acceptable Levels** described within **Section 8.2.7,** while ensuring that the relevant legislation is complied with in order to avoid any health and safety risks or impacts on the marine environment as far as practicable.

The EPSs within **Table 82** have been defined to manage the impacts from the loss of a streamer to **ALARP** and an **Acceptable Level**. Compliance with these standards will ensure that the identified EPO will be achieved for the duration of the Seismic Survey.

Table 82 Environmental Performance Outcome and Standards for Loss of a Streamer

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
EPO: No contact with the seabed by any towed equipment.			
Solid Streamers	**EPS 170**: The Seismic Survey will be carried out using solid streamers.	Pre-mobilisation audit and inspection confirms solid streamers.	Vessel Party Chief.
Pressure Activated Streamer Recovery Devices	**EPS 171**: The streamers will be fitted with Pressure Activated Streamer Recovery Devices at intervals along its length.	Pre-mobilisation audit and inspection confirms presence and operative capability of devices.	Vessel Party Chief.
Streamer depth controlled using depth control 'birds'	**EPS 172**: The streamer will be fitted with depth control birds to control streamer depth.	Pre-mobilisation audit and inspection confirms presence and capability of 'birds'.	Vessel Party Chief.
	EPS 173: Streamer depth will be maintained between 10 m and 30 m depth along the length of the tow, with a general target depth of 7.5 m and depending on the relevant depth to seabed within the area.	Survey data records tow depth of the streamers.	Seismic Operator.
Real time positioning of streamers	**EPS 174**: Intrinsic ranging by modulated acoustics (**irMA**) will be utilised for the real time positioning of the streamers.	Survey data and irMA data shows streamer positions.	Vessel Party Chief.
Regular inspections and maintenance of streamers and associated equipment	**EPS 175**: The streamers and associated equipment (such as tow points etc.) will be regularly inspected and maintained.	Inspection records confirm equipment is fit-for-purpose and records any maintenance work that is required/carried out.	Seismic Operator.
Adherence to vessel SOP's	**EPS 176**: Survey equipment will be prepared, deployed, used and retrieved in accordance with relevant vessel SOPs for each equipment type.	Vessel inspection/maintenance records show checks have been completed and operating checklists in the SOP are filled and signed.	Vessel Master.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
Avoidance of water depths < 20 m	**EPS 177**: The Seismic Vessel will not enter water depths less than 20 m while streamers are deployed.	Vessel records show no breach of these requirements. Bridge logs and vessel track records.	Vessel Master.
Reporting of all incidents of lost equipment	**EPS 178**: Loss of streamer and associated equipment (including in the event that lost equipment is successfully retrieved) will be recorded in an incident report.	Vessel incident report/record.	SLB Project Manager. Vessel Party Chief. Vessel Master.
	EPS 179: If the streamer cannot be retrieved, all relevant stakeholders will be notified as soon as possible through the communication pathways that will be in place. Communications will include GPS coordinates and all other relevant information.	Vessel incident report/record.	SLB Project Manager. Vessel Party Chief. Vessel Master.
	EPS 180: AMSA will be notified of any lost equipment as soon as possible, as a potential navigation hazard.	Vessel incident report/record.	SLB Project Manager. Vessel Party Chief. Vessel Master.
	EPS 181: Any complaints received regarding loss of equipment will be recorded in a complaint register.	Vessel incident report/record.	SLB Project Manager.
Recovery of lost streamer	**EPS 182**: Lost streamer will be located and recovered, if safe and practicable to do so, by either of the survey vessels, in accordance with SLB's Non-Routine Equipment Recovery Procedures.	Vessel incident report/record	SLB Project Manager. Vessel Master (Support Vessel).

8.2.5 Residual Risk

Following the implementation of the control measures in **Table 81**, the likelihood of a lost streamer impacting on marine environmental receptors or users is *Remote*. The consequence from the streamer contacting the seabed is considered *Minor*, based on the assessment within **Section 8.2.2**. Therefore, the residual risk of an impact occurring from the loss of the streamer following the implementation of control measures (**Table 81**), is considered to be **Low** (**Table 83**).

Table 83 Residual Risk Summary for Streamer Loss

Likelihood	Consequence	Residual Risk
Remote	Minor	Low

8.2.6 Demonstration of ALARP

To demonstrate that any potential impacts from the loss of a streamer are managed to **ALARP**, SLB has considered a number of control measures to assess the benefits of their implementation towards risk reduction (**Table 81**), based on a Hierarchy of Controls methodology (**Table 84**). The adopted control measures that will be implemented throughout the Seismic Survey are considered appropriate to reduce the potential environmental impacts arising from a streamer loss and assessments have been undertaken to ensure that all reasonable and practicable control measures or solutions have not been overlooked. As a result, it is considered that any impacts from routine discharges have been reduced to **ALARP**, where the residual risk is **Low** (**Table 83**).

Additional control measures were considered as part of the assessment process towards further risk reduction however it was considered that they did not provide any further environmental benefit or were not reasonably practicable to implement. In addition, the costs (based on the experience of SLB) of implementing such measures would be disproportionate to the benefits that would be gained through their implementation.

Table 84 Hierarchy of Controls for Loss of Streamer

Eliminate	The survey cannot be conducted without the use of streamers.
Substitute	There are no practicable substitutes for using streamers on the Seismic Vessel.
Reduce	Streamer recovery devices will float a lost/broken streamer, or section of streamer, to facilitate recovery by either of the survey vessels before it can make contact with the seabed. The streamer and associated towing equipment will be regularly inspected and maintained for wear-and-tear and any worn or 'tired' parts replaced.
Mitigate	Control measures have been assessed within **Table 81** in order to mitigate the impacts from loss of a streamer to **ALARP** levels. Those which are appropriate and are not impracticable or unfeasible due to disproportionately large costs will be implemented during the Seismic Survey.

The proposed control measures minimise the risk of impact arising from loss of a streamer and are considered appropriate to the localised nature and scale of the potential environmental impacts. The control measures have been developed in accordance with industry best practice. No further practicable controls have been identified to reduce the impact and risks to the marine environment and associated receptors (marine species and stakeholders) associated with losing a streamer.

Given the relatively localised nature of the potential effects associating with the loss of a streamer during the Seismic Survey, the risk of potential impact from streamer loss is reduced to **ALARP**.

8.2.7 Risk Acceptability

Total elimination of all impacts associated with the loss of a streamer cannot be achieved, as a streamer must be towed to acquire the seismic data and there are no practicable alternatives. Following the implementation of the control measures (**Table 81**) the potential impacts to the marine environment and associated receptors from loss of a streamer are likely to be highly localised and short-term and, therefore, the residual risks are considered to be **Low** (**Table 83**) .

The criteria for risk acceptability are defined in **Table 34** and are detailed in **Table 85**. The control measures that will be implemented throughout the Seismic Survey have been developed in accordance with these criteria. Where uncertainty exists around the criteria or the risk, SLB have taken a precautionary approach.

Table 85 Demonstration of Risk Acceptability for Streamer Loss

Criteria for Acceptance	Acceptability Summary
SLB's internal context	The proposed management of the risks of streamer loss and its associated impacts will be informed by SLB's Non-Routine Equipment Recovery Procedures and are within **Acceptable Levels** of SLB's Environmental and QHSE Policy.
Industry Best Practice	The control measures to decrease the risk of streamer loss follow industry best practice and best practice guidelines and include: • The IAGC Environmental Manual for Worldwide Geophysical Operations, which recommends that operators: - Document and communicate their contingency plans for retrieving any equipment to help mitigate environmental impacts associated with the loss of that equipment; - Notify appropriate regulatory agencies in event of equipment loss; and - Make a reasonable effort to retrieve lost equipment as soon as possible after loss occurs. • The APPEA Code of Environmental Practice, which recommends that geophysical surveys should have an environmental objective to reduce the impacts from loss of equipment to **ALARP** and **Acceptable Levels**, including having evidence of appropriate management procedures and an emergency response plan.
External Context – Commonwealth and State Legislative Criteria	There are no relevant legislative requirements identified for the management of the risks and impacts from the potential loss of equipment (i.e. a streamer). However, implementation of control measures will be used to mitigate potential risks and impacts wherever practicable.
External Context – Management Plans, Species Recovery Plans and Conservation Advice	The NOPSEMA guidance note for petroleum activities and Australian Marine Parks (NOPSEMA, 2020d) requires that an EP is developed for undertaking activities such as MSSs. The EP evaluates how environmental impacts and risks will be of an **Acceptable Level** and reduced to **ALARP** and demonstrates that the Seismic Survey will not be inconsistent with the relevant marine park management plan. Operations within the park must ensure the long-term maintenance of biodiversity and other natural values within the reserve. While it is possible that a lost streamer reaching the seabed could cause physical damage to sensitive benthic communities found in some areas of the wider OA, the proposed control measures in place to reduce the risk of streamer loss and subsequent environmental impact to adjacent Australian Marine Parks and will ensure that the integrity of the IUCN reserve management principles will be maintained throughout the survey.

Criteria for Acceptance	Acceptability Summary
	Section 4.5.8 provides an outline of the EPBC Act Conservation Management Plans, Recovery Plans and Conservation Advice relevant to the Seismic Survey. Within these documents, the risk of marine debris impacting those relevant species is highlighted, with the actions required including supporting the implementation of the EPBC Act in accordance with the *Threat Abatement Plan for the impacts of marine debris on vertebrate marine life* (Commonwealth of Australia 2018). The control measures in place during the Seismic Survey will support the implementation of this threat abatement plan.
Social Acceptance – Stakeholder expectations	No concerns were raised in regard to possible impacts associated with the loss of a streamer, and as such no additional control/mitigation measures were expected or put in place as a result. The environmental impacts relating to the loss of a streamer from the Seismic Survey are considered to be at a socially **Acceptable Level**.
Ecologically Sustainable Development	The management of the risk associated with streamer loss can be carried out in compliance with the five principles of ecologically sustainable development as defined within the EPBC Act. These principles have been considered as part of the development of this EP and risk assessment process. The assessment has not identified any adverse impacts to the principles of ESD, with no threats of serious or irreversible damage, no impacts to biological diversity and ecological integrity, no degradation of inter-generational equity, or negative effects on the social and economic integrity in the short or long-term.
Existing Environmental Context	Of relevance, are the maintenance of management objectives and values for protected areas such as the adjacent Oceanic Shoals Marine Park and the Carbonate bank and terrace system of the Sahul Shelf KEF which overlaps OA. While it is possible that a lost streamer reaching the seabed could cause physical damage to benthic habitats and communities comprising the KEF and Oceanic Shoals Marine Park, the implementation of the proposed control measures ensure that the risks and potential impacts associated with the loss of a streamer do not impede the maintenance of management objective or values for protected areas. As a result, the risks and potential impacts associated with the loss of a streamer to these sensitivities is considered Low. It is considered that the proposed control measures provide appropriate protection to the existing marine environment from the risk of a lost streamer and that any associated effects (e.g., physical seabed damage) are at an **Acceptable Level**.
ALARP	Total elimination of all impacts associated with the loss of a streamer cannot be achieved, as a streamer must be towed to acquire the seismic data and there are no practicable alternatives. Following the implementation of control measures, the potential impacts to the marine environment and associated receptors from loss of a streamer are likely to be highly localised and short-term. Therefore, based on the assessment within the EP, the residual risk of the loss of a streamer from the Seismic Survey Vessel is considered to be **Low** and to **ALARP**. Therefore, the potential risk from a lost streamer during the Seismic Survey is considered to be at an **Acceptable Level**.

8.2.8 Streamer Loss Risk Summary

Based on the discussions above, including the potential impacts on the environment and the associated controls measures to be implemented, the residual risk of the loss of a streamer from the Seismic Survey Vessel is considered to be **Low** and to **ALARP**. Therefore, the potential risk from a lost streamer during the Seismic Survey is considered to be at an **Acceptable Level**.

8.3 Vessel Collision or Sinking and Associated Hydrocarbon Spill

8.3.1 Description of Source of Risk

In 2011 AMSA commissioned a study to estimate the risk of pollution from marine oil spills in Australian ports and waters (DNV, 2011). Part of this study assessed the breakdown of spills by accident type as a frequency per year; this assessment found that spill frequencies are dominated by drift grounding (21.6%), transfer spill (19.9%) and powered grounding (19.1%); whereas the frequency of a collision causing a spill is 11.6%.

The Seismic Vessel will be operating in deep offshore waters, with the vast majority of the survey lines being in waters 20- 200 m, or beyond the shelf edge. As outlined in **Section 3.4.5**, bunkering of the vessels will be undertaken at sea. Whilst this activity is recognised as a potential source of risk for a hydrocarbon spill during the Seismic Survey, the control measures and mitigating factors ensure that this risk, and magnitude of potential adverse effects, are small and any effects are restricted to well within the footprint of the OA. Given it is a source of risk, however, this is assessed alongside the risk of vessel collision for the purpose of this EP. The most catastrophic and hence 'worst-case' scenario for a spill occurrence is that associated with a vessel collision/sinking.

A collision between the survey vessels and another vessel (e.g. passing merchant vessels, fishing vessels, passenger vessels, etc.) has the potential to cause widespread environmental impacts. The most significant potential environmental impact associated with vessel collision is related to the vessel(s) sinking and making contact with the sea floor, or damage to the vessel(s) and associated release of on-board hazardous substances, specifically the oil, fuel and lubricants, and the effects of these substances on the marine and coastal environment. A surface release of hydrocarbons from a vessel collision or sinking has the potential to result in ecological impacts on various environmental receptors through surface, dissolved and entrained hydrocarbon exposure.

The very worst-case scenario for a hydrocarbon spill would likely arise where the entire contents of either of the survey vessel's fuel tanks (approximately 2,500 m^3 at 95% full) were released into the surrounding ocean. However, compartmentalised fuel storage systems will be on the vessels to be utilised during the Seismic Survey, which effectively reduced the volume of a spill that could occur if the vessel was damaged (complete rupture of the largest fuel tank at 100% full would result in the release of 257.4 m^3). In addition, onboard emergency procedures include transferring contents of a ruptured tank into other tanks, where possible.

However, a collision at sea is unlikely due to routine seagoing procedures undertaken by the crew and master (in accordance with COLREGs), the slow speeds at which the survey vessels will be operating (4 – 5 knots), notifications issued to other marine users (i.e. Notice to Mariners), as well as state of the art navigational systems (i.e. transmitting and receiving AIS and radar) which are typically found on Seismic Vessels, and which support the seismic data acquisition.

For bunkering of marine diesel between the support vessel(s) and the Seismic Vessel within the OA, two scenarios for a hydrocarbon spill include:

- Loss of containment of marine diesel during bunkering operations, such as a partial or total failure of a bulk transfer hose or fittings during bunkering. This failure may be caused by mechanical stress/ integrity issues that could spill marine diesel to the deck and/or into the marine environment. This is estimated to be in the order of less than 200 L, based on the likely volume of a bulk transfer hose (assuming a failure of the dry break and complete loss of hose volume); and

- Partial or total failure of a bulk transfer hose or fittings during bunkering, combined with a failure in procedure to shutoff fuel pumps, for a period of up to five minutes, resulting in approximately 8 m^3 marine diesel loss to the deck and/or into the marine environment.

8.3.2 Oil Spill Trajectory Modelling

SLB has commissioned an assessment of the oceanic dispersal and beaching potential in the unlikely event of a spill event resulting from vessel collision during the Seismic Survey (Calypso Science, 2022, see full report in **Appendix B**). In the assessment, a stochastic approach has been adopted to define the statistical probabilities related to oil trajectory, dispersion, diffusion, weathering, and beaching patterns. This was achieved by simulating the occurrence of 100 realistic spill events of MGO from three locations within the OA, randomly distributed over the previous decade with a continuous release of 1000 m^3 of MGO over six hours at sea level.

For this EP, the scenario of a hydrocarbon spill associated with bunkering was not included in the modelling outputs. The relatively small volume of any spill associated with a bunkering operation is small by comparison to the worst-case scenarios adopted for the trajectory modelling for vessel collision. Any spill associated with bunkering would be small, contained within the OA, and based on the fate and transport of MGO in the offshore environment, effects would not be expected to extend outside the footprint of the OA and/or persist.

8.3.2.1 Methodology

To guide the site selection, AIS vessel traffic data from 2019 was plotted over the OA, highlighting the regions with highest traffic. On the basis of AIS density and geographic spread, three hypothetical spill locations (A, B, and C) were selected - allowing for maximum distance between the spill locations in order to capture the effect of variation in environmental factors on the spill outcomes (see **Figure 46**).

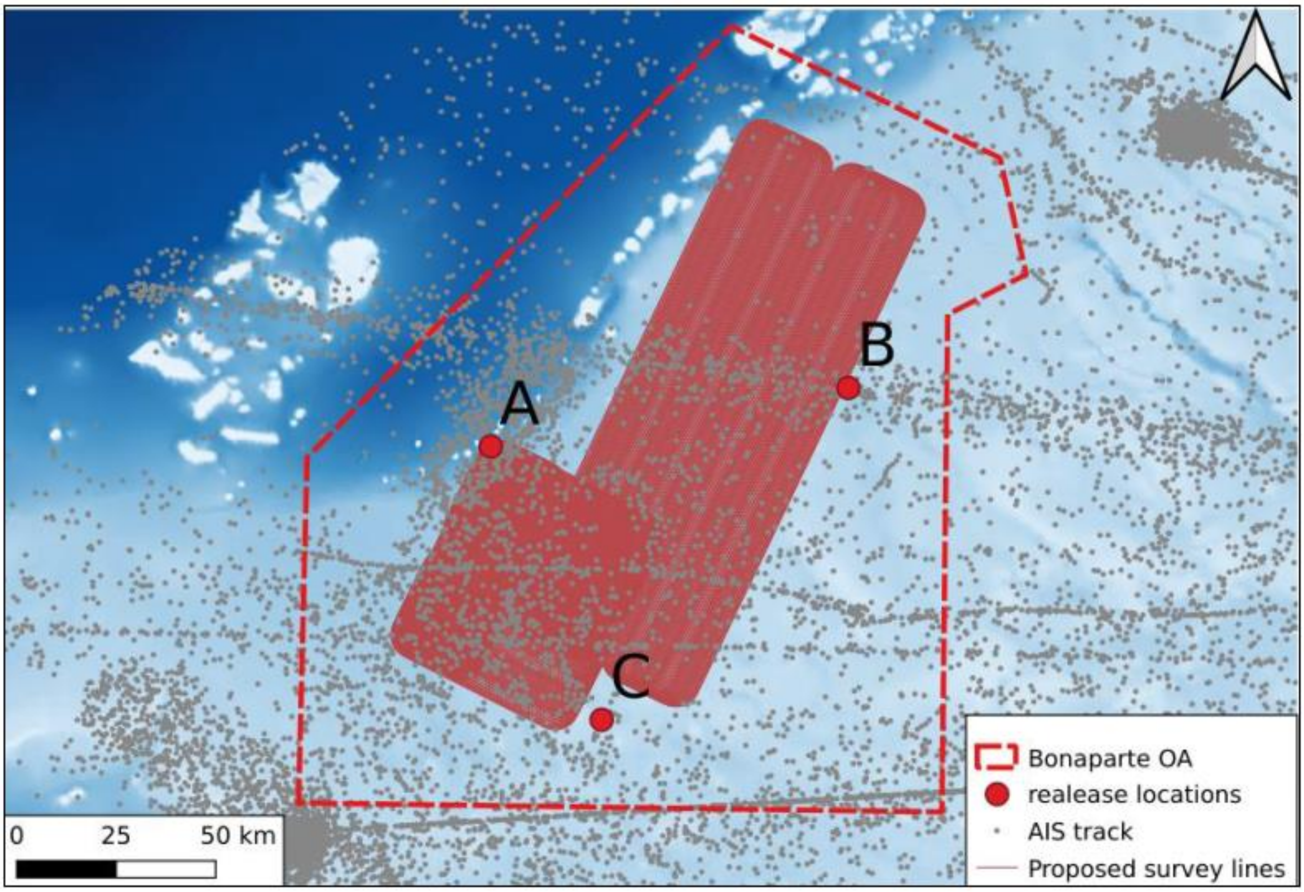


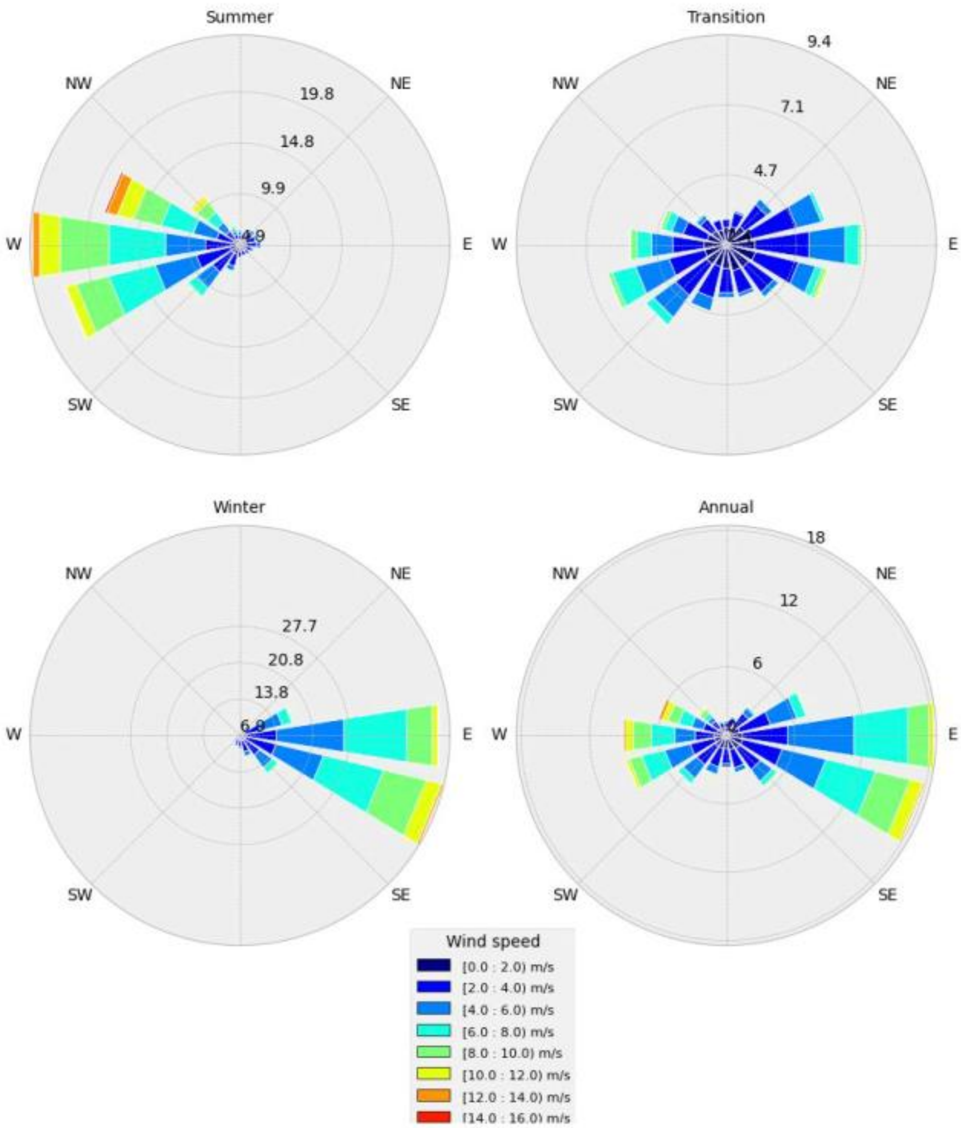
Figure 46 Position of the three spill locations (A-C) chosen within the Bonaparte OA.

The fuel for the Seismic Vessel will either be marine diesel oil or MGO, with the latter having greater environmental persistence following a spill. Accordingly, the more conservative approach has been adopted for the study, with MGO being selected as the spill product. MGO has specific and well documented characteristics which influence its persistence in the marine environment after a spill event. The characteristics of the MGO is presented below.

- Density of 852 kg/m^3 and a kinematic viscosity of 3 cP at 15°C;
- Total wax content of 0.8% by mass with no significant emulsifying properties;
- Low pour point for both fresh oil and 250°C+ residue (<-36 °C);
- Low viscosity for both fresh oil and 250°C+ residue (< 20 mPa·s at 2 °C);
- Intermediate evaporative loss (30.6 vol. % at 250 °C); and
- Relatively high natural dispersion in breaking wave conditions and poor natural dispersion in non-breaking wave (swell) conditions.

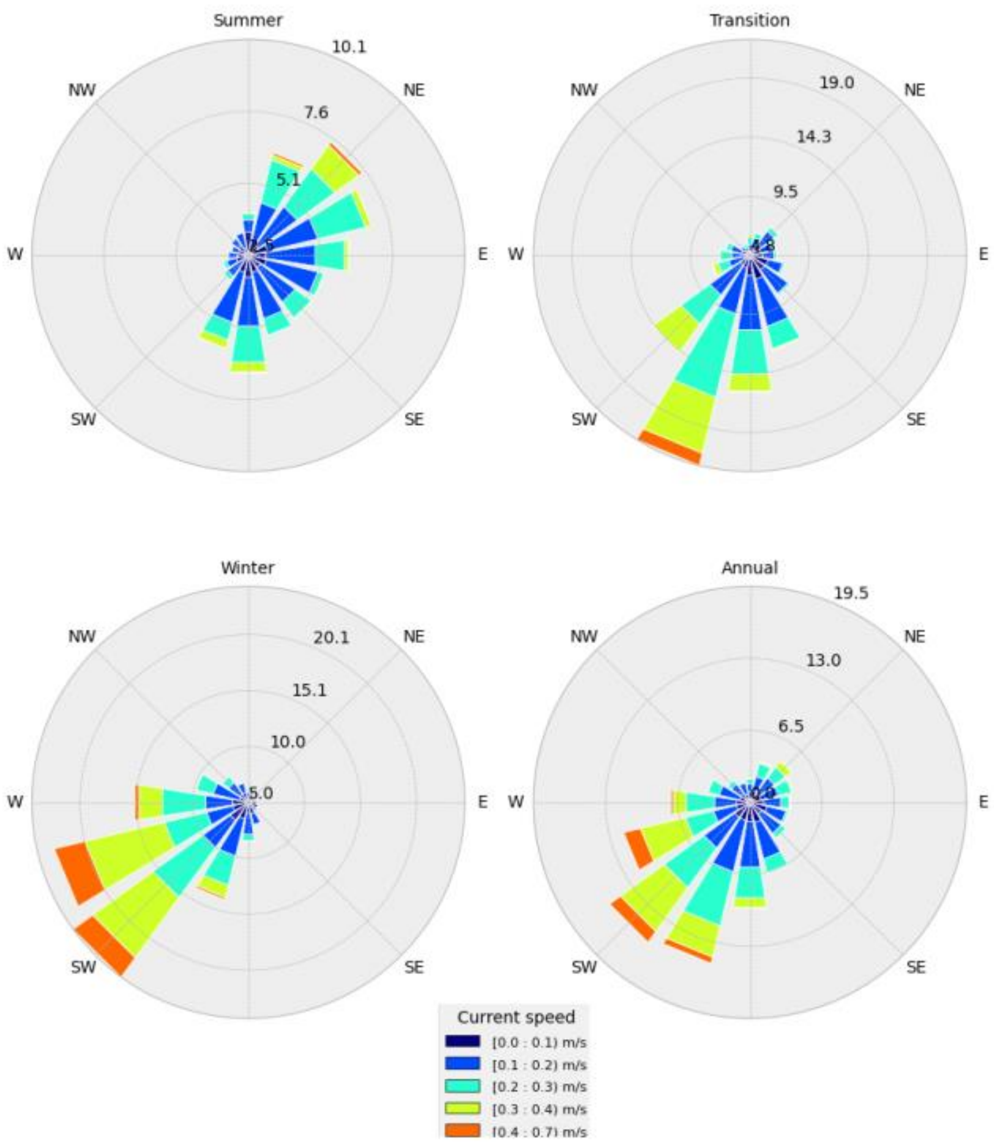
The simulated spill scenario was a surface release of 1,000 m^3 of MGO over a 6-hour period. Each spill was tracked by the model for 90 days, and the results used to form a database of 100 events which were analysed to derive statistics on the fate and mass budgets, plus the probability of occurrence for specific impacts. The OpenOil simulation framework was used to model the weathering dispersal and trajectory of the spill for a maximum exposure of hydrocarbons on the surface, entrained at water depths of 0-10 m and 10 to 20 m, dissolved in depths of 0-10 m and beaching.

Records of historical hindcasts of the wave, wind, and ocean current conditions from 2008-2017 were used to drive the numerical model. Rose plots for the seasonal and annual conditions for winds and surface currents are presented in **Figure 47** and **Figure 48**. Modelling was conducted at any time of year to ensure weather and hydrodynamic conditions provide the worst-case extent of the hydrocarbon release scenario, ensuring conservatism in the modelling.



Note: The wind directional convention is 'coming from'.

Figure 47 Annual and Seasonal Wind Roses at the Centre of the OA, from Hindcast Data 2008-2017



Note: The wind directional convention is 'coming from'.

Figure 48 Annual and Seasonal Current Roses for the Sea Surface (Tidal and Non-tidal) at the Centre of the OA, from Hindcast Data 2008-2017

8.3.2.2 Exposure Values

The outputs of the hydrocarbon spill modelling are used to assess the environmental risk, if a credible hydrocarbon spill scenario occurred, by defining which areas of the marine environment could be exposed to hydrocarbon levels exceeding exposure values that may result in impact to sensitive receptors. The degree of impact will depend on the sensitivity of the biota contacted, the duration of the contact (exposure) and the toxicity of the hydrocarbon mixture making the contact. The toxicity of a hydrocarbon will change over time, due to weathering processes altering the composition of the hydrocarbon.

The modelling considered four key physical or chemical phases of hydrocarbons that pose differing environmental and socioeconomic risks: surface, entrained, dissolved and shoreline accumulated hydrocarbons. The modelling used defined hydrocarbon exposure values, as relevant for risk assessment and oil spill planning, for the various hydrocarbon phases.

Applied exposure values used in the modelling study are summarised in **Table 86**. The adopted exposure values are based primarily on the instantaneous exposure values defined in NOPSEMA Bulletin #1 Oil Spill Modelling (April 2019).

Table 86 Summary of the Hydrocarbon Exposure Thresholds

Exposure Type	Potential Level of Exposure	Hydrocarbon Concentration	Description
Surface hydrocarbons (floating) (g/m^2)	Low	1	This value represents the area where a visible sheen may be present on the surface but is below concentrations at which ecological impacts are expected to occur. It is indicative of perceived impacts and areas that may be temporarily closed as a precautionary measure. It predicts the potential for some socio-economic impact (visual/aesthetic).
	Moderate	10	This represents the minimum oil thickness at which ecological impacts (e.g. to birds and marine mammals) are expected to occur. It is the lowest “actionable” level where spill response may be possible.
	High	50	This value is the estimated minimum floating hydrocarbon threshold for containment and recovery and informs response planning.
Total submerged hydrocarbons (entrained) (ppb)	Low	10	This value establishes the planning area for scientific monitoring based on potential for exceedance of water quality triggers.
	Moderate	100	This represents potential toxic effects, particularly sublethal effects to sensitive species and life stages.
	High	1000	This value represents lethal effects to sensitive species.
Dissolved hydrocarbons (ppb)	Low	10	This value establishes the planning area for scientific monitoring based on potential for exceedance of water quality triggers.
	Moderate	50	This represents potential toxic effects, particularly sublethal effects to highly sensitive species and life stages of fish and invertebrates (e.g. larvae, plankton).
	High	400	This value represents toxic effects including lethal effects to sensitive species.
Accumulated hydrocarbons (shoreline) (g/m^2)	Low	10	This value represents light oiling (equivalent to 2 teaspoons of oil per m2). It is indicative of perceived impacts and shorelines that may be temporarily closed as a precautionary measure, and predicts the potential for some socio-economic impact (visual/aesthetic).
	Moderate	100	This represents the minimum oil thickness at which potential lethal ecological impacts (e.g. to intertidal invertebrates, shorebirds, mammals and reptiles) may occur. It also predicts areas likely to require clean-up effort.
	High	1000	This value predicts areas likely to require intensive clean-up effort. Potential significant impacts to coastal vegetation including mangroves and marshes.

8.3.2.3 Oil Spill Modelling Results

The set of 100 randomly selected spills over an historical decade provides a robust dataset to define the statistics of spill trajectory, beaching along the shore, and expected mass budgets of any spilled MGO.

The characteristics of MGO is that oil will quickly disperse under wave action but tends to persist as a surface slick during calm weather. On the sea surface, strong winds will increase the rate of evaporation, while the wave conditions associated with these winds also act to mix and disperse the oil into the upper layers of the ocean. Consequently, the day-to-day weather conditions strongly influence the mass budget of MGO throughout the simulations.

A summary of the oil spill modelling results is provided below, with a tabulated summary of the results for annual conditions provided in **Table 87**. The EMBA exhibits a southwest/northeast axis with an extension toward the JBG. Some 79% of the runs exceed 1 g/m^2 on the surface and 100% of the runs exceed the 10-ppb threshold in the water column. However, no concentration was found to exceed the highest thresholds. The modelled oil spill EMBA for surface, total submerged (entrained) and dissolved hydrocarbons for relevant Marine Parks, Shoals and banks and BIAs in addition to beaching is presented in **Figure 49, Figure 50, Figure 51** and **Figure 52**.

The results show that the fate of spilled MGO in the Bonaparte Basin is highly dependent on the wind and wave climate. During the transitional months (March, September, October and November) winds and waves are relatively calm and the fuel persists on sea surface for a longer time period than other seasons. There is less dispersion within the water column and more surface trajectory toward JBG. During the winter months (April, May, June, July and August) the plume tends to spread toward the southwest (i.e., Ashmore reef and Cartier Island), whereas during the summer months (December, January, February) the plume trajectory is predominantly directed toward the northeast.

On average, around 1.7% of the spilled volume can be expected to beach during an event at location B and less than 1% at locations A and C. The worst-case outcome from the simulations resulted in 13% of the spilled volume beaching on the North Kimberley Coast. Overall, on an annual basis, the location with the highest chance of oil beaching is JBG (6%), followed by the Ashmore Reef and Cartier Island area (5%) and North Kimberley coast (3%). The minimum times for the beaching concentration to reach 10 g/m^2 is 40 days for the Kimberley coast and 18 days for Ashmore Reef.

Table 87 Annual Maximum Probability (in %) of Potential Sensitive Receptors reaching specific Concentration Thresholds due to a 1,000 m^3 MGO Spill at Location A-C

Potential Sensitive Receptor	Location A						Location B						Location C					
	Surface	Entrained 0-10m		Entrained 10-20m		Dissolved	Surface	Entrained 0-10m		Entrained 10-20m		Dissolved	Surface	Entrained 0-10m		Entrained 10-20m		Dissolved
Hydrocarbon Concentration	1 g/m^2	10 ppb	100 ppb	10 ppb	100 ppb	10 ppb	1 g.m^2	10 ppb	100 ppb	10 ppb	100 ppb	10 ppb	1 g.m^2	10 ppb	100 ppb	10 ppb	100 ppb	10 ppb
Heywood Shoal		1																
Eugene McDermott Shoal								1					2	3	1	1		1
Vulcan Shoal	1													3		3		
Barracouta Shoal		5											1	4	2	2		
Woodbine Bank		2												3		1		
Hibernia Reef		1																
Fantome Shoal	10	18	5	7				2						3				
Sahul Bank	76	97	88	67	15	7	7	15	4	8				4				
Margaret Harries Bank								2										
Gale Bank	1	2				1	2	6	2			2	8	9	1			2
Van Cloon Shoal													4	5				2

Potential Sensitive Receptor	Location A						Location B						Location C					
	Surface	Entrained 0-10m		Entrained 10-20m		Dissolved	Surface	Entrained 0-10m		Entrained 10-20m		Dissolved	Surface	Entrained 0-10m		Entrained 10-20m		Dissolved
Hydrocarbon Concentration	1 g/m^2	10 ppb	100 ppb	10 ppb	100 ppb	10 ppb	1 g.m^2	10 ppb	100 ppb	10 ppb	100 ppb	10 ppb	1 g.m^2	10 ppb	100 ppb	10 ppb	100 ppb	10 ppb
Flat Top Bank								1										
Penguin Shoal	1	1				1							2	1				1
Bassett-Smith Shoal													1	2				1
Holothuria Bank	1					1								1				
Long Reef																		
Johnson Bank		2												3		2		
Kimberley MP (Multiple Use Zone VI)	1	2						2					2	4				1
Cartier Island MP (Sanctuary Zone Ia)		1												3				
Ashmore Reef MP (Recreational Use Zone IV)														2				
Ashmore Reef MP (Sanctuary Zone Ia)		1												2		2		

Potential Sensitive Receptor	Location A						Location B						Location C					
	Surface	Entrained 0-10m		Entrained 10-20m		Dissolved	Surface	Entrained 0-10m		Entrained 10-20m		Dissolved	Surface	Entrained 0-10m		Entrained 10-20m		Dissolved
Hydrocarbon Concentration	1 g/m²	10 ppb	100 ppb	10 ppb	100 ppb	10 ppb	1 g.m²	10 ppb	100 ppb	10 ppb	100 ppb	10 ppb	1 g.m²	10 ppb	100 ppb	10 ppb	100 ppb	10 ppb
Oceanic Shoals MP (Multiple Use Zone VI)	1	6		2		1	37	58	39	35		10	17	25	8	9		6
Joseph Bonaparte Gulf MP (Special Purpose Zone VI)								1						1				
Joseph Bonaparte Gulf MP (Multiple Use Zone VI)		1						2						3				1
Pinnacles of the Bonaparte Basin KEF							5	8	2	1		4	2	5		2		2
Carbonate bank and terrace system of the Sahul Shelf KEF	16	31	13	15		4	79	100	89	74	8	12	78	99	91	73	6	9
Ashmore Reef, Cartier Island and surrounding Commonwealth waters KEF		3		1										4		2		

Potential Sensitive Receptor	Location A						Location B						Location C					
	Surface	Entrained 0-10m		Entrained 10-20m		Dissolved	Surface	Entrained 0-10m		Entrained 10-20m		Dissolved	Surface	Entrained 0-10m		Entrained 10-20m		Dissolved
Hydrocarbon Concentration	1 g/m^2	10 ppb	100 ppb	10 ppb	100 ppb	10 ppb	1 g.m^2	10 ppb	100 ppb	10 ppb	100 ppb	10 ppb	1 g.m^2	10 ppb	100 ppb	10 ppb	100 ppb	10 ppb
Continental Slope Demersal Fish Communities KEF		5												4		2		
Ancient coastline at 125 m depth contour KEF		2											1	2				
Dolphin BIAs														2				
Pygmy Blue Whale BIA	44	55	37	35	1	1	3	9	2	6				8		3		
Seabird BIAs	3	15	1	2		1	2	11		2		1	12	26	3	5		4
Marine Reptile BIAs	1	9		1		1	37	55	32	29		8	14	27	5	9		6
Dugong BIAs														2		2		
Whale Shark BIA	46	71	48	44	4	7	77	91	77	69	8	4	78	99	93	76	6	4
North Kimberley Marine Park								1						2				
Joseph Bonaparte Gulf SE Coastline																		

Note: blank cell is the same as 0 % probability).

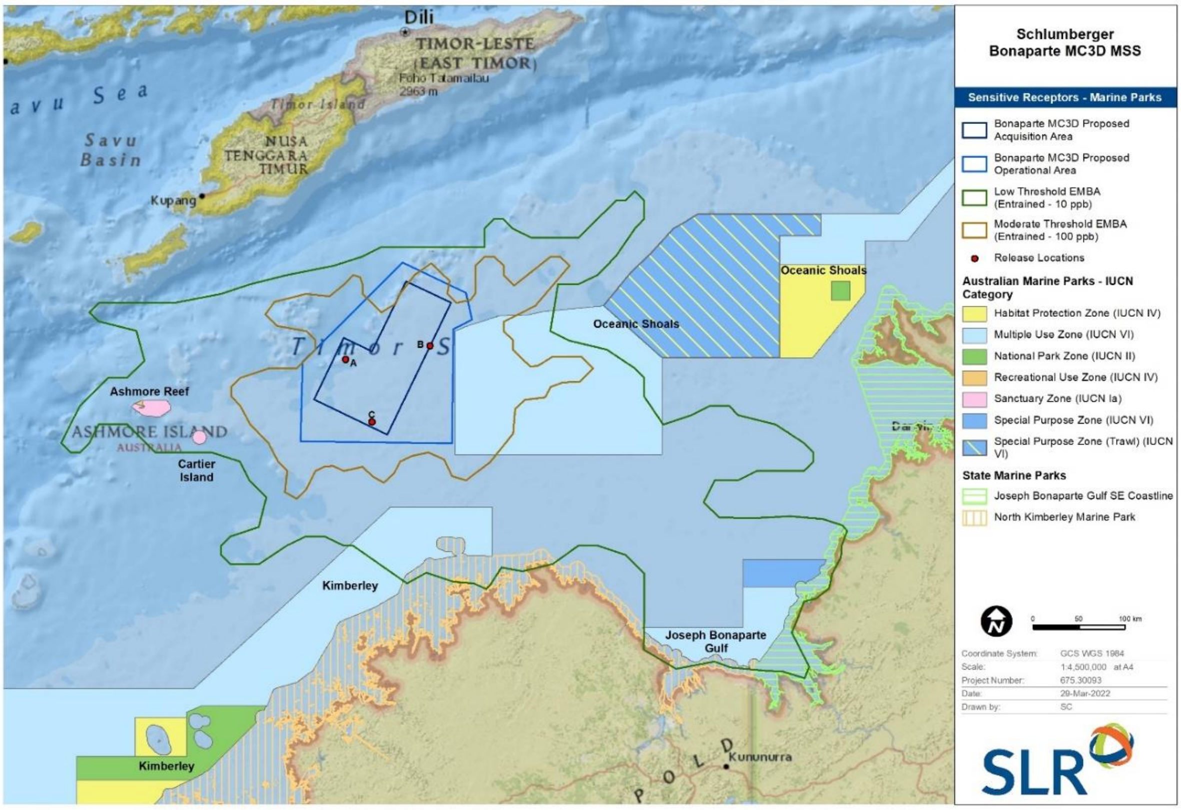


Figure 49 Hydrocarbon Spill Scenario from Release Location A-C for a 1,000 m³ MGO spill – Marine Parks

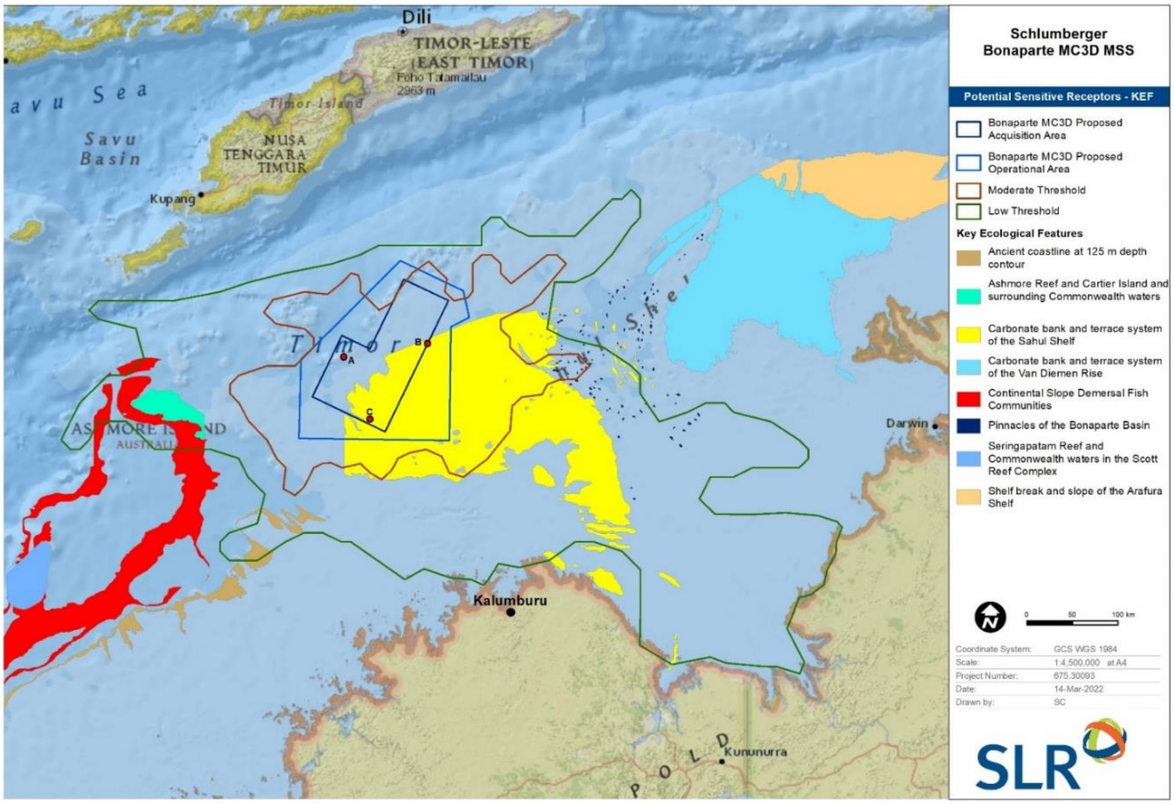


Figure 50 Hydrocarbon Spill Scenario from Release Location A-C for a 1,000 m³ MGO spill - Key Environmental Features

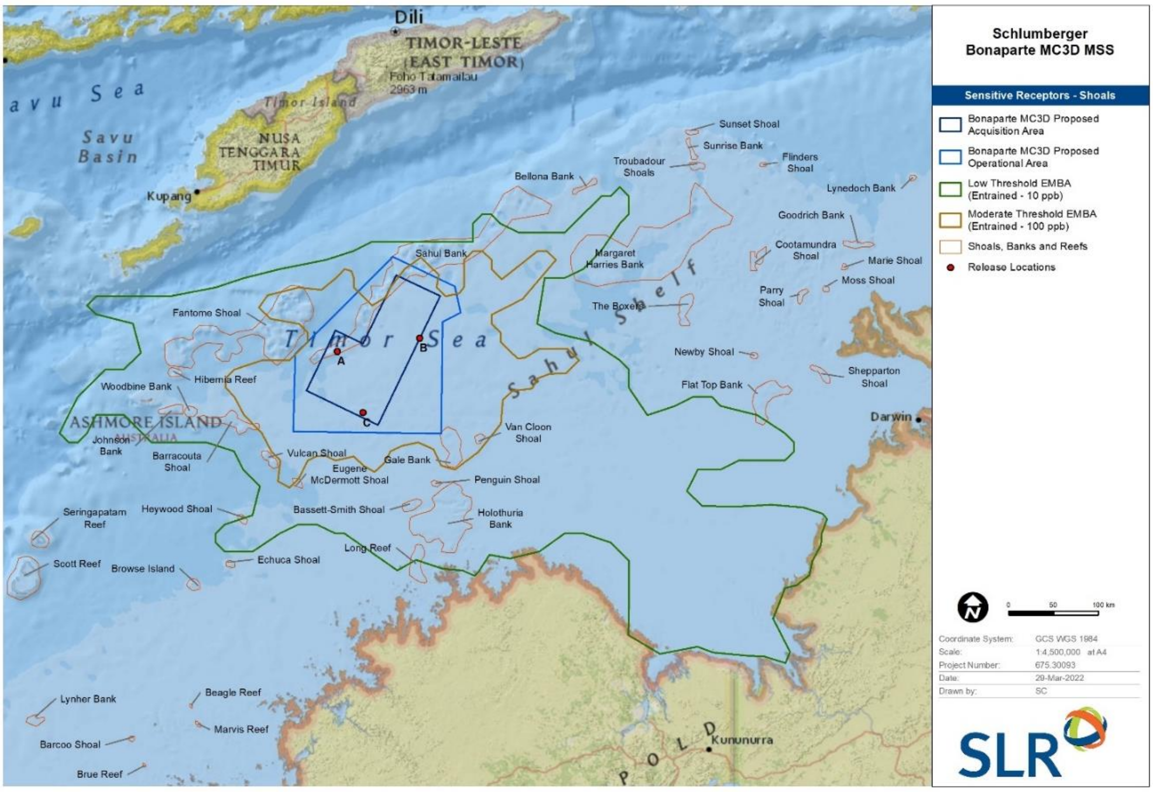


Figure 51 Hydrocarbon Spill Scenario from Release Location A-C for a 1,000 m³ MGO spill – Shoals and Banks

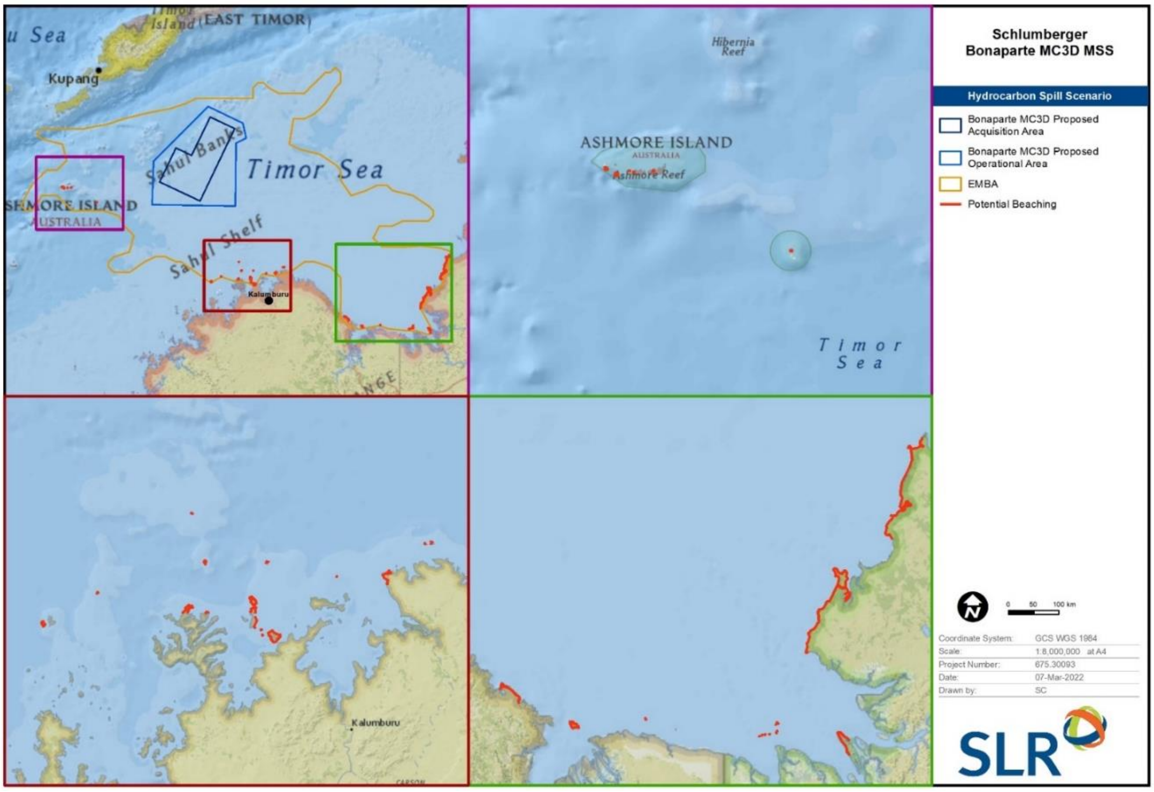


Figure 52 Hydrocarbon Spill Scenario from Release Location A-C for a 1,000 m³ MGO spill – Potential Beaching

8.3.3 Known and Potential Risk to Environmental Receptors

Potential effects of a hydrocarbon spill on the marine environment will be influenced by factors such as the weather and sea conditions at the time (**Section 8.3.2**), the specific characteristics of the hydrocarbon fuel type, effectiveness of clean-up/response measures (**Table 88**) and the sensitivity of the environment and organisms that exist in the affected area (**Section 4.5**). Hydrocarbon spills will affect the water quality in the upper surface waters of the water column and can cause immediate/acute chemical and physical impacts to marine species, as well as longer term/chronic impacts such as bioaccumulation in the food chain and behavioural changes (e.g., predator/prey interactions).

The known effects of hydrocarbon spills on the marine environment are well documented and include, but are not limited to:

- Direct and indirect toxicity effects (e.g. Alonso-Alvarez *et al.,* 2007; Almeida *et al*., 2012; Schwacke *et al*., 2013);
- Removal and damage to, or exclusion from habitats and other important areas (Lee and Page, 1997);
- Bioaccumulation in the food chain, disruption of food chains and predator/prey interactions (e.g. Abbriano *et al.,* 2011; Ansari *et al.,* 2012; Wise *et al*., 2014);
- Loss of waterproofing, buoyancy, swimming ability, filtering capabilities, and thermoregulatory abilities from external oiling (especially in pinnipeds and seabirds) (e.g. Jenssen, 1994; O'Hara and Morandin, 2010); and
- Exclusion of users of the marine environment due to contamination/tainting of edible species or altered perception (e.g., Law and Hellou, 1999; McCrea-Strub *et al.,* 2011; Balcioglu, 2016).

Different hydrocarbon fuel types have different chemical characteristics which influence the fate if released into the receiving environment. Combined with the location of potential release, and prevailing weather conditions, the rate of other processes (dispersion, dilution, partitioning, beaching, biodegradation and photo-oxidation) will be affected.

The modelled fate and exposure probabilities to sensitive receptors of MGO spilled into the marine environment is summarised in **Table 87**. The bulk of MGO spilled into the marine receiving environment will, over time, become dispersed, and undergo physical evaporation, with a component expected to become gradually submerged, and a low proportion potentially beached (depending on location and prevalent weather conditions). these characteristics significant impacts to

Marine fauna in the open ocean areas of the Bonaparte Basin is described as relatively mobile and are expected to be able to display avoidance behaviours in the event of any hydrocarbon release. By contrast, fauna (and flora) with less mobility that would not exhibit immediate behavioural response (e.g. plankton/primary producers, benthic species, early life stages (juvenile) of cephalopods and some vertebrate species) , as well as benthic environments and coastal ecosystems could be at risk of being contacted by a hydrocarbon spill if a release event were to occur during a more sensitive life stage for the animal (i.e., seasonally depended), or on the southern extent of the OA whereby a higher probability of oil beaching may be incurred.

8.3.3.1 Potential Physical Environment Impacts

A vessel collision has the potential to affect the local marine environment by impacting the surrounding water and air quality in the vicinity of the incident. In the unlikely event of a vessel collision/sinking these effects are predicted to be localised and temporary, and conditions will quickly return to background levels on account of weathering of spilled hydrocarbons, on-site response actions (if required), and in-water dilution effects.

Similarly, any release of hydrocarbon as a result of refuelling incident is, by comparison to a vessel collision, regarded as small. It would be highly localised to the vessels and contained within the OA. The small volume of potential discharge would possibly impact the immediate surrounding water and air quality in the vicinity of the spill. Given the small volume of release expected, any acute effects of a spill entering the marine waters are expected to be rapidly mitigated by immediate dilution and dispersion. On board control measures and operational contingencies are expected to minimise further release into the marine receiving environment.

A worst-case larger spill scenario at a southern location in the OA could pose potentially longer-term impacts, given the increased likelihood of oil beaching. Oil beaching has the potential to interfere with sensitive receptors on near shore/ intertidal areas, through habitat modification, or through the physical smothering/impairment of the animal itself (e.g., impairment of their feeding, respiratory and/or locomotory structures). Given the OA is located a significant distance offshore, any potential hydrocarbon release is expected to undergo significant physical dispersion and dissolution, prior to any amount being beached.

Localised seabed damage and disturbance could occur in the event that vessel debris makes contact with the seabed. Across much of the OA the seabed is likely to be composed of gravelly muddy sand and sinking debris would marginally disturb the seabed as it lands, with potential resuspension of fine-grained sediments.

Where possible, damaged vessels resulting from collision would be salvaged and returned to a suitable facility for repair or disposal, and smaller items of debris would be recovered.

Based on the above, the residual risk of a vessel collision and associated hydrocarbon spill on the physical marine environment has been assessed as **Low** (*minor* x *rare*).

Considering the residual risk associated with refuelling and associated hydrocarbon release, impacts to the marine receiving environment are also assessed as **Low** (*possible* x *rare*).

8.3.3.2 Potential Biological Environment Impacts

Potential adverse effects on the marine environment from marine debris released during a sinking event include entanglement and ingestion. Entangled individuals may drown, suffer from injury, or be subject to reduced foraging efficacy and/or predator avoidance. Ingestion of foreign debris is also a possibility which could lead to blocked digestive tracts, internal injury, and suppressed appetite (Laist, 1987). However, the majority of marine debris released through a vessel collision/sinking event would not be of the nature that would cause such effects (i.e. entanglement and ingestion is particularly problematic for plastics and discarded fishing gear), and the majority of such debris would likely remain contained within their collection receptacles onboard the vessel.

In the event of a vessel collision/sinking, the greatest impact to the biological environment will be associated with the release of hydrocarbons. Light oils, such as MGO, are significantly more toxic to marine organisms than heavy crude oils (NOAA, 2022), although lighter oils are less persistent in the marine environment due to evaporation of volatile components. Environmental impacts from a spill following vessel collision/sinking in the marine environment will primarily be restricted to those species that inhabits the sea surface, mainly marine mammals, seabirds and marine reptiles, although fish, cephalopods and zooplankton may also be impacted (at a chronic level) following dispersion and partitioning.

Potential impacts of a hydrocarbon spill to vulnerable receptors found within the OA and EMBA, together with a residual risk assessment, are summarised in the following sections.

8.3.3.2.1 Benthic Invertebrates

A release of hydrocarbons under a worst-case scenario may impact benthic species under certain weather/spill conditions. Benthic invertebrate species (e.g., molluscs, echinoderms) occurring on more shallow areas such as shoals (which are shown to occur within the EMBA) may be more vulnerable adverse effects of hydrocarbon pollution than vertebrate species. Potential impacts can be acute effects (i.e., mortality, significant impairment of behaviour, feeding, motility), or longer term chronic effects (e.g., impaired growth and reduced fecundity).

Sessile invertebrates (e.g., coraline reef assemblages, occurring between shoals, see **Section 4.5.2.1**) and species with low mobility (soft-sediment benthic invertebrates including taxa listed in **Section 4.5.2.2**) may be susceptible to physical effects of vessel collision/sinking. Risk of exposure to any hydrocarbon release, however, is expected to be low given the depth and expected dispersion/evaporation/dissolution of any spilled MGO into the marine receiving environment. Life history strategies (e.g., high fecundity, high recruitment) for many benthic invertebrates also ensures that if any adverse impacts are incurred, localised population resilience and recovery will be rapid.

The Seismic Survey will be undertaken in waters ranging from 20-200 m in depth. This depth physically mitigates and attenuates any potential for direct oiling impacts on the benthic environment from a spill within the OA, including shoals, given and spill plume will largely be buoyant in the surrounding ocean. Any oil beaching is more likely to incur potential direct acute and chronic effects to near shore/intertidal invertebrates if they come into direct contact with any beached MGO. This scenario is highly unlikely, and any effects are expected to be highly localised.

Based on the parameters of the proposed Seismic Survey, the control measures in place and the physical properties of the MGO if it is released in the marine environment, the potential for long-term impacts to benthic invertebrates from an MGO spill are very unlikely. The residual risk to benthic invertebrates arising from an accidental release of MGO as a result of a vessel collision/refuelling incident during the Seismic Survey has been assessed as **Low** (*minor x remote*).

8.3.3.2.2 Zooplankton, Fish Eggs and Larvae

During and after an oil spill event, marine zooplankton, phytoplankton, eggs and larvae may exposed to dissolved oil fractions and dispersed oil droplets. Several studies have demonstrated that plankton may take up dissolved petroleum hydrocarbons by passive mechanisms or consuming contaminated phytoplankton, as well as ingestion of oil droplets (Almeda *et al*., 2016). If dissolved fractions are high, acute toxicity thresholds may be incurred.

A hydrocarbon spill within the EMBA has the potential to overlap with spawning of some fish species (see **Section 4.5.3.1**). Depending on the time of year, larval stages of commercially targeted fish species of *Serranidae* sp. (cods) and *Lutjanidae* sp. (snappers), and *Scombridae* sp. (mackerel) may be affected. Other important planktonic species such as krill, and macro-zooplankton assemblages may be impacted.

Any hydrocarbon spill has the potential to reduce the water quality by increasing toxicity due to the presence of entrained/dissolved hydrocarbons, resulting in localised mortality of plankton due to potentially acute thresholds. Acute toxicity thresholds will be highest in areas close to the spill source. However, MGO is expected to rapidly evaporate and disperse/partition the offshore environment, reducing the acute toxicity of the spill. Whilst localised mortality for zoo- phytoplankton species may occur; this is expected to be localised and short term. Due to their vertical stratification within the water column (eggs and larvae are generally not at the sea surface), eggs and larvae are less likely to come into direct contact with the bulk of any spill.

Planktonic communities impacted by a spill are expected to recover quickly (weeks/months) due to rapid fecundity and recruitment (ITOPF, 2011). The residual risk to plankton arising from an accidental release of MGO as a result of a vessel collision/refuelling incident during the Seismic Survey has been assessed as **Low** (*minor x remote*).

8.3.3.2.3 Fish, Sharks and Rays

The primary pathways to exposure for fish from a hydrocarbon spill are through direct dermal contact such as oiling of gills/smothering (Hook *et al*., 2016), and/or ingestion of contaminated prey.

Fish are also at risk from an MGO spill due to partitioning of dissolved hydrocarbons and any entrainment of hydrocarbons within the water column (leading to exposure through ingestion or dermal contact). This risk is reduced by the fact that adult fish have chemoreceptors – sensitive for detecting taste and smell, which can enable them to avoid the areas of a spill where there are hydrocarbons within the water column (NERA, 2018).

Due to their mobility, it is unlikely that pelagic fish would be exposed to acutely toxic concentrations of spilled hydrocarbons for the extended periods of time required to result in acute toxicity to be incurred. NOAA (2012) and ITOPF (2011) have reported that deaths of adult fish are rarely observed from hydrocarbon spills in the open ocean due to the rapid dilution and evaporation.

The Bonaparte Basin supports a diverse assemblage of fish and thirteen threatened and/or migratory species of sharks and rays identified by the EPBC Protected Matters search may be present within the EMBA (refer to **Section 4.5.3**). Given the absence of critical habitat for most of these species, significant numbers are not expected to be impacted; however, the southern part of the OA overlaps with a whale shark foraging BIA (See **Figure 18**). This BIA represents waters where solitary whale sharks may forage during the migration from Ningaloo, which occurs primarily in Spring (September to November). Oil spill modelling predicted that should a spill occur; the BIA could be exposed to moderate concentrations of entrained hydrocarbons (100 ppb) (refer to **Section 8.3.1**). Information on the possible effects on whale sharks of an oil spill are largely unknown, but could have serious implications; for example, if a spill were to occur, the health of individual whale sharks, or the group as a whole, could be affected both directly through ingestion of oil and indirectly through disruption to food sources (DPAW, 2013). The risk for this to happen is however particularly higher for an oil spill containing crude oil than MGO that rapidly dilutes and evaporates in the water column.

Other species of sharks and rays could be present at low densities all year round within the OA and EMBA; however, the absence of any known feeding, resting or breeding areas means significant numbers are unlikely to be impacted if an unplanned release were to occur.

As the fish populations within the OA and EMBA are highly mobile pelagic species, it is unlikely that fish populations would be subjected to sufficient hydrocarbon contamination for periods long enough to result in mortality. Fish populations are likely to be distributed over a wide geographical area so impacts on populations or species level are considered to be negligible. Combined with these factors and the rapid dispersion of marine diesel, the residual risk to fish species arising from an accidental release of MGO as a result of a vessel collision/refuelling incident during the Seismic Survey has been assessed as **Low** (*minor x remote*).

8.3.3.2.4 Marine Reptiles

Marine reptiles are particularly at risk from a hydrocarbon spill as they need to surface for breathing, and may be exposed to ingestion, inhalation and/or skin contact with hydrocarbons on the ocean surface. MGO has a low stickiness so it is unlikely to stick to turtles in large amounts and would likely wash of skin surfaces; however, MGO may cause skin irritation to sensitive organs such as eyes. If hydrocarbons from the spill reached the shoreline in large amounts which coincided with turtle hatchlings going to sea, then this could have an impact on the survival of those turtles.

Ten species of threatened marine reptile and/or migratory species has been identified as possibly being present within the EMBA (**Section 4.5.5**). In the unlikely event of a hydrocarbon spill occurring, individuals traversing open water may come into contact with water column (submerged/dissolved) or surface MGO. The EMBA overlaps or are located close to several foraging and three nesting/internesting BIAs (refer to **Section 4.5.5**). Oil spill modelling predicted that the foraging BIAs may be partially exposed to low concentrations of sea surface hydrocarbons (1 g/m^3), low concentrations of dissolved hydrocarbons (10 ppb) and moderate concentrations of entrained hydrocarbons (100 ppb) should a spill occur (see **Table 87**).

A hydrocarbon spill within the OA may result in impacts to individual marine turtles and a potential disruption to a portion of the foraging/internesting habitat; however, this is not expected to result in a threat to the overall population viability due to the rapid dispersion of MGO. The residual risk to marine reptiles arising from an accidental release of MGO as a result of a vessel collision/refuelling incident during the Seismic Survey has been assessed as **Low** (*minor x remote*).

8.3.3.2.5 Cetaceans

Marine mammals in the area could potentially ingest MGO when feeding in open water, or they could get coated with MGO when they surfaced to breath. However, given MGO has a low stickiness, it is likely that it would wash off the dorsal surfaces of cetaceans as they dived into deeper waters. MGO contact with sensitive body parts such as eyes may cause injury or damage and when cetaceans surface to breath, and there is the potential for volatile hydrocarbons to be inhaled. Hydrocarbons are fat-soluble and therefore tend to bioaccumulate before being eliminated by metabolism and excretion (Troisi *et al*., 2007). Physiological effects from internal contamination include dehydration, anaemia, organ damage, intestinal ulceration, immunosuppression, irritations and burns to mucous membranes (Balsiero *et al*., 2005). Cetaceans that spend extended periods of time at the sea surface will be particularly at risk to the effects of an MGO spill.

Eleven migratory marine mammal species were identified by the EPBC Protected Matters search within the EMBA (See **Section 4.5.6**). Of these, one is listed as endangered (blue whale (considered to be the pygmy blue whale sub-species) and two as vulnerable (fin whale and sei whale). The hydrocarbon spill EMBA overlaps breeding and foraging BIAs for Australian snubfin dolphins, Indo-Pacific humpback dolphins, spotted bottlenose dolphins, and dugong. The EMBA also overlaps the migration BIA for pygmy blue whales. However, the BIAs (except for pygmy blue whales) are all located south of the area predicted to be affected by surface hydrocarbons from an oil spill **(Section 8.3.2**).

These species are expected to be present in the EMBA in low numbers and limited to isolated individuals or small pods and in the unlikely event of a spill occurring, they are not expected to remain in the vicinity of spilled hydrocarbons for extended periods. Although surface feeding cetaceans would be sensitive to a hydrocarbon spill, the residual risk of a vessel collision/refuelling incident and associated MGO spill on cetaceans has been assessed as **Low** (*minor x remote*) on account of their ability to metabolise hydrocarbons, low degree of adhesiveness of the MGO, and the fast dispersion and weathering of volatile hydrocarbons.

8.3.3.2.6 Seabirds and Migratory Shorebirds

Seabirds are susceptible to potential impacts at various exposure levels for surface oil through pathways such as a reduction in insulation and waterproofing, ingestion, impaired flight and navigation (AMSA, 2017). Depending on the length of time of exposure, especially in the case of areas of heavy oiling, direct contact with surface hydrocarbons can result in irritation of the skin and eyes and some individuals may die as a result of exposure.

Oiling, or external contamination of seabirds is particularly problematic and can lead to a loss of insulation, buoyancy, and the ability to fly or swim (as observed for penguins, but noting there are no penguin colonies in the EMBA). Seabirds will groom/preen themselves in an attempt to remove any contamination, leading to ingestion and further toxicity effects from any MGO which might have adhered to their fur/feathers. However, MGO has a dispersive nature, and the majority of seabirds are highly mobile so if any hydrocarbon was spilt, a significant/acute impact is unlikely.

Sixteen threatened bird species, as identified by the EPBC Protected Matters database search may be encountered during the Seismic Survey (refer to **Section 4.5.7**). Four of the threatened bird species may occur in the OA, with the remaining species potentially present within the EMBA. The EMBA overlaps breeding BIAs for 10 bird species, none of which are located within the OA. The maximum probability of an oil spill reaching specific concentration thresholds at the surface close to BIAs are relatively low, 2-12 %, slightly higher (up to 26%) for entrained oil 0-10 m (see **Table 87**). This is unlikely to have any major impact on nesting or egg laying individuals in colonies, since the closest breeding BIA are located at a minimum of 50 km from the OA, however, it is possible that individuals could come into contact with surface or entrained MGO while foraging (diving and skim feeding) closer to the OA. Although oceanic seabird species can travel long distances to forage in offshore waters, most breeding seabirds tend to forage in nearshore waters near their breeding colony, resulting in intensive feeding by higher seabird densities in these areas during the breeding season and making these areas particularly sensitive in the event of a spill.

Shorebirds foraging for food in intertidal areas or along the high-tide mark may encounter weathered hydrocarbons, subsequently returning to the next and/or ingested. However, by the time this may occur, the hydrocarbons are expected to be heavily weathered and likely to permeate through the sandy areas, limiting the potential accumulation on adult birds. Potential toxicity effects from ingestion of weathered hydrocarbons are not expected due to the properties of MGO, with the volatile aromatics evaporating rapidly after a spill event.

The residual risk to seabirds arising from an accidental release of MGO as a result of a vessel collision/refuelling incident during the Seismic Survey has been assessed as **Low** (*minor x remote*).

8.3.3.3 Potential Risk to Cultural and Heritage Sites

Sections 4.6.1.1 and **4.6.1.2** detail the southern extent of the EMBA that overlaps with the Western Australia Native Title Determination Area, namely areas on Uungugu Indigenous Protection Area, and Balanggarra Region. Traditional fishing is also recognised to occur across the EMBA (in particular, across the Ashmore Islands, but not expected to be within the OA) (see **Section 4.6.1.2**). There are no protected shipwrecks within the OA, and nine submerged shipwrecks across the outer margins of the EMBA.

Predicted probabilities of any released MGO impacting on the waters around Ashmore Reef (overlapping with cultural fishing grounds) and the waters of the North Kimberly Marine Park (partially overlapping with Uungugu Indigenous Protection Area) were low (range 1-4% Ashmore Ref, 1-2% North Kimberly Marine Park, **Table 87**). For any potential oil beaching, the worst-case scenario for oil beaching identifies isolated coastal margins located in both the Uungugu and Balanggarra areas, as well as isolated sections on Ashmore Island, as potential sites that may be subject to the beaching of oil.

Given the OA is located a significant distance offshore, any potential hydrocarbon release is expected to undergo significant physical dispersion and dissolution, prior to any amount being beached. Any potential beached amount is expected to be low and restricted to minor outcrops rather than the mainland. Natural weathering/attenuation processes are anticipated to adequately mitigate any residual risk of beached oil droplets at these remote locations. Submerged shipwrecks on the outer edge of the EMBA are not anticipated to be exposed to surface oil plumes and predicted low concentrations of dispersed/entrained oil to these will not be expected to incur any adverse effects.

The residual risk to cultural/heritage areas arising from an accidental release of MGO as a result of a vessel collision/refuelling incident during the Seismic Survey has been assessed as **Low** (*minor x remote*).

8.3.3.4 Potential Risk to Coastal Marine Environment

Calculations for beaching of a MGO spill (**Section 8.3.2**), indicates that most of the spilt substance will have weathered or dispersed before the spill reaches coastal areas. On average, around 1.7% of the spilled volume can be expected to beach during an event at location B and less than 1% at locations A and C. The worst-case outcome from the simulations resulted in 13% of the spilled volume beaching on the North Kimberley Coast.

Due to the low density and viscosity of MGO (i.e., the spilt hydrocarbon would float and rapidly disperse, evaporate and reduce in toxicity), combined with high wave energy within the OA coastal habitats and communities are unlikely to be impacted by an MGO spill. Hydrocarbons that contact soft-sediment habitats such as estuaries and sandy beaches may become entrained within the fine grains of the substrate. Results of the modelling demonstrate (on an annual average across scenarios) rapid dispersion and evaporation of MGO, which also significantly reduces the volume reaching any shoreline locations. For any shoreline environments, it is expected that given the significantly reduced amount coming into contact, coupled with natural attenuation and weathering, toxicity and persistence of its parent form will be reduced. The highest concentrations, and therefore likely impacts, of hydrocarbons that may be deposited in the coastal environment will be along the high-water mark or strandline. Wave-exposed sandy shores are often considered to have a low vulnerability and sensitivity due to the natural cleaning of the waves (Law *et al*., 2011).

On the other hand, low energy intertidal habitats may potentially be more affected by an MGO spill. Due to the low-energy nature of these environments (and increased accumulation/depositional zones), any beached MGO will not be re-suspended by wave action. Accumulation of MGO will, however, breakdown on the shoreline by natural weathering and biodegradation processes, which is considered the most appropriate response method due to these habitats being easily damaged by clean-up techniques (Hook *et al*., 2016).

The OA overlaps with one KEF, the Carbonate bank and terrace system of the Sahul Shelf. There are six other KEFs within the EMBA or close to it:

- Ashmore Reef and Cartier Island and surrounding Commonwealth Waters;
- Continental Slope Demersal Fish Communities;
- Ancient Coastline at 125m Depth Contour;
- Pinnacles of the Bonaparte Basins;
- Carbonate bank and terrace system of the Van Diemen Rise; and
- Shelf break and slope of the Arafura Shelf.

A summary of the relevant KEFs in each area is described in **Section 4.4.3**.

The carbonate bank and terrace system of the Sahul Shelf KEF is the only KEF predicted to be exposed to concentrations of surface and entrained hydrocarbons at moderate exposure values. The other KEFs have a low probability of contact with entrained hydrocarbons above the low exposure value only. The values and sensitivities of the KEFs are generally related to benthic habitats and communities which support areas of enhanced diversity and productivity. A release of MGO to the marine environment would result in a localised reduction in water quality in the upper surface waters of the water column and therefore impacts to the habitats of the KEFs is not considered likely.

Marine Protected Areas are described in **Section 4.4.1**. The OA does not overlap with any MP boundaries; however, the EMBA overlaps with five Marine Parks:

- Oceanic Shoals Marine Park;
- Ashmore Reef Marine Park;
- Cartier Island Marine Park;
- Kimberley Marine Park; and
- Joseph Bonaparte Gulf Marine Park.

The Oceanic Shoals is the only marine park predicted to be exposed to concentrations of entrained hydrocarbons at moderate exposure values. The other MPs have a low probability (0-4%) of contact with entrained and dissolved hydrocarbons above the low exposure value only.

The EMBA partially overlaps with the Multiple Use Zone (IUCN VI) of the Oceanic Shoals Marine Park. The designated natural values of the OSMP include a range of species (including species listed as threatened, migratory, marine or cetacean under the EPBC Act), and foraging and internesting habitat for marine turtles. Potential impacts to these values and commercial fishing from a worst-case marine diesel spill within the OA are assessed in the sub-sections above.

Based on the above and including numerous control measure (**Section 8.3.5**) to be implemented, the residual risk to the coastal marine environment from an accidental release of MGO as a result of a vessel collision/refuelling incident during the Seismic Survey has been assessed as **Low** (*minor x remote*).

8.3.4 Known and Potential Risk to Stakeholders and Other Marine Users

Commercial fisheries and coastal shipping operations are considered the most at risk of vessel collisions due to their presence in, or transiting through, the OA. Due to the low potential volumes of an MGO spill that could result from a collision/sinking event, socio-economic impacts on existing interests are likely to be low.

There may be some temporary disruption to fishing activities if a spill occurred and entrained or surface hydrocarbon plume moved through a fishing ground, where it could have potential to coat the buoys and ropes of fish or rock lobster pots. In the worst-case would be if nursery habitats in intertidal margins for commercial fish species were impacted by a spill; however, through the literature no specific locations were identified as standing out as being important such as this. Given the distance offshore of the OA, it is expected if a spill occurred, by the time any MGO made it to shore, it would not be at the volumes or concentrations that would decimate an intertidal community.

The most obvious effect from a vessel collision/sinking to existing interests in/around the OA is the potential for casualties and injury. Released debris may float, either at the surface or partially submerged, creating a navigation hazard to other users of the marine environment, while MGO released from the vessel(s) will likely disperse and weather with time, unless making landfall where risks to the public could occur.

8.3.4.1 Potential Risks to Commercial Fishing

Following a collision/sinking large debris that settles on the seabed, such as a vessel itself, pose a risk to commercial trawl fisheries. Trawling would not be safe around such debris as trawl gear may become entangled.

Potential effects of a hydrocarbon spill (such as MGO) on fisheries include effects on fish populations, contamination of equipment (e.g., nets, and boats), displacement from fishing grounds, contamination of catch, loss of revenue from disruption, and negative public perception of fish quality and safety. Given the low volume of MGO that might potentially escape in the event of a collision/sinking, the likely impacts to commercial fisheries would be relatively short-lived, and reasonably localised around the vessel collision/sinking location.

Any fishing equipment such as nets and lines that contacts a spill may become fouled by hydrocarbons, for example fishing nets towed through spill areas or lifted through surface slicks. However, it is highly unlikely that fishermen will knowingly enter into a spill area, making fouling of equipment unlikely. A more likely effect comes from displacement of fishing vessels from regular fishing grounds, possibly reducing the potential of a vessel to catch their quota or increasing the time and fuel consumption costs by having to travel to other unaffected fishing areas.

Economic impacts from loss of revenue and profit due to inability to fish in certain areas following a hydrocarbon spill will initially impact the fishing companies. However, trickle-down effects also occur, with the potential for employees to suffer from loss of wages and job cuts (McCrea-Strub *et al*., 2011), as well as sub-contractors and supply companies becoming effected.

The consequence of a hydrocarbon spill associated with a vessel collision, if it occurred, impacting commercial fisheries is Moderate to Severe, depending on the spill location and proximity to coastal areas; however, the likelihood of a collision occurring is Remote due to the extensive control measure that will be in place. In addition, all other maritime users out at sea also have many control measures in place to prevent collisions as well and keep their crew and vessel safe and reduce the risk of an incident. MSSs take place all around the world and have done so for many years, and from investigations undertaken as part of the development of this EP, there have been no incidents found that have occurred during an MSS that have resulted in a release of MGO to the marine environment. Consequently, a vessel collision/sinking and subsequent hydrocarbon spill provides a worst-case residual risk ranking of **Low** (Severe x Remote).

8.3.4.2 Potential Risks to Commercial Shipping

Heavy vessel traffic directly South of the OA is expected, due to vessels heading in and out of Darwin (refer to **Section 4.7.4**). Traffic within the OA itself is relatively low (in comparison to other locations along WA).

In the event of a vessel collision and significant marine diesel spill, the AMSA Joint Rescue Coordination Centre may issue a warning to shipping traffic in the area to avoid the incident location. Exclusion zones surrounding a spill will reduce access for shipping vessels for the duration of the response undertaken for spill clean-up (if applicable); vessel may have to take detours leading to potential delays and increased costs.

Debris left floating in the ocean following a vessel collision/sinking provides a hazard to marine shipping traffic and may force vessels to reduce speed in the known area of a debris field, or alter courses to avoid the area, reducing efficiency. This would be advised via safety communications and Notices to Mariners to alter regular routes to avoid movement through contaminated areas and areas involving clean-up activities. This impact would apply to both offshore and coastal routes.

Due to advance communications and vessel's ability to alter course to avoid floating debris and/or hydrocarbon spills, the environmental risk and subsequent effect of a vessel collision/sinking on commercial shipping would be **Low** (*minor x rare*).

8.3.4.3 Potential Risks to Tourism and Recreation

Tourism and recreational activities in the region occur predominantly in State/Territory waters adjacent to population centres, such as Broome and Darwin. Charter vessels may occasionally transit through the EMBA between Darwin and the northern Kimberley coastline, however interactions with the Seismic Survey are considered unlikely due to the remoteness of the OA. No whale watching activity is known or expected to occur within the OA or the EMBA and recreational diving is not anticipated to occur within the OA (see **Section 4.7.2**).

Debris released from a collision/sinking may pose a temporary and localised navigational risk to recreational and tourism vessels plying the coastal waters and drifting or washed-up debris could have negative effects on the aesthetic qualities of the area for tourists. Effects of a hydrocarbon spill on tourism and recreational activities include lost abilities to carry out activities due to loss of habitats, displacement of tourism/recreational vessels from areas (e.g. within oil slicks and during clean-up activities), displacement of marine organisms (which may have attracted tourists) by presence of slicks, and loss of revenue from changes in public perception including reduced aesthetic qualities of coastal environments where hydrocarbons land or persist. As a result of these potential impacts to tourism and recreational activities if a spill occurred, the impacts are considered to be **Low** (*minor x rare*).

8.3.5 Control Measures

The potential control measures implemented during the Seismic Survey to manage any potential impacts from vessel collision/sinking and associated hydrocarbon spill to **ALARP** have been included in **Table 88**. These control measures have been assessed to consider the environmental benefits gained through implementing the controls relative to their time, effort and monetary cost, with a clear delineation of those which will be implemented during the Seismic Survey and those which won't. Justifications have been provided for each of the decisions.

Table 88 Assessment of Control Measures for Vessel Collision/ Sinking or Refuelling and Associated Hydrocarbon Spills

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
No refuelling will occur at sea	P = No E = No	Refuelling operations are one of the most likely causes of a hydrocarbon spill occurring during marine operations. However, given the offshore location of the OA this activity cannot be removed from the operation of the Seismic Survey. It is not considered a Practical option and given the probable increase in vessel activity associated with bunkering, it is not considered Effective at significantly reducing risk. The removal of this activity would reduce the potential risk of a hydrocarbon spill occurring in the first place, and the potential impacts of a spill on the environment. Removing the refuelling operations at sea from the Seismic Survey will potentially increase the risks to the health and safety of employees, and the environment with additional trips to port. These trips would be expected to incur additional risks in themselves (i.e., vessel collision/sinking) that are not considered insignificant.	No	No
Vessel will only utilise MGO	P = Yes E = Not Effective	Utilising a certain type of fuel is not effective in reducing the risks of a vessel collision and hydrocarbon spill, but it is important for considering the types of responses required for clean-up. Utilising MGO would have less impacts on the marine environment should a spill occur compared to other heavier oils and the same level of response would not be required for the clean-up.	No	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Compliance with COLREGS	P = Yes E = Effective	At all times during the survey the crew of the survey vessels will comply with COLREGS, including maintaining a visual watch and undertaking a full radar scanning watch for the presence of any other vessels in close proximity or any vessel on a course heading towards them or the other vessel involved in the survey. Early detection of approaching vessels will allow the survey vessels to attempt to communicate with approaching vessels to avoid chances of collision. The slow speed of the vessels during the operational phase of the survey (4 – 5 knots) will then also allow the vessels plenty of time to attempt communication following early detection and if required make appropriate evasive manoeuvres. In addition to the above, having navigational lighting and day-shapes compliant with COLREGS for safe passage at sea and specific to each vessel and its activities will provide further means in reducing the chance of vessel collisions.	Yes	Yes
Compliance with Marine Order 21 (Safety and Emergency Arrangements) 2016	P = Yes E = Effective	Marine Order 21 provides information about safety measures such as manning, bridge visibility etc. and emergency procedures. Complying with these requirements will reduce the potential risk of a collision at sea, and also mean compliance is maintained with the respective aspects of the International Convention of the Safety of Life at Sea (SOLAS).	Yes	Yes
Compliance with Marine Order 30 (Prevention of Collisions) 2016	P = Yes E = Effective	Complying with the requirements of Marine Order 30 will ensure all measures (such as lighting, signals etc.) to prevent collisions are maintained to reduce the risk to **ALARP**.	Yes	Yes
Radio communications watch kept at all times.	P = Yes E = Effective	Survey vessels will keep open radio communications between each other as well as scanning local working channels and the emergency channel (VHF 16) for contact with other vessels that may be operating in the vicinity, and therefore reduce the potential for collision.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Vessel fuel to be stored in compartmentalised and/or multiple separate onboard fuel tanks.	P = Yes E = Effective	Fuel systems onboard the survey vessels (carrying MGO) will consist of multiple smaller tanks throughout the vessel or larger tanks built of multiple separate compartments. This will reduce the potential volumes of MGO that could be released to the environment in the event of a tank being ruptured during a collision/sinking event.	Yes	Yes
Emergency Response Plan for Hydrocarbon Spills that complies with Marine Order 91.	P = Yes E = Effective	If a MGO spill does occur following a vessel collision/sinking SLB will implement the response strategy in accordance with the Shipboard Oil Pollution Emergency Plan (**SOPEP**), and also in line with relevant legislation and industry standards. SLB will also undertake all required notification and reporting during planning stages of mobilisation phase of survey. In the event of a vessel collision/sinking and there is a resultant MGO release, notification will be provided to AMSA and regulatory agencies in accordance with the Implementation Strategy – Reporting **Section 10.6**.	Yes	Yes
Testing of SOPEP	P = Yes E = Effective	Prior to the commencement of survey operations, the SOPEP will be tested including testing of communications and a vessel-based drill in hydrocarbon spill response.	Yes	Yes
Utilising accurate weather forecasting information for planning operations	P = Yes E = Effective	SLB will subscribe to a weather monitoring service that will provide updated forecasts (including wind, waves/seas and currents) four times daily allowing vessel masters to best plan the vessels movements and operations to occur when and where in the OA the weather is safest/most-suitable.	Yes	Yes
Contract in place with appropriate service provider to initiate real-time modelling in case of a spill	P = Yes E = Effective	Undertaking real-time modelling will provide assurances that response options can be tailored to the specific spill situation. The modelling will be based continuous weather monitoring which will be utilised in conjunction with hindcast data to predict the potential beaching locations (if any exist).	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
In case of a spill, SLB will implement relevant Type I Operational Monitoring	P = Yes E = Effective	Type I Operational Monitoring (such as using the Support Vessel to monitor the spill) will be undertaken in the unlikely event of a hydrocarbon spill to provide up-to-date information on the fate of hydrocarbon in the water. This monitoring will allow appropriate response options to be established with the Control Agency.	Yes	Yes
Type II Scientific Monitoring undertaken in case of spill if real-time modelling shows the spill will impact land, in consultation with the Control Agency	P = Yes E = Effective	Depending on the fate of any hydrocarbon spill, based on the real-time modelling and operational monitoring described above, Scientific Monitoring may be required (if directed by the Control Agency) to monitor the impacts from a spill occurrence.	Yes	Yes
Hydrocarbon spill response training and competencies will be maintained throughout the Seismic Survey to avoid unplanned environmental impacts due to human error	P = Yes E = Effective	Ensuring all staff members have appropriate training is vital in responding to a hydrocarbon spill. Drills will also be undertaken to ensure all staff are competent in responding to spills under the vessel specific SOPEP; these drills will be conducted at regular intervals to ensure the competencies are maintained throughout the operation.	Yes	Yes
Automated Identification System transponders fitted to survey vessels and tail buoy.	P = Yes E = Effective	AIS transponders will transmit key information to all vessels able to receive AIS data and will include details such as vessel GPS position, identity, type, speed, course and caution notes). The AIS system will also receive AIS information from other vessels in the area.	Yes	Yes
All crew will participate in the vessel and environmental induction prior to the commencement of operations	P = Yes E = Effective	It is a standard industry practice to hold inductions for all onboard the vessels, with participation in induction meetings compulsory. During inductions, crew will be made aware of their responsibilities with regard to effects of discharges to the marine environment and their roles with regard to clean-up of any accidental discharges.	Yes	Yes
Notice to Mariners issued prior to commencement of survey	P = Yes E = Effective	A Notice to Mariners will be submitted to the AHO prior to the beginning of the survey to inform affected parties of the location of the survey and activities that will occur, so that other vessels using the area are informed and know the best course of action to avoid interacting with the Seismic Vessel and associated equipment.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Spill response equipment will be available and maintained onboard each vessel and located in close proximity to hydrocarbon areas. And crew onboard will be trained in how to respond to any incident utilising the response equipment available.	P = Yes E = Effective	The availability of spill response equipment in close proximity to any hydrocarbon areas allows a quick response to any hydrocarbon spills into the marine environment. Vessel master will authorise actions in accordance with the vessel-specific SOPEP and the survey specific OPEP to limit the escape of hydrocarbons.	Yes	Yes
Undertake hydrocarbon spill modelling prior to EP submission	P = Yes E = Effective	A hydrocarbon spill modelling prior to the submission of this EP has been undertaken and was considered being useful to map the potential risks of vessel collision and hydrocarbon spills. As the OA covers a very wide area it is difficult to determine the ideal location to base the modelling on, thereby the spill modelling was undertaken at three different locations, see method and results in **Section 8.3.2.** As outlined in the control measures to be implemented above, SLB will also implement real-time modelling in the event of a spill which will provide more detailed and realistic areas of potential beaching along the coastline to assist in responding to a spill occurrence.	Yes	Yes
Alternative Control Measures:				
Eliminate vessels	P = No E = Very Effective	There are no practicable methods for undertaking the Seismic Survey without the use of vessels.	Yes	No

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Eliminate presence of other hydrocarbon fluids onboard vessels (e.g. lubricants, hydraulic fluids)	P = No E = Effective	Lubricating and hydraulic fluids are required for the normal operation and maintenance of the vessels and equipment and as such cannot be completely eliminated. Storage in suitably bunded areas as detailed above will reduce risk associated with these fluids. Lubricating oils and hydraulic fluids are typically stored in 50 – 200 L steel drums either in a designated storage room, or a bunded area on deck. Therefore, any potential spills of these substances on deck are likely to be <200 L in a contained area. Hydrocarbons which occur in greater (>200 L) quantities on the vessels, for example waste engine oil, hydraulic fluid and main engine lubricating oils, are generally stored in designated storage tanks below deck and therefore are unlikely to be a direct hazard for deck spills (unless smaller quantities have been transported to the deck to be used for deck activities). It is possible that spills or leaks from hydraulic hoses on hydraulically operated equipment such as cranes and winches may occur, but if so, the fluid is likely to be contained within a bund or drip tray, and the volume of fluid loss will be low (<1 L). It is therefore highly unlikely that a non-contained spill of hydrocarbon fluids will occur onboard vessels; however, should such fluids enter the marine environment, their impact is likely to be low-minimal as the small volumes will quickly evaporate, disperse and weather.	Yes	No
Substitute MGO for an alternative fuel or wind-powered vessels	P = No E = Not Effective	MGO is already a vast improvement over HFO, and lighter alternative fuels or wind power are not feasible to use in the vessels that will be utilised for the survey as they have not been commercially proven for use in large vessels. It is expected that the high energy marine environment in which the OA is located will aid in the rapid dispersion (in the direction of the prevailing wind and current) and evaporation of MGO should it enter the marine environment. Warmer water temperatures during summer months will further accelerate this process.	No	No

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Undertake refuelling at port	P = No E = No	All refuelling will be undertaken offshore, within the OA. It is expected this will be kept to a minimum and will occur every five weeks. Refuelling at port is not practical given the offshore location of the OA. Refuelling at port would incur increased risk of vessel collision and increase the duration of the Seismic Survey. All bunkering vessels will be required to adhere to the SOPEP and associated control measures. All bunkering operations will be undertaken during suitable weather conditions. No bunkering will take place during marginal/adverse weather conditions. All contractor approvals and permits will be in place prior to the Seismic survey commencing. All contractor processes will be assessed for compliance, including record keeping, maintenance, permits, and schedules.	Yes	Yes
Use a Seismic Vessel with smaller fuel and oil tank sizes	P = No E = Effective	This would mean more frequent trips to port for refuelling which would increase costs and the duration of the survey, as well as result in greater risks. Furthermore, implementing this control measure would likely lead to a delay in the timing of data acquisition due to the time needed to contract an appropriate Seismic Vessel. Data delivery to clients would consequently be delayed and requirements not met.	Yes	No
The Seismic Survey will be restricted to daylight hours	P = No E = Effective	The cost of the survey would increase substantially as the survey duration would double. Health and safety risks and potential impacts to marine life (e.g. cetaceans) would also increase due to the longer survey duration.	Yes	No
Reduce size of the OA to decrease chance of spills reaching emergent lands	P = No E = Effective	The size of the OA has already been reduced substantially (~ 25,800 km^2). Further reductions would result in SLB being unable to fulfil primary objectives of the survey and data requirements. The likelihood of vessel collision or sinking and an associated hydrocarbon spill is extremely unlikely and is no greater than that for other vessels that may enter the OA and surrounding waters.	Yes	No

8.3.6 Environmental Performance Outcomes

The EPOs for the management of environmental risks from a vessel collision/sinking/refuelling (and associated hydrocarbon spill) are:

- No collision with other marine users;
- No loss of operational integrity/malfunction associated with bunkering; and
- No release of hydrocarbons into the marine environment.

It is considered that the above EPOs, as a result of the implementation of the control measures (**Table 88**), will allow the ongoing environmental performance of the Seismic Survey in accordance with the **Acceptable Levels** described within **Section 8.3.9**, while ensuring that the relevant legislation is complied with to avoid any health and safety risks or impacts on the marine environment as far as practicable.

The EPSs within **Table 89** have been defined to manage the impacts from vessel collisions/refuelling and associated hydrocarbon spill to **ALARP** and an **Acceptable Level**. Compliance with these standards will ensure that the identified EPOs will be achieved for the duration of the Seismic Survey.

Table 89 Environmental Performance Outcomes and Standards for Vessel Collision/Sinking and associated Hydrocarbon Spill

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
EPO: No collision with other marine users			
Adherence to COLREGs	**EPS 183**: Essential navigation lighting and day-shapes will be utilised to maintain compliance with COLREGs.	Pre-mobilisation audit and inspection prior to beginning of survey will confirm correctly functioning lighting and communication equipment.	Vessel Master.
Compliance with Marine Order 21	**EPS 184**: The manning of the vessels will be kept above minimum standards and visibility from the bridge is maintained as per Chapter V Regulation 22 of SOLAS.	Bridge log shows appropriate manning of vessels by suitably qualified and certified crew.	Vessel Master.
Pre-survey stakeholder engagement	**EPS 185**: Stakeholder engagement will be conducted with all identified stakeholders prior to the commencement of the Seismic Survey.	EP submitted to NOPSEMA confirms stakeholder engagement. Stakeholder Engagement Register.	SLB Project Manager.
Ongoing communication with marine users	**EPS 186**: A 48-hour 'look-ahead' plan will be provided to marine users detailing the survey activities over the next 48 hours. The 48-hour look-ahead plans will be updated and issued every 24 hours and distributed to relevant stakeholders via email.	Documentation of consultation and issuing of 48-hour look-ahead plans demonstrate compliance. Forms part of ongoing consultation strategy.	SLB Project Manager.
	EPS 187: A Notice to Mariners will be published and distributed by the AHO under the Navigation Act 2012.	Inspection of Notices to Mariners publications to formally confirm notice has been issued. Copies kept on file.	SLB Project Manager.
	EPS 188: Stakeholder engagement will continue throughout the duration of the survey with identified stakeholders.	Documentation of consultation Forms part of ongoing consultation strategy.	SLB Project Manager.
	EPS 189: The Seismic Vessel will monitor local working channels as well as emergency channel 16 and agreed working channel between the vessels.	Daily vessel report from each watch includes communication checks and records of any communication/ interaction with other vessels.	Vessel Master.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
Compliance with Marine Order 30	**EPS 190**: The Seismic Vessel will display the relevant day shapes, lights and reflective tail buoys to indicate the vessel is engaged in towing, in this activity it is a seismic streamer. The day shapes and lights will identify to the other vessels that the Seismic Vessel is limited in its ability to manoeuvre.	Pre-mobilisation audit and inspection prior to beginning of survey will confirm that the relevant equipment is onboard, tested and operational.	Vessel Master.
AIS tracking and receiving vessel location	**EPS 191**: Vessels and associated survey equipment (e.g. tail buoys) will have correctly fitted and functioning AIS transponders.	Pre-mobilisation audit and inspection prior to beginning of survey confirms correct operation of all AIS transponders for both transmitting and receiving.	Vessel Master.
EPO: No release of hydrocarbons into the marine environment.			
Refuelling at sea	**EPS 192**: All refuelling operations for the vessels will be undertaken at sea	Bunker documentation.	Vessel Master.
Vessels will only utilise MGO	**EPS 193**: MGO is the primary fuel for vessels associated with the Seismic Survey. No HFO powered vessels will be used.	Bunker documentation.	Vessel Master.
Vessels fuel storage	**EPS 194**: Fuel tanks onboard the vessels will be compartmentalised or consist of multiple smaller tanks throughout the vessel.	Pre-mobilisation audit and inspection prior to beginning of survey will confirm.	Vessel Master.
Compliance with MARPOL Annex I and Marine Order 91	**EPS 195**: An IOPP will be held where required under vessel class.	Pre-mobilisation audit and inspection prior to beginning of survey will confirm.	Vessel Master.
Emergency Response Plan for hydrocarbon spill	**EPS 196**: SOPEP formulated, known to all staff and kept up to date onboard the vessels so that in the event of a collision where hydrocarbons are released there is a plan in place to contain or clean-up.	Pre-mobilisation audit and inspection prior will confirm vessels holds an up-to-date SOPEP. Induction records show content of induction meeting and participation of crew.	SLB Project Manager. Vessel Master.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	EPS 197: The Vessel Master will authorise actions in accordance with the vessel specific SOPEP and the survey specific OPEP to limit the escape of hydrocarbons.	Incident Report.	SLB Project Manager. Vessel Master.
	EPS 198: Notification procedures will be implemented, including AMSA and regulatory agencies, including: • AMSA report notification; • NOPSEMA reports; • Regulatory agencies (including DNP); • SLB incident report; and • Pollution report (**POLREP**).	In event of vessel collision/sinking and release of MGO all appropriate forms will be completed and submitted to relevant authorities.	SLB Project Manager. Vessel Master.
Testing of SOPEP	**EPS 199**: Prior to the commencement of the Seismic Survey operations, the SOPEP will be tested including testing of communications and a vessel-based drill in hydrocarbon spill response.	Induction and daily records confirm testing of SOPEP has occurred and drills have been carried out.	Vessel Master.
Accurate, up-to-date weather forecasting	**EPS 200**: Survey vessels, as well as onshore project team, to receive wind, wave and current information for the OA four times daily from subscription service.	Copies of the forecasts will be included with the daily reports/logs and kept on file.	SLB Project Manager. Vessel Masters.
Real-time modelling contract in place for hydrocarbon dispersion and trajectory	**EPS 201**: Prior to the commencement of the Seismic Survey, SLB will secure services (signed contract) with a third party for provision of real-time modelling of a hydrocarbon spill if and when required	Service contract in place prior to commencement of the survey.	SLB Project Manager.
Type I Operational Monitoring	**EPS 202**: If health & safety requirements permit, the Support Vessel assisting the Seismic Survey will be used in the monitoring of any hydrocarbon spill.	Incident report.	Vessel Master.
Type II Scientific Monitoring	**EPS 203**: Prior to the commencement of the Seismic Survey, SLB will secure services (signed contract) with a third party for standby services in order to undertake Type II scientific monitoring as specific within the OPEP, should a hydrocarbon spill reach the shoreline,	Service contract in place prior to commencement of the survey.	SLB Project Manager.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
Hydrocarbon spill response training and competencies	**EPS 204**: Prior to the commencement of the Seismic Survey an audit will be conducted to ensure all staff are trained and inducted satisfactorily to ensure they are competent in responding to a hydrocarbon spill.	Pre-mobilisation audit results. Induction and daily records confirm training and induction has been carried out and crew present.	SLB Project Manager. Vessel Master.
Spill response equipment	**EPS 205**: Spill response equipment will be available and maintained/re-stocked onboard each vessel and located in close proximity to hydrocarbon areas. Crew will be trained in using response equipment.	Inspection records confirm equipment is fit-for-purpose and records any re-stocking of supplies as required.	Vessel Master.
Insurance Policies in place	**EPS 206**: SLB will have insurance policies in place to cover the costs of any scientific monitoring or clean-up costs if any remediation is required in the event of a large hydrocarbon spill.	Insurance policies to include the State waters and Australian Commonwealth waters.	SLB Project Manager.

8.3.7 Residual Risk

Following the implementation of the control measures detailed in **Table 88** the likelihood of an impact from vessel collision/sinking/refuelling and associated hydrocarbon spill is *Remote*.

The worst-case consequence from a refuelling incident relates to a relatively small hydrocarbon spill and is considered Possible based on discussions within Section 8.3.3. Therefore, using the risk matrix outlined in Section 6.5 the residual risk from an impact occurring from refuelling and associated hydrocarbon spill, following the implementation of control measures (**Table 88**), the residual risk ranking is Low (**Table 90**)

Table 90 Residual Risk Summary for Refuelling

Likelihood	Consequence	Residual Risk
Possible	Low	Low

The worst-case consequence from a collision/sinking relates to a significant hydrocarbon spill and is considered *Severe* based on discussions within **Section 8.3.3**. Therefore, using the risk matrix outlined in **Section 6.5** the residual risk from an impact occurring from vessel collision/sinking and associated hydrocarbon spill, following the implementation of control measures (**Table 88**), the residual risk ranking is **Low** (**Table 91**).

Table 91 Residual Risk Summary for Vessel Collision/Sinking

Likelihood	Consequence	Residual Risk
Remote	Severe	Low

8.3.8 Demonstration of ALARP

To demonstrate that any potential impacts from vessel collision/sinking/refuelling and associated hydrocarbon spill are managed to **ALARP**, SLB has considered a number of control measures to determine the benefits of their implementation towards risk reduction (**Table 88**), based on a Hierarchy of Controls methodology described within **Section 6.6** above, and as summarised in **Table 92**. The adopted control measures that will be implemented throughout the Seismic Survey are appropriate to reduce the environmental impacts from a vessel collision/sinking and assessments have been undertaken to ensure that all reasonable and practicable control measures or solutions have not been overlooked. As a result, it is considered that any impacts that may arise from a vessel collision have been reduced to **ALARP**, where the residual risk from adoption of these control measures is reduced to **Low** (**Table 91**).

Additional control measures were considered as part of the assessment process towards further risk reduction; however, it was considered that they did not provide any further environmental benefit or were not reasonably practicable to implement. In addition, the costs (based on the experience of SLB) of implementing such measures would be disproportionate to the benefits that would be gained through their implementation.

Table 92 Hierarchy of Controls for Vessel Collision/Sinking/Refuelling and Associated Hydrocarbon Spill

Eliminate	The use of vessels cannot be eliminated as a Seismic Vessel and Support Vessel have to be used to undertake the required data collection. The OA is also an open ocean area where other vessels (fishing, shipping, cargo, recreational) are not restricted from entering and may pass through any part of the area (within reason) at any time thus other vessels cannot be eliminated either. A Support Vessel is also needed for a number of reasons and cannot be removed from the operations. Refuelling at sea cannot been eliminated from the Seismic Survey, thus this source of risk cannot be eliminated. Refuelling at port would incur more frequent vessel movement and increase the risk of vessel collision. The consequence of vessel collision and associated hydrocarbon spill are higher than those associated with potential hydrocarbon loss associated with refuelling at sea.
Substitute	There are no suitable substitutes for use of a Seismic Vessel to undertake the survey in the required location.
Reduce	SLB aims to reduce the amount of time the vessels are in the OA by working 24/7 whenever possible. Reducing the number of vessels by removing the presence of a Support Vessel could reduce the risk of a collision/sinking. But at the same time this reduction could increase the risk of a collision between other vessels and the Seismic Vessel and/or its towed equipment. Thus, a reduction in the number of vessels isn't a practicably feasible option. Refuelling is expected to occur every five weeks, undertaken within the OA, and to be kept to a minimum to reduce vessel traffic.
Mitigate	Control measures have been assessed within **Table 88** in order to mitigate the impacts from a possible vessel collision/sinking to **ALARP** levels. Those which are appropriate and are not impracticable or unfeasible due to disproportionately large costs will be implemented during the Seismic Survey.

The proposed control measures minimise the risk of a vessel collision/sinking/refuelling incident and associated hydrocarbon spill and are considered appropriate to the possible scale of potential environmental impacts that may occur in this rare instance. The proposed control measures are in accordance with industry best practice. No further practicable controls have been identified to reduce the impact and risks to the marine environment and/or marine organisms from a vessel collision/sinking/refuelling incidents.

A vessel collision is considered highly unlikely given the control measures outlined within **Table 88**. In addition, refuelling is by comparison a Low risk, due to the negligible to low consequence of a minor hydrocarbon spill, which would be controlled by on board mitigations and controls. Combined with the fact that the Seismic Survey will be a temporary activity and hence the risk will be limited to that specific time period, it is considered that the potential risks of a vessel collision/sinking/refuelling and its associated impacts (such as a hydrocarbon spill) have been reduced to **ALARP**.

8.3.9 Risk Acceptability

Total elimination of all risks associated with potential vessel collision/sinking/refuelling cannot be achieved as there are no practicable alternatives to using vessels to undertake the survey safely and effectively, in particular vessels powered by hydrocarbon fuel supplies. Following the implementation of the control measures detailed in this assessment (**Table 88**), the impacts/risks to the marine environment and associated receptors from vessel collision/sinking could have *Severe* consequences. For refuelling, given the reduced volume of any spill, the impacts to the marine receiving environment are *Negligible* to *Minor*. In the remote likelihood of a collision/sinking which results in a hydrocarbon and/or debris release, impacts to the marine environment are not expected to be long-term, given the properties of MGO in the ocean, with full recovery in time.

The criteria for risk acceptability are defined in **Table 34** and detailed in **Table 93**, where the control measures that will be implemented throughout the Seismic Survey have been developed in accordance with these criteria. Where uncertainty exists around the criteria or the risk, SLB have taken a precautionary approach.

Table 93 Demonstration of Risk Acceptability for Vessel Collision or Sinking and Associated Hydrocarbon Spill

Criteria for Acceptance	Acceptability Summary
SLB's internal context	The proposed management of the risks of vessel collision/sinking and the associated impacts are within **Acceptable Levels** of SLB's Environmental and QHSE Policy.
Industry Best Practice	The proposed control measures to decrease vessel collision/sinking/refuelling incidents follow industry best practice and best practice guidelines, including: • The IAGC Environmental Manual for Worldwide Geophysical Operations which contains recommendations for SOPEPs, the mitigation of spills and leaks, and incident reporting; and • APPEA Code of Environmental Practice: offshore geophysical surveys are recommended to have environmental objectives to reduce impacts from spills and disturbance to seabed (e.g. in event of sinking), including having evidence of appropriate management procedures and emergency response plans being in place.
External Context – Commonwealth and State Legislative Criteria	The proposed control measures for vessel collision/sinking/refuelling incidents during the Seismic Survey are consistent with the following relevant legislation: • The Navigation Act 2012 - requires approved navigation systems for maritime safety, navigation efficiency and management of marine pollution; • The PSPPS Act; • The Environment Regulations; and • Control measures relating to hydrocarbon spills to the ocean are consistent with MARPOL (Annex 1 Regulations for Prevention of Pollution by Oil) and Marine Order 21, 30 and 91, including having an approved and tested SOPEP for all vessels involved in the survey.
External Context – Management Plans, Species Recovery Plans and Conservation Advice	The OA does not overlap with any AMP boundaries; however, the EMBA overlaps with five relevant AMPs (Kimberley, Cartier Island and Ashmore Reef Marine Parks, as well as Oceanic Shoals and Joseph Bonaparte Gulf Marine Parks). Oil pollution response, environmental monitoring and remediation activities can be undertaken with IUCN Category VI zones (Oceanic Shoals, Kimberley and Joseph Bonaparte Marine Parks), when undertaken in accordance with a NOPSEMA approved EP that has met all required environmental management arrangements for the activity covered in the class approval. However, any oil pollution incident that may affect other IUCN category zones requires prompt consultation with the Director of National Parks. Any spill occurring within, or likely to impact, any Australian Marine Park should be notified to the Director of National Parks as soon as possible, by contacting the Marine Park Compliance Duty Officer (0419 293 465). Notifications must include time and location of the incident, response arrangements as per the OPEP and contact details for titleholder and response coordinators. The Implementation strategy for the Seismic Survey covers details of the notifications that would be undertaken in the event of reportable and recordable incidents as well as SLB's OPEP which details SLB's arrange for responding to a hydrocarbon spill event.

Criteria for Acceptance	Acceptability Summary
Social Acceptance – Stakeholder expectations	During consultation with interested stakeholders no concerns about the impacts from responding to a hydrocarbon spill were raised and as such no additional control/mitigation measures were expected or put in place. However, the Director of National Parks noted that they are to 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. To ensure this expectation is met, a corresponding control measure is proposed to be implemented, as outlined in **Table 89**. As such, the environmental impacts relating to responding to a hydrocarbon spill were considered to be at a socially **Acceptable Level**.
Ecologically Sustainable Development	The management of the impacts associated with vessel collision/sinking and associated impacts (e.g. hydrocarbon spill) can be carried out in compliance with principles of ecologically sustainable development as defined within the EPBC Act. The assessment has not identified any adverse impacts to the principles of ESD, with no threats of serious or irreversible damage, no impacts to biological diversity and ecological integrity, no degradation of inter-generational equity, or negative effects on the social and economic integrity in the short or long-term.
Existing Environmental Context	Following the implementation of the control measures detailed in this assessment, the impacts/risks to the marine environment and associated receptors from vessel collision/sinking could have *Severe* consequences. In the remote likelihood of a collision/sinking which results in a hydrocarbon and/or debris release, impacts to the marine environment are not expected to be long-term, given the properties of MGO in the ocean, with full recovery in time. Consideration has been given to the potential impacts on the environmental sensitivities within the OA. Of relevance to the OA, is the potential risk of impact to protected species such as marine mammals (including the pygmy blue whale), whale sharks, marine turtles and seabirds. Following the implementation of control measures the potential risk of any impacts occurring to protected species are considered to be Low. In the unlikely event that a spill occurs, toxicity will be highest in areas close to the spill source. However, MGO is expected to rapidly evaporate and disperse/partition the offshore environment, reducing the acute toxicity of the spill. Whilst some of the potential impacts to sensitive receptors identified were substantial, including localised mortality (e.g., zooplankton), toxic effects (e.g., whale shark) and/or, in the case of oil beaching, disruption or damage to important habitat (e.g., turtle and seabird nesting habitat), the effects are expected to be localised and short term. Therefore, the threat to protected ecological populations was considered to be Low. Due to the low risk of potential impacts to benthic habitats and communities which contribute to the value of protected areas such as the Oceanic Shoals Marine Park and Carbonate bank and terrace system of the Sahul Shelf KEF, impacts to these sensitivities are not expected. The release of hydrocarbons has the potential to impact the coastal environment and, by extension, sites of cultural heritage value through beaching. The worst-case outcome from the simulations resulted in 13% of the spilled volume beaching on the North Kimberley Coast, an area typified by high incidence of registered cultural heritage sites and two areas determined to have native title. Results of the modelling indicate that rapid dispersion and evaporation of MGO will significantly reduce the volume reaching shoreline locations where this material will be broken down through natural weathering and biodegradation. Based on this assessment and the implementation of proposed control measures, the risks to the coastal marine environment and sites of cultural heritage value are considered Low.

Criteria for Acceptance	Acceptability Summary
	Debris released from a collision/sinking may pose a temporary and localised navigational risk to commercial shipping and tourism operations, as well as causing temporary impacts to visual amenity which preclude typical tourism activities. Additionally, impacts to the profitability of fishing activities following a hydrocarbon spill are expected to impact fishers and their associated operations initially. Following the implementation of the proposed control measures these potential impacts to shipping, tourism, recreational and commercial fishing activities if a spill occurred, the impacts are considered to be Low. The proposed control measures provide appropriate protection to the marine environment and from the risk of vessel collision/sinking and associated effects (debris and hydrocarbon release), and further/alternative control measures would give very little or no further protection from vessel collision/sinking while greatly increasing time and cost of the survey and also increase the potential conflict and displacement with the fishing industry.
ALARP	Total elimination of all risks associated with potential vessel collision/sinking cannot be achieved as there are no practicable alternatives to using vessels to undertake the survey safely and effectively. Following the implementation of the control measures detailed in this assessment, the impacts/risks to the marine environment and associated receptors from vessel collision/sinking could have *Severe* consequences. In the remote likelihood of a collision/sinking which results in a hydrocarbon and/or debris release, impacts to the marine environment are not expected to be long-term, given the properties of MGO in the ocean, with full recovery in time. The risks of a vessel collision occurring are reduced in a number of ways, including the adherence to legislative requirements and industry best practice, along with operating conditions (such as vessel operating at slow speeds). In addition, SLB has removed the chance of an MGO spill occurring at sea from vessel refuelling as these operations will be undertaken in port. Therefore, the risks associated with a vessel collision and any associated hydrocarbon spill is considered to be **ALARP**. Should an unlikely vessel collision occur, which results in a hydrocarbon spill, SLB has put in place numerous measures to ensure monitoring of the situation is maintained to allow appropriate remediation. Therefore, the residual risk of a vessel collision occurring, with the associated controls in place, is considered to be at an **Acceptable Level**.

8.3.10 Vessel Collision/Sinking/Refuelling Incident and Associated Hydrocarbon Spill Risk Summary

Based on the discussions above, including the potential impacts on the environment and the associated controls measures to be implemented, the residual risk of vessel collision/sinking/refuelling incidents and associated hydrocarbon spill is considered to be **Low**.

The risks of a vessel collision occurring are reduced in a number of ways, including the adherence to legislative requirements and industry best practice, along with operating conditions (such as vessel operating at slow speeds). In addition, SLB has removed the chance of a hydrocarbon spill occurring at sea from vessel refuelling as these operations will be undertaken in port. Therefore, the risks associated with a vessel collision and any associated hydrocarbon spill is considered to be **ALARP**.

The risks associated with refuelling are largely managed by appropriate vessel control measures – including adherence to EPS, refuelling/mechanical/equipment failure controls. All vessels will have adequate spill kits and be required to adhere to/implement the SOPEP. Appropriate vessel records will be required (logs, inspection records, maintenance schedules etc).

Should an unlikely vessel collision occur, which results in a hydrocarbon spill, SLB has put in place numerous measures to ensure monitoring of the situation is maintained to allow appropriate remediation.

Therefore, the residual risk of a vessel collision occurring, with the associated controls in place, is considered to be at an **Acceptable Level**.

8.4 Hydrocarbon Spill Response

8.4.1 Description of Source of the Risk

In the unlikely event that a hydrocarbon spill occurs within the marine environment from a vessel associated with the Seismic Survey, a number of spill response options can be initiated for a clean-up response. The following is an assessment of the response options that could be adopted should a hydrocarbon spill occur.

The potential response actions will be based on a Net Environmental Benefit Analysis (**NEBA**) approach which considers the advantages and disadvantages of the different spill response options to determine if there would be a net environmental benefit resulting from the implementation of a particular response. NEBA takes into account the hydrocarbon type, the sensitivities within the wider area of the spill, and the potential impacts, both positive and negative, of the proposed response strategy. This analysis is used for the preliminary assessment to determine the level of spill response required. During a spill event, the NEBA will be revisited regularly as more information becomes available on weather conditions relevant to at spill location, the spill trajectory and locations of sensitive receptors in the surrounding areas.

Initial response to an oil spill incident will be undertaken by the relevant Vessel Master. For vessel oil spill incidents, the Vessel Master will act in accordance with the relevant Shipboard Oil Pollution Emergency Plan (**SOPEP**) where applicable. Oil spills from vessels are categorised in two levels:

- **Level 1 Vessel Spill** - Initial activations for a Level 1 spill are based on a spill incident that will not have an adverse effect on the public or the environment and can be controlled by the use of resources typically available aboard the vessel without the need to mobilise an Incident Management Team or other external assistance. Spills that require this level of response may arise from blown hydraulic hoses, dropped or leaking drums of fuel or lubricant or minor refuelling accidents; and

- **Level 2 Vessel Spill** - Level 2 spills are those that require external assistance and resources to mitigate impacts from the spill and will involve response activation through additional support teams. The worst-case vessel spill scenarios during the activities fall into this category which include a vessel refuelling incident and a fuel tank rupture incident.

The residual risk to environmental receptors from the response methods utilised to clean up a hydrocarbon spill have been assessed as **Low** (*Minor* x *Rare*).

Table 94 provides an overview of the response options available with an assessment on the advantages and disadvantages of each option, and their appropriateness for use if a spill occurred during the Seismic Survey.

Table 94 Assessment of Spill Response Options

Response Option	Advantages of use	Disadvantages of use	Appropriateness of use
Source control (securing cargo / trimming)	Reduction in volume of MGO entering the marine environment.	No disadvantages identified.	This response option is suitable to both Level 1 and Level 2 responses and will be adopted in accordance with the SOPEP onboard the vessels. In the event of a fuel tank rupture, or hydrocarbon storage spill occurring, cargo of the affected tank/storage containers is to be secured by any available means, including transfer to another storage area, another vessel or through pumping in water to create a water cushion. Trimming the vessel may also be used to avoid further damage to intact tanks. These actions will minimise the volume of MGO spilled.
Natural weathering (monitor and evaluate – vessel/aerial surveillance and trajectory modelling)	Provides valuable information for situational awareness to inform response options. Surveillance results can also be used to assist in escalating or de-escalating response strategies as required.	Does not directly reduce potential impacts from the spill. Potential increase in the vessel/aviation activity in the area resulting in increased disturbance to fauna, including increased risk of collisions.	Vessel surveillance will be done for level 1 and level 2 spills using available vessels on scene, such as the Support Vessel and Chase Vessel, for opportunistic surveillance operations. However, priority for human health and safety will take place should a significant vessel casualty occur. SLB will have a contract in place with an appropriate service provider to initiate real-time modelling in the case of a spill. These modelling outputs can be used to guide appropriate response options. Monitoring requirements and approach will be assessed by the relevant Control Agency.
Physical break-up (vessel prop-washing)	Enhances natural degradation processes through the water column.	Increased vessel activity – additional noise, light, and atmospheric emissions. Increased health and safety risks from the presence of additional vessels. Potential for reduced evaporation of MGO by entraining it into the water column.	This response option may be utilised during the Seismic Survey. Vessel prop washing promotes entrainment within the water column and reduces potential evaporation, potentially keeping the substance in the water for longer periods. However, this option would only be undertaken if requested by the Control Agency, which their decision-making process would be dependent on the spill location and a NEBA.

Response Option	Advantages of use	Disadvantages of use	Appropriateness of use
Application of dispersants	No advantages identified for MGO as it is not a persistent hydrocarbon. MGO has a high natural dispersion rate in the marine environment.	Additional release of chemicals into the marine environment that may have toxic effects on marine fauna.	This response option is not recommended for the Seismic Survey as it is not beneficial for reducing the net environmental impact of a MGO spill. It has a low probability of increasing the dispersal rate of the spill whilst introducing more chemicals into the marine environment.
Contain and recover (booms and skimming)	MGO potentially removed from the environment. Reduces chances for fauna to become oiled.	Use is restricted by surrounding weather conditions – i.e. in rough weather conditions, booms and skimmers will not work. Increased vessel activity – additional noise, light, and atmospheric emissions. Very labour intensive with an increased volume of waste generated.	This response option is not recommended for the Seismic Survey as the fast-spreading rates of MGO and the low viscosity will cause the slick to break-up and disperse quickly resulting in a reduced ability to contain and recover the MGO from the ocean.
Protect and deflect (booms etc.)	MGO potentially removed from the environment. Reduces chances for shoreline fauna to become oiled.	Increased activity – additional noise, light, and atmospheric emissions. Very labour intensive with an increased volume of waste generated. Potential additional damage to intertidal and benthic habitats from equipment.	This option is not recommended for the Seismic Survey as MGO is not expected to be persistent and corralling of MGO is generally not effective. Tidal flushing and bioremediation are expected to be sufficient in the worst-case scenarios to prevent any significant environmental impact.
Shoreline clean-up (physical removal, surf washing, flushing, natural dispersion)	MGO potentially removed from the environment. Reduces chances for shoreline fauna to become oiled.	Increased activity – additional noise, light, and atmospheric emissions. Very labour intensive with an increased volume of waste generated. Potential damage to sensitive shoreline species. Weather dependant.	This option is not recommended as it is an intrusive response that requires careful site-specific planning in order to reduce secondary impacts of beach erosion and spreading oil beyond shorelines. This response has the potential to cause more harm due to secondary disturbance compared to the initial potential light oiling. Therefore, if light shoreline contact occurs, SLB considers that any onshore response options would best occur under the National Plan.
Oiled Wildlife Response (capture and rehabilitation)	Aids recovery of oiled wildlife.	Increased activity – additional noise, light, and atmospheric emissions. Approaching marine fauna could flee and dive into spilled MGO as a result of activity.	Undertaking this response option has the potential to result in more harm if poorly executed.

Response Option	Advantages of use	Disadvantages of use	Appropriateness of use
		Pre-emptive capture may result in reduced survival.	Activities such as hazing (dispersing) of birds will not be undertaken given the low likelihood of a spill of a size presenting a significant risk of oiling wildlife unless at the direction of, and under direct supervision of trained personal from the Control Agency. Capture and rehabilitation may be undertaken under the National Plan.

The activities associated with a response to a hydrocarbon spill introduce further risks to marine fauna and flora, including:

- Increased disturbance of avifauna (both shore and sea birds) and marine mammals;
- Increased risk of vessel strikes with an increased number of vessels in the area conducting the response;
- Potential inclusion of additional chemical agents into the marine environment (i.e. dispersants);
- Potential physical damage to habitats from deployment of booms in the intertidal zone; and
- Potential damage to intertidal habitats from trampling (via foot or vehicles), removal of oiled sediment, chemical control agents and dispersants.

8.4.2 Control Measures

Control measures that have been considered for the Seismic Survey to manage the potential risk/impacts associated with hydrocarbon spill response options are listed in **Table 95**. These control measures have been assessed to consider the environmental benefits gained through implementing the controls relative to their time, effort and monetary cost, with a clear delineation of those which will be implemented during the Seismic Survey and those which won't. Justifications have been provided for each of the decisions.

Table 95 Assessment of Control Measures for Hydrocarbon Spill Response

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Implemented Control Measures:				
The SOPEP will be implemented for first strike response to level 1 and level 2 spills	P = Yes E = Effective	SLB will implement the response strategy in accordance with the SOPEP, and also in line with relevant legislation and industry standards.	Yes	Yes
Operational monitoring will be undertaken in order to inform and update the Control Agency about the behaviour of the spill	P = Yes E = Effective	Operational Monitoring (such as using the Support Vessel to monitor the spill) will be undertaken in the unlikely event of a hydrocarbon spill to provide up-to-date information on the fate of any hydrocarbon spill in the water. This monitoring will allow appropriate response options to be established with the Control Agency.	Yes	Yes
Contract in place with appropriate service provider to initiate real-time modelling in case of a spill	P = Yes E = Effective	Undertaking real-time modelling will provide assurances that response options can be tailored to the specific spill situation. The modelling will be used to predict the potential beaching locations (if any exist).	Yes	Yes
Hydrocarbon spill response training and competencies will be maintained throughout the Seismic Survey to avoid unplanned environmental impacts due to human error	P = Yes E = Effective	Ensuring all crew have appropriate training is vital in responding to a hydrocarbon spill. Drills will also be undertaken to ensure all crew are competent in responding to spills under the vessel specific SOPEP. These drills will be conducted at regular intervals to ensure competencies are maintained for the duration of the Seismic Survey.	Yes	Yes
A hydrocarbon spill will be immediately reported from the SLB onboard representative to SLB in Perth to ensure all notifications are provided as per **Section 10.7.**	P = Yes E = Effective	Notifications will ensure quick and appropriate response to a spill scenario and will be in accordance with SOPEP and in accordance with relevant legislation and industry standards.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Fishing industry and other relevant marine users will be notified	P = Yes E = Effective	Communication with marine users allows those potentially affected by a hydrocarbon spill to plan activities in a manner that reduces the risk of interactions.	Yes	Yes
NEBA to be conducted prior to response actions	P = Yes E = Effective	Response actions will be based on a NEBA approach which considers the advantages and disadvantages of the different spill response options to determine if there would be a net environmental benefit resulting from the implementation of a particular response.	Yes	Yes
Alternative Control Measures:				
Eliminate vessels to avoid spill, and hence avoid impacts from response options.	P = No E = Very Effective	There are no practicable methods for undertaking the Seismic Survey without the use of specialist survey vessels.	Yes	No
Pre-activity monitoring program and development of detailed Type II Monitoring Plan	P = No E = Fairly Effective	SLB do not consider it practicable to undertaken monitoring or development of a detailed Type II monitoring program in response to the unlikely risk of a hydrocarbon spill. The characteristics of MGO will likely result in rapid dispersion. In addition, SLB will implement various controls that will reduce the risks of vessel collision; implementation of SOPEP to prevent loss of an entire tank contents.	No	No
Additional response equipment on board the Support Vessel	P = No E = No	It is not reasonable for additional resources to be provided and maintained on the Support Vessel in the unlikely event of a spill. The Support Vessel is already equipped to best practice levels and supported by the National Plan. In order to carry the additional equipment (such as booms), additional vessels would be required.	No	No
Arrangements for aerial monitoring	P = No E = No	It is not considered that these resources could be mobilised faster than what can already be achieved under the National Plan arrangement.	No	No

8.4.3 Environmental Performance

The EPO for the response to a hydrocarbon spill is:

- No hydrocarbon spill will result in secondary impacts to the marine environment and all responses will be undertaken in accordance with the vessel SOPEP.

It is considered that the above EPO, as a result of the implementation of the control measures (**Table 95**), will allow the ongoing environmental performance of Seismic Survey in accordance with the **Acceptable Levels**, while ensuring that relevant legislation is complied with in order to avoid any health and safety risks or impacts on the marine environment as far as practicable.

The EPSs within **Table 96** have been defined to manage impacts from a hydrocarbon spill response to **ALARP** and an **Acceptable Level**. Compliance with these standards will ensure that the identified EPO will be achieved for the duration of the Seismic Survey.

Table 96 Environmental Performance Outcome and Standards for Hydrocarbon Spill Response

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
EPO: No hydrocarbon spill will result in secondary impacts to the marine environment and all responses will be undertaken in accordance with the vessel SOPEP.			
Implementation of SOPEP	**EPS 207**: The Vessel Master will authorise actions in accordance with the vessel specific SOPEP and survey specific SOPEP to limit the escape of hydrocarbons.	Incident Report.	Vessel Master.
Operational Monitoring	**EPS 208**: Support Vessel that is associated with the Seismic Survey will be available as a vessel of opportunity to monitor the spill if safe to do so and where NEBA identifies a net benefit to do so, as agreed with the Control Agency.	Incident Report. NEBA Report.	Vessel Master. SLB Project Manager.
Real-time Spill Modelling	**EPS 209**: Prior to the commencement of the Seismic Survey, SLB will secure services (in the form of a signed contract) with a third party for provision of real-time modelling (dispersion and trajectory) if and when required.	Service contract in place prior to commencement of Seismic Survey.	SLB Project Manager.
Hydrocarbon spill response training and competencies	**EPS 210**: Prior to the commencement of the Seismic Survey an audit is conducted with all maritime crew to ensure all staff are trained and inducted satisfactorily to ensure they are competent in responding to a hydrocarbon spill.	Pre-mobilisation audit results. Induction and daily records confirm training and induction has been carried out and crew present.	Vessel Master. SLB Project Manager.
Reporting of hydrocarbon spill	**EPS 211**: Initial SOPEP report requirements will be undertaken and SLB will be immediately notified.	Phone/email records. Consultation records.	Vessel Master. SLB Project Manager.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
	EPS 212: External notifications in the event of a level 1 or level 2 spill will be carried out as per the following reporting schedule: • SLB Project Manager – immediately; • NOPSEMA – verbal notification within two hours; • NOPSEMA – written NOPSEMA Incident Report Form no later than three days after notification; • National Offshore Petroleum Titles Administration – verbal or written incident summary within one day; and • Director of National Parks – as soon as possible following incident.	Phone/email records. Consultation records.	Vessel Master. SLB Project Manager.
	EPS 213: External notifications in the event of a Level 2 spill will be carried out as per the following reporting schedule: • AMSA – verbal notification within two hours, with follow-up written POLREP as soon as practicable; • WA DoT MEER (if spill affects Western Australian state waters) – verbal notification as soon as possible, with follow-up written POLREP as soon as practicable; • NT DEPWS (if spill affects Northern Territory waters) – verbal notification as soon as possible, with follow-up written POLREP as soon as practicable; • Type II Monitoring Service Provider – verbal notification within two hours with follow-up formal notification if and when a scientific monitoring program initiation criterion is met.	Phone/email records. Consultation records.	Vessel Master. SLB Project Manager.
48-hour look-ahead	**EPS 214**: A 48-hour 'look-ahead' plan will be provided to marine users detailing the survey activities over the next 48 hours. The 48-hour look-ahead plans will be updated and issued every 24 hours and distributed to relevant stakeholders via email.	Documentation of consultation and issuing of 48-hour look-ahead plans demonstrate compliance. Forms part of ongoing consultation strategy.	SLB Project Manager.
Conducting NEBA	**EPS 215**: Response actions will be based on a NEBA approach in consultation with Control Agency.	NEBA Report.	Vessel Master. SLB Project Manager.

8.4.4 Residual Risk

Following the implementation of the control measures in **Table 95**, the likelihood of impacts from the response to a hydrocarbon spill is *Rare*. The consequence from impacts from the response to a hydrocarbon spill is considered *Minor*, based on the discussions within **Section 8.4.1**. Therefore, the residual risk of an impact from the response to a hydrocarbon spill following the implementation of control measures (**Table 95**), is considered to be **Low** (**Table 97**).

Table 97 Residual Risk Summary for Hydrocarbon Spill Response

Likelihood	Consequence	Residual Risk
Rare	Minor	Low

8.4.5 Demonstration of ALARP

To demonstrate that any potential risks from the response to a hydrocarbon spill are managed to **ALARP**, a number of control measures have been considered to determine the benefits of their implementation and to ensure continual risk reduction (**Table 95**), based on a Hierarchy of Controls methodology (**Table 98)**. The adopted control measures that will be implemented throughout the Seismic Survey are considered appropriate to reduce the environmental risks from the response to a hydrocarbon spill and assessments have been undertaken to ensure that reasonable and practicable control measures or solutions have not been overlooked. As a result, through the application of industry best practice and/or comparable standards to further control risk reduction, it is considered that any impacts from the response to a hydrocarbon spill are reduced to **ALARP**, where the residual risk is **Low** (**Table 97**).

Additional control measures were considered as part of the assessment process towards further risk reduction however it was considered that they did not provide any further environmental benefit or were not reasonably practicable to implement. In addition, the costs (based on the experience of SLB) of implementing such measures would be disproportionate to the benefits that would be gained through their implementation.

Table 98 Hierarch of Controls for Hydrocarbon Spill Response

Eliminate	A significant response to a hydrocarbon spill is required; however, those methods that increase the risks to the environment have been eliminated (such as releasing a chemical dispersant) as the benefit of using these methods does not outweigh the risks associated with their use.
Substitute	There are no suitable substitutes for the response to a hydrocarbon spill event. The most applicable response has already been determined, using the NEBA approach (**Table 95**).
Reduce	The methods will also be analysed in consultation with the Control Agency through a NEBA process to ensure the most appropriate method is used in responding to a spill event. Any reduction in the impacts of a response to a hydrocarbon spill will be weighed against the net environmental benefit achieved.
Mitigate	Control measures have been assessed within **Table 95** to mitigate impacts associated with the nominated response(s) to a hydrocarbon spill to **ALARP** and **Acceptable Levels**. Those measures which are appropriate and are not impractical or unfeasible will be implemented during the Seismic Survey.

The proposed control measures minimise the risk of impacts associated with the response to a hydrocarbon spill and are considered appropriate to the relevant nature and scale of potential environmental impacts which may occur as a result of unplanned hydrocarbon spill. The proposed control measures have been developed in accordance with industry best practice. No further practicable controls have been identified to reduce the impact and risks to the marine environment and/or marine organisms from the response to a hydrocarbon spill.

Given the occurrence of a hydrocarbon spill is unlikely, coupled with the control measures outlined within **Table 95**, it is considered that the potential risk of impacts from the response to a hydrocarbon spill has been reduced to **ALARP**.

8.4.6 Risk Acceptability

Complete elimination is not possible as the response to a hydrocarbon spill is required. Following the implementation of the control measures detailed in this assessment (**Table 95**), the residual risks to the marine environment and associated receptors from the response to a hydrocarbon spill is **Low** (**Table 97**).

The criteria for risk acceptability is defined in **Table 32** and detailed in **Table 99**, where the control measures that will be implemented throughout the Seismic Survey have been developed in accordance with these. Where uncertainty exists around the criteria or the risk, SLB have taken a precautionary approach.

Table 99 Demonstration of Risk Acceptability for Hydrocarbon Spill Response

Criteria for Acceptance	Acceptability Summary
SLB's internal context	The proposed management of the risks of an impact from the response to a hydrocarbon spill are consistent with SLB's Environmental and QHSE Policy.
Industry Best Practice	The NEBA controls are in line with industry best practice with the depth of controls provided considered to reflect best practice and reasonable for the nature and scale of the activity. The APPEA Code of Environment Practice objectives with respect to reducing the impact from events such as spills to a level which is **ALARP** and acceptable are met by demonstrating the adoption of appropriate management procedures for the activity and having an appropriate emergency response plan. The IAGC Environmental Manual for Worldwide Geophysical Operations sets objectives in relation to hazardous materials for spill leak response which is met by the Seismic Survey.

Criteria for Acceptance	Acceptability Summary
External Context – Commonwealth and State Legislative Criteria	The proposed control measures for responding to a hydrocarbon spill during the Seismic Survey are consistent with the following relevant legislation: • Australian Maritime Safety Authority Act 1990; • International Convention on Oil Pollution Preparedness, Response and Cooperation 1990; • United Nations Convention on the Law of the Sea 1982; • International Convention for the Prevention of Pollution from Ships 1973; • Protection of the Sea (Civil Liability for Bunker Fuel Pollution Damage) Act 2008; • EPBC Act; • EPBC Regulations; and • Protection of the Sea (Prevention of Pollution from Ships) Act 1983 and its associated Marine Order 91 (Marine Pollution Prevention – Oil).
External Context – Management Plans, Species Recovery Plans and Conservation Advice	The OA does not overlap with any AMP boundaries, however, the EMBA overlaps with 5 relevant AMPs (Kimberley, Cartier Island and Ashmore Reef Marine Parks, as well as Oceanic Shoals and Joseph Bonaparte Gulf Marine Parks). Oil pollution response, environmental monitoring and remediation activities can be undertaken with IUCN Category VI zones (Oceanic Shoals, Kimberley and Joseph Bonaparte Marine Parks), when undertaken in accordance with a NOPSEMA approved EP that has met all required environmental management arrangements for the activity covered in the class approval. However, any oil pollution incident that may affect other IUCN category zones requires prompt consultation with the Director of National Parks. Any spill occurring within, or likely to impact, any Australian Marine Park should be notified to the Director of National Parks as soon as possible, by contacting the Marine Park Compliance Duty Officer (0419 293 465). Notifications must include time and location of the incident, response arrangements as per the OPEP and contact details for titleholder and response coordinators. The Implementation strategy for the Seismic Survey covers details of the notifications that would be undertaken in the event of reportable and recordable incidents as well as SLB's OPEP which details SLB's arrange for responding to a hydrocarbon spill event.
Social Acceptance – Stakeholder expectations	During consultation with interested stakeholders no concerns about the impacts from responding to a hydrocarbon spill were raised and as such no additional control/mitigation measures were expected or put in place. However, the Director of National Parks noted that they are to 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. To ensure this expectation is met, a corresponding control measure is proposed to be implemented, as outlined in **Table 96.** As such, the environmental impacts relating to responding to a hydrocarbon spill were considered to be at a socially **Acceptable Level**.
Ecologically Sustainable Development	The management of the risk proposed by SLB associated with the response to a hydrocarbon spill can be carried out in compliance with the five principles of ecologically sustainable development as defined within the EPBC Act. These principles have been considered as part of the development of the EP and risk assessment process. The assessment has not identified any adverse impacts to the principles of ESD, with no threats of serious or irreversible damage, no impacts to biological diversity and ecological integrity, no degradation of inter-generational equity, or negative effects on the social and economic integrity in the short or long-term.

Criteria for Acceptance	Acceptability Summary
Existing Environmental Context	Following implementation of control measures the potential risk of any impacts occurring to water quality, and marine flora and fauna in the surrounding marine environment from the response to a hydrocarbon spill is unlikely. It is also highly unlikely to pose a risk to the management objectives for protected or sensitive areas (i.e. Australian Marine Parks, KEFs etc.), habitats (i.e. subtidal), fauna and flora present. No impacts are predicted on the existing environment within or surrounding the OA from a response to a hydrocarbon spill. Due to the open ocean nature of the OA, in the unlikely event that a spill occurs, the MGO would undergo rapid and significant dilution as soon as it entered the receiving environment, and concentrations would quickly dilute and disperse. The resulting response to a spill of this nature would be to primarily monitor and observe the spill, with the resulting impacts of such a response principally being from additional vessels within the OA. The proposed control measures provide appropriate protection to the marine environment from the response to a hydrocarbon spill, and from a detailed assessment process it is considered that any further/alternative control measures would give very little or no further protection from the response to a hydrocarbon spill. The Implementation strategy for the Seismic Survey provides further details of SLB's OPEP which details SLB's arrangements for responding to a hydrocarbon spill event.
ALARP	Complete elimination is not possible as the response is required in the event of a hydrocarbon spill. Based on the assessment above, including consideration of the potential impacts on the environment and the associated controls measures to be implemented, the residual risk to the marine environment and associated receptors from the response to a hydrocarbon spill is considered to be **Low** and to **ALARP**. Therefore, the potential risk of impacts occurring from the response to a hydrocarbon spill during the Seismic Survey is considered to be at an **Acceptable Level**.

8.4.7 Hydrocarbon Spill Response Risk Summary

Based on the discussions above, including the potential impacts on the environment and the associated controls measures to be implemented, the residual risk from the response to a hydrocarbon spill is considered to be **Low** and to **ALARP**. Therefore, the potential risk of impacts occurring from the response to a hydrocarbon spill during the Seismic Survey is considered to be at an **Acceptable Level**.

8.5 Accidental Release of Hazardous and Non-Hazardous Materials

8.5.1 Description of Source of the Risk

The survey vessels utilised during the Seismic Survey will use, store and/or carry a range of chemicals onboard as part of standard day to day operations, including paints, hydraulic fluid, cleaning products and others. The activities will also result in the generation of a range of wastes both solid and liquid, including sewage, bottles, cardboard, paper, cans, domestic garbage and other liquid wastes. Routine discharges of biodegradable wastes have been assessed in **Section 7.3** and incineration of wastes have been assessed in **Section 7.4**, while garbage waste not able to be macerated or incinerated will be stored onboard the vessels for onshore disposal at suitable facilities. The following section deals with risks and impacts associated with accidental releases of hazardous and non-hazardous materials to the marine environment during the Seismic Survey.

Hazardous and non-hazardous materials can be accidentally released to the marine environment through machinery failure, malfunction, or operator error (such as split hydraulic hoses releasing fluids), leak from containment or inadequate clean-up of hazardous substances (such as following a split container), or if materials are lost overboard during bad weather or while transferring between vessels.

Notably, **Section 8.3** assesses the risks associated with unplanned release of hazardous materials, specific to hydrocarbon liquids (spills). These are not considered further within this section.

8.5.2 Known and Potential Risk to Environmental Receptors

The release of hazardous chemicals/liquid wastes has the potential to reduce water quality to a degree which poses risk to marine receptors. This could impact on marine organisms from plankton through to large marine mammals, fish and seabirds, either through direct exposure or as a result of ingesting prey in which toxic substances have bioaccumulated. The potential impacts associated with exposure to (hazardous and non-hazardous) wastes depend on a range of factors, including the toxicity, concentration and phase of the relevant compound and the nature of the exposure scenario itself. The amalgamation of these factors determines whether there is an observable effect, such as toxic, sub-lethal and lethal effects. The volume of hazardous materials that could potentially be released unintentionally from either of the survey vessels is small and, therefore, is likely to be rapidly dispersed and diluted to a point where concentrations are below levels expected to cause effects to marine organisms. In the event of an onboard spill, it’s expected that hazardous waste would be contained on the vessel and cleaned up in accordance with the SOPEP and standard clean-up procedures, decreasing chances of a major release to the receiving marine environment.

Due to the offshore nature of the OA, and the localised nature of any unplanned releases, sensitive marine habitats are unlikely to be affected as these exist primarily on the seabed and/or in the nearshore environment. Potential decreases in water quality and effects on pelagic species following an accidental release of hazardous material would be highly localised and temporary.

Non-hazardous materials such as paper, cardboard, wood and packaging can also potentially cause impacts if accidentally released into the marine environment, including direct physical impacts to marine organisms (strangling, choking) or the benthic environment if materials sink (localised crushing, smothering), or indirect impacts related to a reduction in water quality (e.g. through the breakdown of materials into smaller components and/or leaching of chemicals into the water column). Consequently, control measures are in place for the management of this waste to prevent any such discharge overboard.

The residual risk to environmental receptors arising from an accidental release of hazardous and non-hazardous materials during the Seismic Survey has been assessed as **Low** (*Minor* x *Unlikely*).

8.5.3 Control Measures

The potential control measures that have been considered during the Seismic Survey to manage any potential impacts from the accidental release of hazardous and non-hazardous materials to **ALARP** have been included in **Table 100**. These control measures have been assessed to consider the environmental benefits gained through implementing the controls relative to their time, effort and monetary cost, with a clear delineation of those which will be implemented during the Seismic Survey and those which won't. Justifications have been provided for each of the decisions.

Table 100 Assessment of Control Measures for Accidental Release of Hazardous and Non-Hazardous Materials

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
Implemented Control Measures:				
All wastes will be stored in suitably capped/lidded receptacles to ensure they remain secure on the vessels under all conditions.	P = Yes E = Effective	Ensuring all waste is securely stored aboard the vessels will prevent hazardous and non-hazardous wastes from being accidentally lost overboard into the marine environment. No domestic, maintenance, hazardous, solid or plastic waste will be intentionally discharged to the ocean. Such wastes will be stored onboard to be disposed at suitable facilities onshore.	Yes	Yes
All hazardous substance storage areas will be designed and maintained to support some form of containment/bunding.	P = Yes E = Effective	Containment/bunding will be in place around all locations where hazardous substances/materials are stored onboard the vessels to capture any spilled substances/materials and prevent them from entering the marine environment.	Yes	Yes
All hazardous substances carried onboard the vessels must have Material Safety Data Sheets (**MSDS**) with all crew trained in their location and use.	P = Yes E = Effective	MSDS contain detailed information about each hazardous substance and required information for handling and clean-up procedures in event of a spill, which will assist with minimising risk to the environment and workers in the event of an incident.	Yes	Yes
Suitable spill kits will be located close to the location of hazardous substances to allow timely response and clean-up in the event of a spill/incident	P = Yes E = Effective	Hazardous substances carried onboard the vessels will be stored in different areas and may require different methods to contain/clean-up a spill. Suitable spill kits will be located in close proximity to storage and areas of use to allow timely response and minimise the risk of release to the marine environment. Crew will be appropriately trained in the use of the spill kits.	Yes	Yes
Every reasonable effort must be made to retrieve any materials lost to the marine environment. In the event the retrieval is not safe or practicable, every reasonable effort must be made to inform other marine users of any objects lost overboard.	P = Yes E = Effective	In event materials are lost overboard, for example packaging/pallets, crew should make all reasonable efforts to retrieve the items. Where items cannot be retrieved, or cannot be found, communication with other marine users in the area should be undertaken, e.g. Notices to Mariners for large items.	Yes	Yes

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
All equipment shall be regularly serviced and maintained in accordance with original manufacturer's specifications and the vessels planned maintenance schedules.	P = Yes E = Effective	To reduce the risks of equipment failure, leading to accidental release of hazardous/non-hazardous materials, all equipment should be regularly serviced and maintained to detect early faults/defects that could cause failures.	Yes	Yes
Vessels and equipment will be operated by trained and experienced crew	P = Yes E = Effective	Accidental release of materials may occur as a result of improper/incorrect use of onboard equipment during normal operations. Crew will not operate equipment/machinery they are not trained/experienced in operating and will follow SOP or manufacturers guidelines for safe operation.	Yes	Yes
All crew will participate in the vessel and environmental induction prior to the commencement of operations	P = Yes E = Effective	It is a standard industry practice to hold inductions for all onboard the vessels, with participation in induction meetings compulsory. During inductions, crew will be made aware of their responsibilities with regard to effects of discharges to the marine environment and their roles with regard to clean-up of any accidental discharges.	Yes	Yes
All equipment located on the vessel's deck that uses hydrocarbons will be surrounded by primary bunding (e.g. deck edge lip), as a minimum	P = Yes E = Effective	Accidental release of materials may occur as a result of the use of machinery on deck. Bunding captures materials onboard the vessels and allows for an appropriate clean-up response, to avoid accidental release to the receiving marine environment.	Yes	Yes
Deck scupper plugs will be available beside all deck drainage points that lead overboard	P = Yes E = Effective	Deck scupper plugs allow for drainage to be blocked off, stopping wastes (including hazardous wastes) from entering the marine environment through deck drainage systems.	Yes	Yes
Alternative Control Measures:				
All packaging, handling and containers to be made of biodegradable materials.	P = No E = Somewhat Effective	Some materials/substances carried onboard cannot be safely contained within biodegradable containers and attempting to do so may place crew at greater danger and increase risk of incident which could result in risk to environment.	No	No

Control Measure	Practicability/ Effectiveness	Justification	Impact Reduction?	Will it be adopted?
No generation of hazardous/non-hazardous wastes onboard the vessels which require storing.	P = No E = Very Effective	Health and safety of crew requires that foods, materials, equipment be appropriately packaged for storage onboard the vessels for use at later date, thereby generating packaging wastes which must be stored aboard the vessels to be later disposed of onshore.	Yes	No

8.5.4 Environmental Performance

The EPO for the management of environmental impacts associated with the accidental release of hazardous and non-hazardous materials is:

- No accidental release of hazardous and non-hazardous materials into the marine environment.

It is considered that the above EPO, as a result of the implementation of the control measures (**Table 100**), will allow the ongoing environmental performance of the Seismic Survey in accordance with the **Acceptable Levels** described within **Section 8.5.7**, while ensuring that the relevant legislation is complied with in order to avoid any health and safety risks or impacts on the marine environment as far as practicable.

The EPSs within **Table 101** have been defined to manage the impacts from accidental release of hazardous and non-hazardous materials to **ALARP** and an **Acceptable Level**. Compliance with these standards will ensure that the identified EPO will be achieved for the duration of the Seismic Survey.

Table 101 Environmental Performance Outcome and Standards for Accidental Release of Hazardous and Non-Hazardous Materials

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
EPO: No accidental release of hazardous and non-hazardous materials into the marine environment.			
Secure storage of generated wastes	**EPS 216**: Generated solid wastes will be separated and securely stored in tightly capped/lidded containers/areas for later disposal onshore. Generated wastes will be characterised and managed in accordance with MARPOL Annex V, Marine Order 94 and Marine Order 95 .	Pre-mobilisation inspection confirms suitable storage areas for generated wastes which are labelled and have appropriate means of preventing wastes from escaping.	Vessel Master.
Containment/bunding of hazardous substance areas	**EPS 217**: Hazardous storage areas (e.g. hydrocarbons and chemicals) will be fully bunded and drain to the bilge water tank treatment system. Spill response kits will be stored nearby the storage location of these hazardous substances for clean-up purposes in the event of an unplanned spill.	Audit records confirm location of stored hazardous substances, the spill kit and appropriate bunding.	Vessel Master.
Deck scupper plugs	**EPS 218**: Scupper plugs, or equivalent drainage control measures, will be readily available to allow drains to be blocked in the event of a hydrocarbon or chemical spill to deck (i.e. outside bunded areas).	Audit records confirm location of drainage control measures. Induction records show crew are appropriately trained in how to implement scupper plugs.	Vessel Master.
Bunding surrounding deck machinery/equipment	**EPS 219**: All equipment located on the vessel's deck that uses hydrocarbons will be (as a minimum) surrounded by primary bunding (e.g. deck edge lip).	Pre-mobilisation inspection confirms appropriate bunding is in place around relevant deck machinery/equipment.	Vessel Master.
General chemical management procedures	**EPS 220**: Potential impacts to the environment are reduced through following correct procedure for the safe handling and storage of hazardous/non-hazardous materials, in accordance with MARPOL Annex III and Marine Orders 94.	Pre-mobilisation inspection confirms suitable vessel SOP are in place to allow safe handling and storage of hazardous/non-hazardous materials.	Vessel Master.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
MSDS for hazardous substances	**EPS 221**: Hazardous/non-hazardous materials will be appropriately stored and handled in accordance with the relevant MSDS requirements and the International Maritime Dangerous Goods Code to reduce the risk of an environmental incident. MSDS for all hazardous substances (as defined in the International Maritime Dangerous Goods Code) onboard the vessel will be kept readily available in locations known to all crew.	Pre-mobilisation inspection confirms correct and in-date MSDS are onboard for all hazardous substances.	Vessel Master.
Spill kits located throughout vessels	**EPS 222**: Spill kits of appropriate size and composition for the type/class of hazardous substance will be located close to location of these hazardous substances. Crew will be appropriately trained in how to use the spill kits and how to properly dispose of any soiled spill kits following clean up.	Pre-mobilisation inspection confirms correct type and size of spill kit and their proximity to the hazardous substance location. Induction records show crew are appropriately trained in how to use the spill kits.	Vessel Master.
Participation of all crew in vessel induction	**EPS 223**: All crew will participate in a vessel induction prior to the commencement of the survey, outlining their roles and responsibilities while onboard.	Induction records show content of induction meeting and participation of crew.	Vessel Master.
Prompt clean-up of spills/leaks	**EPS 224**: All leaks/spills will be cleaned up immediately upon discovery of the leak/spill with soiled response-equipment appropriately disposed of.	Vessel incident records verify actions taken to clean up any spills.	Vessel Master.
Accidental releases will be documented as incidents and other marine users notified	**EPS 225**: Hazardous/non-hazardous materials will be appropriately stored and handled to reduce the risk of an environmental incident. In event of accidental release, the incident will be correctly reported and documented, including issuing of warnings to other marine users.	Accidental release of hazardous or non-hazardous materials occurring aboard vessels involved in the survey must be appropriately recorded in incident reports. Objects unable to be found/retrieved must be documented and communicated to other marine users nearby, such as via Notice to Mariners for large items.	Vessel Master. SLB Project Manager.

Control Measure	Environmental Performance Standard	Measurement Criteria	Responsible Party
Vessel and equipment serviced and maintained appropriately and operated by trained and experienced crew	**EPS 226**: Risk of equipment failure (leading to accidental material releases) reduced by regular service and maintenance according to vessel SOP, original equipment manufacturer's recommendations and vessel service schedule. All equipment to be correctly operated only by trained and experienced staff.	Pre-mobilisation inspection confirms equipment is in current test/ certification and maintenance records show completed work. Staff training records show which crew hold suitable certification/training to operate equipment.	Vessel Master.

8.5.5 Residual Risk

Following the implementation of the control measures in **Table 100**, the likelihood of a risk to the marine environment from accidental release of hazardous and non-hazardous materials is *Unlikely*. The consequence of accidental release of hazardous and non-hazardous materials from the survey vessels is considered *Minor*, based on the assessment within **Section 8.5.2**. Therefore, the residual risk of an impact occurring from an accidental release of hazardous and non-hazardous materials from the survey vessels, following the implementation of control measures (**Table 100**), is considered to be **Low** (**Table 102**).

Table 102 Residual Risk Summary for Accidental Release of Hazardous and Non-Hazardous Materials

Likelihood	Consequence	Residual Risk
Unlikely	Minor	Low

8.5.6 Demonstration of ALARP

To demonstrate that the risk from any potential impacts from accidental release of hazardous and non-hazardous materials are managed to **ALARP**, a number of control measures have been considered to assess the benefits of their implementation and to ensure continual risk reduction (**Table 100**), based on a Hierarchy of Controls (**Table 103)**. The adopted control measures that will be implemented throughout the Seismic Survey are considered appropriate to reduce the environmental impacts from accidental release of hazardous and non-hazardous materials from the vessels during the Seismic Survey and an assessment was undertaken to ensure that all reasonable and practicable control measures or solutions have not been overlooked. As a result, through application of industry best practice and/or comparable standards to further control risk reduction, it is considered that any impacts from the accidental release of hazardous or non-hazardous materials has been reduced to **ALARP**, where the residual risk of an impact from adoption of these control measures is reduced to **Low** (**Table 102**).

Additional control measures were considered as part of the assessment process towards further risk reduction; however, it was considered that they did not provide any further environmental benefit or were not reasonably practicable to implement. In addition, the costs (based on the experience of SLB) of implementing such measures would be disproportionate to the benefits that would be gained through their implementation.

Table 103 Hierarchy of Controls for Accidental Release of Hazardous and Non-Hazardous Materials

Eliminate	Hazardous and non-hazardous wastes will be generated throughout the voyage as a result of critical operations required to support the activities and hazardous materials are required to keep the vessels operational, thus these cannot be completely eliminated from the Seismic Survey.
Substitute	While the least harmful substance that will perform the specified role will be chosen during the survey, and materials with biodegradable/recyclable packaging will be used where possible, some materials cannot be safely substituted without placing greater risk on the vessel/crew and increasing risk of accidental release.
Reduce	Waste storage areas will be tightly secured/closed and fitted with the relevant bunding to prevent accidental release overboard of materials. Equipment will be serviced and maintained appropriately, and operated only by trained and experienced personnel, to reduce risk of equipment failure which can lead to accidental releases.
Mitigate	Control measures have been assessed within **Table 71** in order to mitigate the risk of impacts from accidental release of hazardous and non-hazardous materials to **ALARP** levels. Those which are appropriate and are not impracticable or unfeasible due to disproportionately large costs will be implemented during the Seismic Survey.

The proposed control measures reduce the risk of impact associated with the accidental release of hazardous and non-hazardous materials and are considered appropriate to the localised nature and small scale of potential impacts from an accidental release event. The proposed control measures have been developed in accordance with industry best practice. No further practicable controls have been identified to reduce the risk of impact and risks to the marine environment and/or marine receptors from the accidental release of hazardous and non-hazardous materials.

Given the relatively localised nature of potential effects associated with the accidental release of hazardous and non-hazardous materials (excluding fuel/hydrocarbons), it is considered that the risk of potential impacts from accidental release of hazardous and non-hazardous materials are reduced to **ALARP**.

8.5.7 Risk Acceptability

Total elimination of all risks associated with accidental release of hazardous and non-hazardous materials cannot be achieved, as hazardous substances must be used onboard the vessel. These materials, along with non-hazardous materials, and the packaging that holds all these materials must be stored onboard the vessel during the survey and there are no practicable alternatives. Following the implementation of the control measures (**Table 100**) the potential risk of impacts to the marine environment and associated receptors from accidental release of hazardous and non-hazardous materials are likely to be localised and short-term.

The control measures that will be implemented for the duration of the Seismic Survey have been developed in accordance with the criteria for risk acceptability which are detailed in **Table 34** and further defined within **Table 104**. Where uncertainty exists around the criteria or the risk, SLB have taken a precautionary approach.

Table 104 Demonstration of Risk Acceptability for Accidental Release of Hazardous and Non-Hazardous Materials

Criteria for Acceptance	Acceptability Summary
SLB's internal context	The proposed management of the impact/risks the accidental release of hazardous and non-hazardous materials are consistent with SLB's Environmental and QHSE Policy.
Industry Best Practice	The proposed control measures to decrease the risk of an accidental release of hazardous and non-hazardous materials follows industry best practice and best practice guidelines for MSSs, including: • The IAGC Environmental Manual for Worldwide Geophysical Operations which recommends that: - Vessels ensure they have MSDS for all hazardous materials and that they are up to date (i.e. within four years of issue date); - Carry suitable spill kits; - No direct discharge of any products into the sea; - Vessels ensure hazardous materials are handled and stored correctly; and - Records of hazardous material use, storage, disposal and incidents/spills are kept; • The APPEA Code of Environmental Practice which recommends that suitable waste management practices are used based on preventing, minimising, recycling, treating and disposing of wastes in accordance with any statutory requirements and procedures.
External Context – Commonwealth and State Legislative Criteria	The proposed control measures during the Seismic Survey are consistent with the following relevant standards/documents: • MARPOL Annex III Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form; • MARPOL Annex V Prevention of Pollution by Garbage from Ships; • The Protection of the Sea (Prevention of Pollution from Ships) Act 1993; • Marine Order 94 (Marine pollution prevention – packaged harmful substances) 2014; • Marine Order 95 (Marine pollution prevention – garbage) 2013; and • Marine Notice 2017/4 MARPOL Annex V Discharges.
External Context – Management Plans, Species Recovery Plans and Conservation Advice	The management of the risk associated with an accidental release of hazardous and non-hazardous materials can be carried out in compliance with the five principles of ecologically sustainable development as defined within the EPBC Act. These principles have been considered as part of the development of this EP and risk assessment process. The assessment has not identified any adverse impacts to the principles of ESD, with no threats of serious or irreversible damage, no impacts to biological diversity and ecological integrity, no degradation of inter-generational equity, or negative effects on the social and economic integrity in the short or long-term.
Social Acceptance – Stakeholder expectations	No concerns were raised in regard to the risks of accidental release of hazardous and non-hazardous materials. As such the risk of environmental impacts relating to accidental releases of hazardous and non-hazardous materials from Seismic Vessel and Support Vessel were considered to be at a socially **Acceptable Level**.

Criteria for Acceptance	Acceptability Summary
Ecologically Sustainable Development	The management of the risk associated with an accidental release of hazardous and non-hazardous materials can be carried out in compliance with the five principles of ecologically sustainable development as defined within the EPBC Act. These principles have been considered as part of the development of this EP and risk assessment process. The assessment has not identified any adverse impacts to the principles of ESD, with no threats of serious or irreversible damage, no impacts to biological diversity and ecological integrity, no degradation of inter-generational equity, or negative effects on the social and economic integrity in the short or long-term.
Existing Environmental Context	The release of hazardous wastes into the marine environment can adversely impact on marine environmental (water) quality and, subsequently marine species, biodiversity ecosystem function, social amenity and human health. Marine debris such as plastic wastes and/or packaging can potentially pose a risk for many marine organisms, including protected species, through multiple impact pathways, including ingestion, entanglement, chocking and smothering. Impacts to water quality and marine organisms resulting from the unplanned release of hazardous and non-hazardous substances are expected to be minor, temporary, highly localised and, in the case of non-hazardous materials, proportional to the size of solid waste. Hazardous substances accidentally released into the marine environment would be quickly diluted and/or dispersed. Therefore, impacts to marine organisms are not expected. Of relevance to the OA, are the maintenance of management objectives and values for protected areas such as the adjacent Oceanic Shoals Marine Park and Carbonate bank and terrace system of the Sahul Shelf KEF. Following the implementation of proposed control measures, the potential risk of impacts to marine environmental quality, marine receptors and, therefore, protected areas from the accidental release of hazardous and non-hazardous materials is Low.
ALARP	Hazardous and non-hazardous wastes will be generated throughout the voyage as a result of critical operations required to support the activities and hazardous materials are required to keep the vessels operational, thus these cannot be completely eliminated from the Seismic Survey and there are no practicable alternatives. Following the implementation of the control measures, the potential risk of impacts to the marine environment and associated receptors associated with the release of hazardous and non-hazardous materials are likely to be temporary and highly localised. Based on the assessment above, including the potential impacts on the environment and the associated controls measures to be implemented, the residual risk of an accidental release of hazardous and non-hazardous materials from the survey vessels is considered to be **Low** and to **ALARP** levels. Therefore, the impacts from this activity associated with the Seismic Survey are considered to be at an **Acceptable Level**.

8.5.8 Accidental Release of Hazardous and Non-Hazardous Material Risk Summary

Based on the assessment above, including the potential impacts on the environment and the associated controls measures to be implemented, the residual risk of an accidental release of hazardous and non-hazardous materials from the survey vessels is considered to be **Low** and to **ALARP** levels. Therefore, the impacts from the Seismic Survey are considered to be at an **Acceptable Level**.

9 Cumulative Effects

Cumulative effects due to exposure to seismic energy may occur under the following scenarios, including:

- Simultaneous exposure to separate MSSs being conducted in the same area, at the same time – acoustic footprints overlap in space and time;
- Multiple exposures due to individual MSS undertaken consecutively - two or more MSS undertaken across the same area within a short period of time;
- Multiple exposures during a single MSS – including infill of seismic data gaps within the same survey; and
- Interaction between different sources of sound – e.g. vessel noise and seismic energy.

Any of these scenarios could increase the overall underwater sound exposure for key receptors to levels that are above those associated with the conduct of a single MSS. Acoustic energy from multiple seismic surveys and shipping traffic are of particular interest as these are the two most likely potential contributors to cumulative effects of underwater noise in the Bonaparte Basin. There is also a high likelihood that infill of seismic data gaps will be required. The noise impacts of infill lines have been identified throughout **Section 7.2**.

9.1 Characterising the nature and scale of cumulative effects

Potential cumulative impacts from successive seismic surveys on receptors are highly variable based on the recovery period of the receptors and the timing between the surveys. As outlined through **Section 7.2**, the range at which the various receptors recover from sounds exposure can be between minutes and hours, through to weeks and months; examples of the recovery periods for the key receptors are as follows:

- Zooplankton abundance (including eggs and larvae) will likely recover and replenish to natural levels within hours of exposure as discussed within **Section 7.2.2.1.1**;
- Benthic invertebrates may experience sub-lethal and chronic effects for weeks to months as outlined within **Section 7.2.2.1.2**. However, it is worth noting that any effects on the community composition are considered to be negligible in relation to natural variability;
- Potential effects on fish species are dependent on the species and their hearing sensitivity, but effects will likely last for minutes to hours as discussed in **Section 7.2.2.1.3**; and
- Changes in migrating or foraging marine fauna (e.g. cetaceans, turtles, whale sharks) will likely return to normal within hours or days after exposure as outlined within **Section 7.2.2.1.5** and **7.2.2.1.6**.

Based on the discussions above, the longest potential recovery period relates to immobile benthic invertebrate communities, although noting that those effects are considered negligible in relation to the natural variability of those communities.

9.2 Concurrent and Consecutive Marine Seismic Surveys

To assess the potential for concurrent and consecutive seismic surveys to occur in the Bonaparte Basin, an online search of NOPSEMA's 'Activity Status and Summaries' web page was undertaken to identify any EP applications, recently approved EPs (i.e. between 2021 and 2022) or historical seismic activity (i.e. between 2015 and 2020) within 400 km of the OA. Overall, thirteen historical and two proposed MSSs were identified through this process with their details and status provided in **Table 105**, and locations in **Figure 53**.

In some instances, it was not possible to ascertain whether approved activities had been undertaken. Where this occurred, a precautionary approach was adopted, and it was assumed the MSS proceeded in accordance with the project description and timeline provided in the EP.

Table 105 MSS in the Bonaparte Basin submitted and/or approved by NOPSEMA since 2015

Survey Name	Applicant	Date of EP submission	Status
Proposed MSSs			
Galactic Hybrid 2D MSS Located approximately 388 km northeast of OA	Woodside Energy Ltd	10 September 2021	Under assessment
Petrel Sub-Basin South-West 3D Marine Seismic Survey Located approximately 174 km southeast of OA	Santos Offshore Pty Ltd	12 July 2021	Approved on 6 January 2022 Planning to be finalised in March 2023 (Maximum 90 days of acquisition)
Historical MMSs			
Petrelex 3D MSS Located approximately 213 km southeast of OA	Polarcus Seismic Limited	11 July 2019	Approved on 4 October 2019 Finalised during 2020 (Maximum 64 days of acquisition)
Cygnus 3D MSS Phase 3 South Partially overlaps with OA	Polarcus Seismic Limited	21 March 2019	Approved on 5 June 2019 Finalised during 2020 (Maximum 36 days of acquisition)
Factory 3D MSS Located approximately 55 km southwest of OA	Shell Australia Pty Ltd	29 March 2019	Approved 16 September 2019 Finalised during 2020 (Maximum 90 days of acquisition)
Beehive 3D MSS Located approximately 287 km southeast of OA	Finniss Offshore Exploration Pty Ltd	8 February 2018	Approved 22 May 2018 Finalised during 2019 (Maximum 30 days of acquisition)
Zénaïde 3D MSS Located approximately 35 km southeast of OA	Polarcus Seismic Limited	13 September 2017	Approved 7 December 2017 Finalised during 2018 (Maximum 60 days of acquisition)
Fishburn WA-459-P 3D MSS Located approximately 130 km southeast of OA	Santos Offshore Pty Ltd	8 June 2017	Approved 22 June 2017 Finalised during 2017 (Maximum 21 days of acquisition)
Bethany 3D MSS Located approximately 195 km northeast of OA	Santos Offshore Pty Ltd	13 April 2017	Approved 28 March 2018 Finalised during 2018 (Maximum 75 days of acquisition)

Survey Name	Applicant	Date of EP submission	Status
Cygnus SW MSS Located approximately 52 km southwest of OA	Spectrum Geo Pty Ltd	24 January 2017	Approved 4 May 2017 Finalised during 2018 (Maximum 90 days of acquisition)
Cygnus 3D MSS (2017-2018) Partially overlaps with OA	Polarcus Seismic Limited	6 October 2017	Approved 1 December 2017 Finalised 2017 - 2018 (Maximum 12 months of acquisition)
Cygnus 3D MSS (2015-2017) Partially overlaps with OA	Polarcus Seismic Limited	20 August 2015	First approval 14 December 2015 Finalised 2015 - 2016 (Maximum 12 months of acquisition)
Gravis MC3D MSS Partially overlaps with OA	CGG Services (Australia) Pty Ltd	14 April 2015	Approved 25 August 2015 Finalised in 2017 (Maximum 24 months of acquisition)
Quoll 3D MSS Located approximately 17 km west of OA	Searcher Seismic Pty Ltd	1 May 2015	Approved 16 June 2015 Finalised 2015 (Maximum 6 months of acquisition)
Forge MC3D MSS Partially overlaps with OA	PGS Australia Pty Ltd	19 June 2015	Approved 4 November 2015 Finalised 2016 (Maximum 24 months of acquisition)

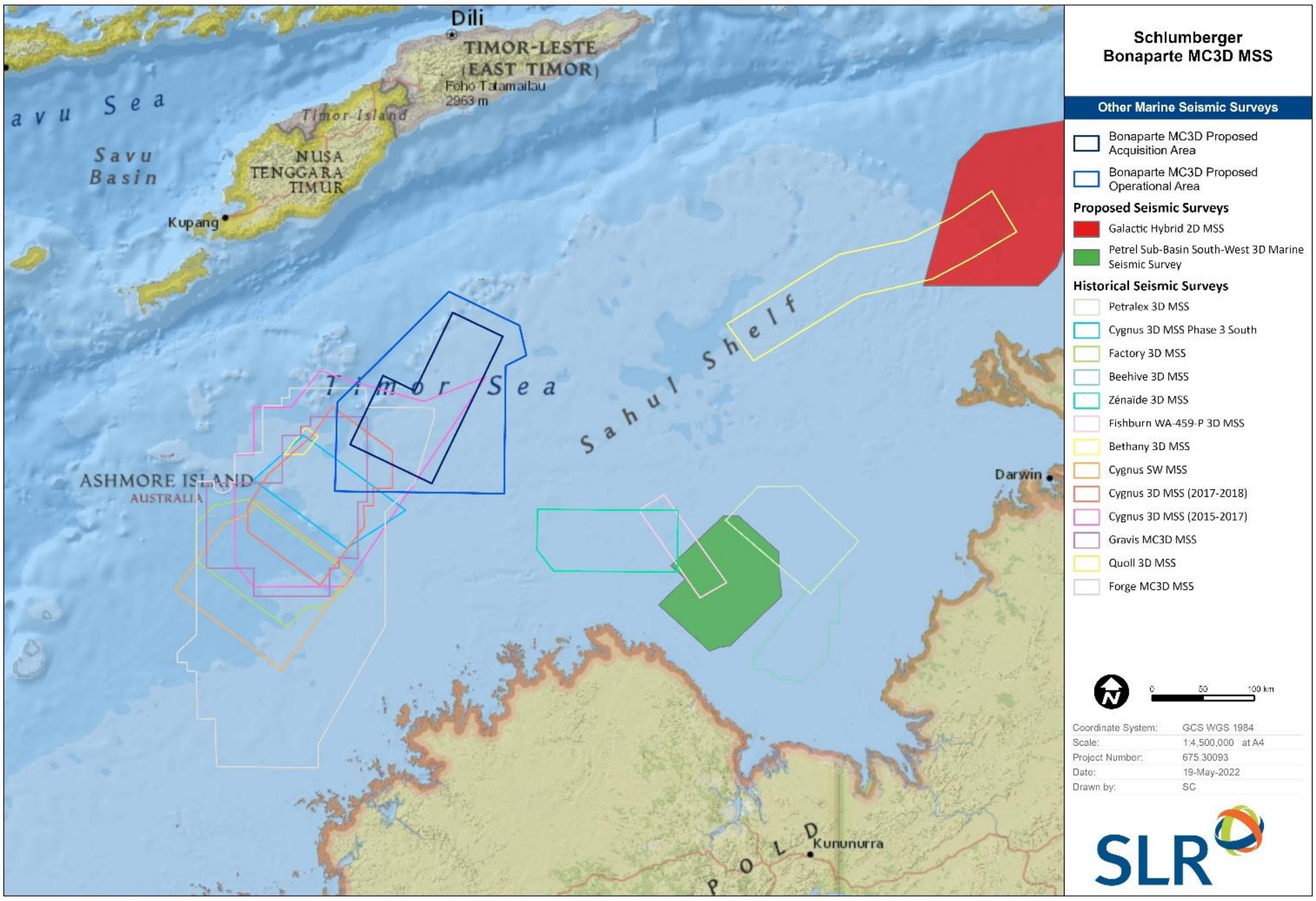


Figure 53 Planned and Previous Seismic Surveys Acquired since 2015 in the Bonaparte Basin

No other Seismic Surveys were reported to be under assessment or have recently been approved to take place within or in proximity to the OA. Therefore, it's anticipated that multiple MSSs will not be conducted within the OA, neither at the same time or within quick succession of the proposed Seismic Survey.

Given that Seismic Activity has not been undertaken within or close to the OA since mid-2020, ecological receptors are expected to have recovered. As a result, there is not expected to be any potential for cumulative impacts on marine receptors from seismic energy released from the previous MSSs. In addition, recent research indicates that short-term (acute) noise exposures (like those associated with seismic surveys) are less likely to affect marine species at a population level compared to long-term (chronic) noise exposures (Ellison *et al*., 2016).

SLB are not aware of any additional proposed MSSs for the Bonaparte Basin and given the timeframe for gaining regulatory approval for an EP, it is unlikely that any emerging projects would contribute to potential cumulative acoustic disturbance within the OA. Should SLB become aware of another MSS being approved for the Bonaparte Basin, the potential for cumulative effects from spatially and/or temporally overlapping surveys would be reassessed.

9.3 Multiple Exposures – Infilling

During the acquisition of seismic data, occasional gaps in the data coverage occur, due to a variety of possible causes, such as malfunction of seismic equipment, minor navigation errors causing the vessel to move off-track, data errors, or enforced periods of non-acquisition due to interactions with marine species, weather constraints or vessel issues. These data gaps may negatively impact on the overall integrity and usefulness of the seismic data and prevent the objectives of the survey being achieved. Critical gaps in the seismic data coverage require 'infilling' with new data and the Seismic Vessel is required to re-run data acquisition across each area of data gap.

Infilling has the potential to expose resident marine species, such as site-attached benthic species, to a second dose of seismic energy within a relatively short period of time. The time interval between initial data acquisition and infilling depends on a variety of factors, including data processing, vessel scheduling, local conditions and competing data priorities. Re-acquisition time intervals typically vary from a few hours to a few days, with longer intervals expected to reduce the seismic exposure risk to site-attached species. Note however that Przeslawski *et al.* (2016) concluded that none of the most recent studies (i.e. Parry *et al.*, 2002; Harrington *et al*., 2010; Aguilar de Soto *et al.,* 2013; Day *et al.*, 2016) indicate that MSSs cause catastrophic or short-term mortality on benthic shellfish (scallops) under realistic exposure scenarios. Furthermore, Przeslawski *et al.* (2016) state that effects on the catch rates or abundances have not been detected for cephalopods, bivalves, gastropods, decapods, stomatopods, or ophiuroids (Wardle *et al.,* 2001; Parry *et al.*, 2002; Christian *et al.,* 2003; Parry and Gason, 2006). These scientific results indicate that MSSs are unlikely to impact site-attached benthic species populations; however, it is noted that these studies focused on the effects associated with single exposure scenarios.

Infill lines need to be done on a planned basis as it takes a lot of time to turn the Seismic Vessel around and traverse the same area. This means that often the infill lines will be left to the end of the operations to best acquire them most efficiently. Therefore, this will likely result in a significant time period between the original acquisition and the infill line. Nevertheless, as discussed within **Section 3.4.3**, it is anticipated that in most cases any infill lines required would be completed on a different day, with at least a 24-hour delay. However, any repeated noise exposure at a location within 24 hours would contribute to cumulative noise exposure for assessment to the noise thresholds and to determine zones of impact. The noise impacts of infill lines occurring up to 24 hours and the resulting increase in zones of impact for particular species have been identified throughout **Section 7.2**.

9.4 Multiple Sound Sources

Cumulative noise impacts can also occur due to seismic activities overlapping with existing background noise in and around the OA, such as from vessel traffic (including fishing vessels, oil and gas support vessels and regional shipping traffic). **Section 4.7.4** provides details on the shipping activity that occurs in the general Bonaparte Basin. The 'background' noise levels associated with shipping are known to affect the communication calls between marine mammals due to 'masking', whereby calls are not as easily heard above the noisy background. Masking is a complex phenomenon and masking levels are difficult to predict for any particular combination of sender, environment, and receiver characteristics (Erbe *et al*., 2016). The Seismic Survey will comprise of one Seismic Vessel, and two smaller ancillary vessels including a Support Vessel and Chase Vessel. Consequently, the increase in vessel noise will be small compared to the regular acoustic disturbance generated by commercial vessels traversing the OA.

The Bonaparte Basin is transited by large commercial vessels, hence shipping noise is an existing feature of these waters, and marine mammals that are resident within the area are likely to have adapted to the persistent background noise. In the presence of constant noise, marine mammals sometimes adapt their vocalisations in order to overcome the effects of masking (e.g. McGregor *et al*., 2013) (further described in **Section 7.2.2**). In contrast, marine mammals that seasonally migrate through the OA are more likely to experience masking effects from vessel noise and noise generated during the Seismic Survey.

The cumulative effects of exposure to multiple sound sources may be more relevant at the population level on a chronic basis than at the individual level on an acute basis (Ellison *et al*., 2016), and therefore introducing short-term (acute) seismic-based noise to an area that has an existing high background of vessel noise, such as the Bonaparte Basin, is unlikely to impact marine species at the population level.

Marine environments differ in their resilience to anthropogenic stressors (Ban *et al*., 2010), and the potential for cumulative effects is likely to be related to physical features such as water depth, seabed characteristics and coastline shape. A higher risk from noise is evident in shallow waters and enclosed bays where the attenuation potential is lower, whereas open coastlines allow sound to dissipate more rapidly and therefore the risk is lower.

9.5 Conclusions

The potential for cumulative noise impacts associated with the proposed Seismic survey is low considering that:

- Given the time that has elapsed since previous surveys were undertaken in this area, all receptors are expected to have recovered from the effects of previous surveys prior to commencement of the proposed Seismic Survey. 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 Seismic Survey;
- SLB are not aware of any additional proposed MSSs for the Bonaparte Basin and given the timeframe for gaining regulatory approval for an EP, it is unlikely that any emerging projects would contribute to potential cumulative acoustic disturbance within the OA. Should SLB become aware of another MSS being approved for the Bonaparte Basin, the potential for cumulative effects from spatially and/or temporally overlapping surveys would be reassessed;
- The necessity of infilling critical gaps in the seismic data is not expected to significantly increase sound exposure impacts on marine species, especially since the open ocean environment of the OA will ensure continual movement and mixing of the water mass, and the minimum time between undertaking infilling; and
- Additional vessel noise associated with the survey vessels will be small compared to the background noise associated with marine traffic and fishing. The introduction of short-term (acute) seismic-based noise to this area that has an existing high background of vessel noise is unlikely to impact marine species at a population level.

10 Implementation Strategy

Regulation 14 of the Environment Regulations requires an EP to contain an implementation strategy. As outlined within NOPSEMA (2020), there are four key elements that an implementation strategy should include, these are:

- An environmental management system consistent with AS/NZS ISO 14001;
- Provision of reporting, monitoring, recording, audit, management or non-conformance and review of the titleholder's environmental performance to ensure that EPOs and EPSs in the EP are being met;
- An OPEP and demonstration that appropriate arrangements are in place for the activation of this plan in the event of a spill; and
- Arrangements for ongoing consultation with relevant authorities, persons and organisations in order to demonstrate that there is an effective two-way communication process in place between the titleholder and relevant person.

The following sections outline the methods in which SLB will conform to the requirements of Regulation 14.

10.1 Schlumberger Environmental Management System

As defined within Regulation 4 of the Environment Regulations, an Environmental Management System includes the responsibilities, practices, processes and resources used to manage the environmental aspects of an activity. The design and implementation of the Seismic Survey will be conducted within the framework of SLBs HSE Management System.

The underlying approach for the Environmental Management System and the EP in general, is based on the Plan-Do-Check-Act concept outlined within AS/NZS ISO 14001:2016. This is followed through the EP by planning various control measures to reduce impacts and risks to **ALARP** and **Acceptable Levels**, implementing these controls during the Seismic Survey, checking these controls are operating effectively utilising appropriate monitoring, recording and auditing, then ensuring any changes required are done through a Management of Change (**MoC**) process.

The key components of the HSE Management System include:

- Undertake the Seismic Survey in accordance with the QHSE Policy (**Figure 2**) and this EP;
- The implementation, management and review of the EP (including during emergencies or potential emergencies) following the chain of command outlined within the Roles and Responsibilities (**Section 10.2**), including establishing appropriate communications to ensure the flow of information achieves the relevant operational tasks and environmental performance (**Section 10.2.1**);
- Applicable training, competencies and awareness are managed through SLBs Training Management System (**Section 10.3**) to ensure control measures that are in place can be effectively implemented;
- Undertake inspections, audits and management of compliance in accordance with **Section 10.4**, including the review of the EP to ensure ongoing reduction of risks and impacts to **ALARP** and **Acceptable Levels** for the duration of the Seismic Survey;
- Ensuring any change to operations are managed through a MoC procedure (**Section 10.4.5**); and

- Reporting procedures (**Section 10.6**), including environmental performance reporting, environmental incident reporting, marine mammal observation reporting, marine mammal collision reporting and marine pest/disease reporting are followed.

As part of SLBs Environmental Management System, SLB has undertaken comprehensive consultation during the development of this EP (**Appendix E**, **F**, & **I**) and are committed with ongoing consultation with relevant authorities of the Commonwealth, State and all other relevant interested persons and organisations. The ongoing stakeholder engagement strategy is outlined in detail within **Section 5.4.7**.

Various management plans and operational procedures will be implemented for the duration of the Seismic Survey to ensure that environmental performance measures stated throughout the EP are achieved. In addition, the vessel contractor will have their own suite of operational procedures and management plans that will apply to the vessels utilised for the Seismic Survey. The key safety and environmental policies, operational procedures and management plans that are relevant to the Seismic Survey include:

- The contents of this EP;
- SLB QHSE Policy (**Figure 2**);
- Vessel specific SOPEP;
- Vessel specific Ballast Water Management Plan;
- Vessel specific Garbage Management Plan; and
- Vessel specific SEEMP.

In addition to the above, a project specific HSE Plan will be developed that SLB and the vessel contractor will abide by for the duration of the Seismic Survey. This HSE Plan will be tailored to capture all of the environmental management measures proposed for implementation during the Seismic Survey, including meeting the various EPOs and EPSs, in order to ensure the potential impacts and risks from the Seismic Survey on the receiving environment are reduced to **ALARP** and an **Acceptable Level**.

10.2 Roles and Responsibilities

As stated in the NOPSEMA Guidance Note (NOPSEMA, 2020), a clear definition of the roles and responsibilities of all personnel involved in the Seismic Survey ensures effective and consistent implementation of all the environmental management requirements set out in this EP and SLB's commitments to reducing potential impacts to the receiving environment to **ALARP** and an **Acceptable Level**.

While the respective Vessel Master has the overall responsibility to maintain health and safety standards for everyone on-board the survey vessels, it is the responsibility of all SLB employees and contractors to apply the requirements of any HSE Policy and to ensure that their work is carried out in a safe manner and in a way that minimises any further potential risk to the receiving environment.

Table 106 outlines the roles of SLB employees and contractors that will be involved in the Seismic Survey and their responsibilities for the duration of the survey.

The organisation structure of the SLB management team and HSE representatives is provided in **Figure 54**. This is the management structure that will be in place for the duration of the Seismic Survey.

Table 106 Roles and Responsibilities during the Seismic Survey

Role	Responsibility
SLB Director	• Overall accountability for the Seismic Survey; • Overall accountability for compliance with the SLB HSE Management System; and • Ensures staff members are provided with sufficient resources to ensure compliance with regulatory requirements and that all statutory approvals are obtained prior to the commencement of the Seismic Survey activities.
SLB Project Manager	• Coordinates all regulatory approvals required for the Seismic Survey; • Responsible for hiring qualified and experienced MMOs and PAM Operators; • Ensures all reporting required under **Section 10.6** occurs in accordance with the relevant requirements; • Responsible for all consultation activities and ensures that ongoing consultation is carried out in a manner that is consistent with SLB's stakeholder strategy (**Section 5.4**); • Ensures all records are kept and maintained, and made available to relevant authorities on request; and • Ensure that any review of, and change to, the EP is undertaken in accordance with SLB's MoC process (**Section 10.4.5**).
SLB Onboard Representative	• Reports to SLB Project Manager; • Responsible for notifying SLB Project Manager of any incidents and maintains the collection of records; • Responsible for the internal recording and reporting of any HSE incidents and leads the investigation on such incidents; • Ensures that the relevant records and monitoring data is undertaken; • Ensures that all vessel crew are adhering to the requirements stipulated within the EP; • Responsible for carrying out any HSE inductions with regard to requirements of the EP and any internal SLB policies; • Conducts environmental inspections/audits of the survey activities against the EP; and • Prepares and submits daily status reports to SLB Project Manager.

Role	Responsibility
Vessel Master (survey vessels)	• Overall control of vessel and operates vessel in a safe and responsible manner, and is responsible for the management of health and safety of all crew; • Ensure vessel complies with all relevant legislation such as the Navigation Act 2012, COLREGs, UNCLOS, MARPOL and the EPBC Regulations 2000 (with regard to interactions between the vessel and cetaceans); • Ensure compliance with the approved EP and the associated control measures are enforced; • Provide schedule updates for Notice to Mariners to the AHO; • Maintain clear communication with vessel crew; • Ensure all crew members go through a vessel induction when first boarding the vessel, and on each crew change so that they are aware of their roles and responsibilities and any workplace, health and safety requirements/hazards while on-board the vessel; • Ensure all maintenance, emergency drills, and training are undertaken to schedule and all records are maintained; • Liaise with all SLB representatives including SLB On-board Representative and SLB Project Manager; and • Notify the appropriate authorities of any incidents at sea (e.g. collision, near-miss, hydrocarbon spill, etc.) and follow-up with any required actions.
Watch keeper	• Maintenance of bridge watch in compliance with the International Convention of Standards of Training, Certification and Watch keeping for Seafarers, including visual scanning, and monitoring of AIS and radar systems.
Party Chief	• The ultimate leader of the seismic operators and survey crew; • Ensures the quality of work the crew is performing in the field is high; • Ensures the job is progressing according to the plan agreed by the client and seismic crew; • Ensures all the survey crew are aware of the HSE Management Systems and Policies onboard; and • Produce reports as necessary, including the final project report, regular operations, HSE reports and technical performance reports.
Seismic operators	• Deployment and maintenance of acoustic source and streamer; • Operation of acoustic source, including initiation of soft-start and shut-down procedures; and • Communicate with Vessel Master, MMOs and PAM Operators to implement soft-start and shut-down procedures, and to ensure acquisition/activation of the acoustic source only occurs within the Acquisition Area.

Role	Responsibility
General vessel crew (survey vessels)	• Undertake work in a manner that is in accordance with all health and safety procedures and to ensure there are no unforeseen adverse effects on the marine environment; • Keep a watching brief on any potential changes to the Seismic Survey which have the potential for changing the impact and/or risk profile, or which may cause deviation from the EP; • Report all hazards, near-misses and incidents to supervisor as soon as possible; • Maintain a high standard of housekeeping; and • Participate in vessel inspections, inductions, safety drills, and health and safety meetings when required.
Marine Subcontractor	• Be a local point of contact for fishermen to raise issues; and • Liaise with fishermen should fishing equipment along sail lines be required to be moved.
MMO	• Maintenance of constant day light visual observations for marine mammals and marine fauna; • Maintenance of communication with Vessel Master, PAM Operators and acoustic control room to initiate EPCA Act Policy Statement 2.1. Part A and additional Part B mitigation measures described in **Section 2** and **Section 3.4** such as, implementation of soft-start and shut-down procedures of the acoustic source as appropriate, Shut-down Zones and extended Shut-down Zones; and • Preparation of cetacean survey reports (in collaboration with PAM Operator) that outline any marine mammal observations, interactions, and mitigation actions taken.
PAM Operator	• Deployment and maintenance of PAM equipment; • Maintenance of 24-hour monitoring (day and night) of PAM equipment for acoustic detections of cetacean presence; • Maintenance of communication with Vessel Master, MMOs and acoustic control room to initiate mitigation measures described in **Table 56** and **Section 3.4** such as shut-downs of acoustic source; and • Preparation of cetacean survey reports (in collaboration with MMO) that detail any cetacean detections, interactions, and mitigation actions taken.

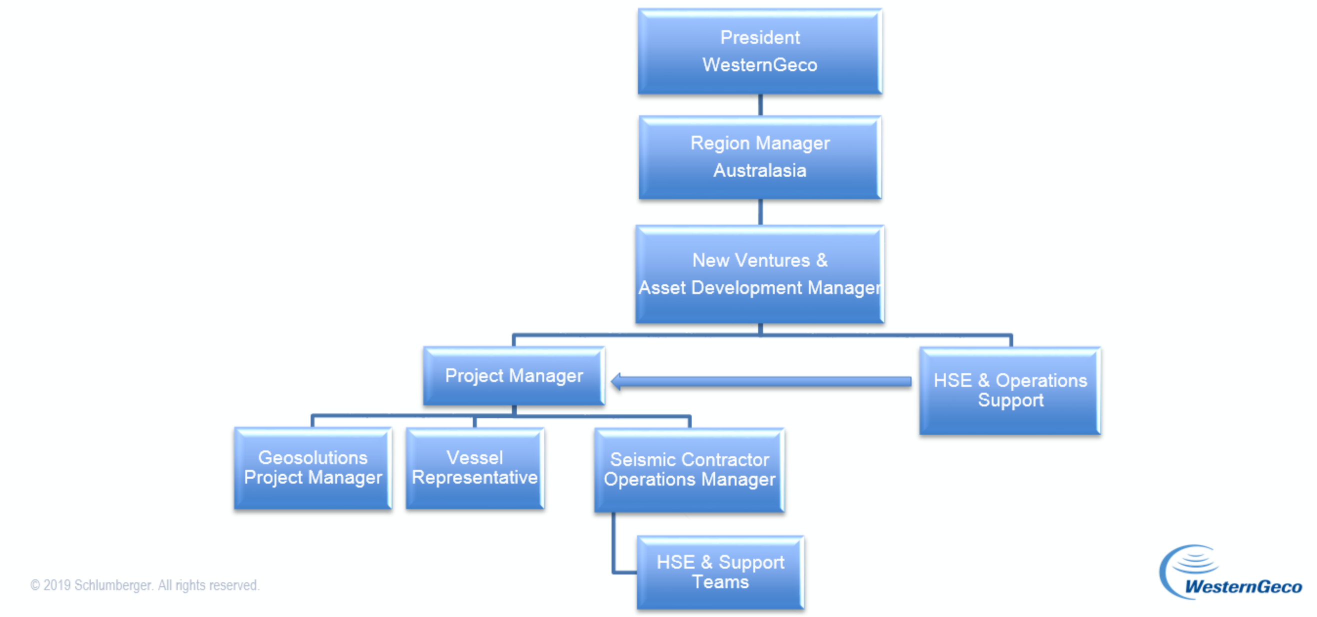


Figure 54 Organisation Chart

10.2.1 Communications

The Vessel Master and SLB Onboard Representative are jointly responsible for keeping the vessel crew informed about environmental issues, acting as a focal point for personnel to raise environmental issues, and consulting and involving all personnel in the following areas:

- Issues associated with the implementation of the EP;
- Any proposed changes to equipment, systems, or methods of operation of plant, where these may have potential environmental implications; and
- Any proposals for the continuous improvement of environmental protection, including the setting of environmental outcomes and training schemes.

Weekly HSE meetings will be held onboard each vessel used for the duration of the Seismic Survey with minutes recorded for all items and issues discussed and what the action items are. The minutes of each meeting, including action items from the meetings, will be made available to all personnel following the meeting.

Other forms of internal communication include daily toolbox meetings, which are undertaken at the start of each day, at the start of each shift or before every critical or unfamiliar job. This toolbox meeting includes all personnel involved in the task and includes aspects such as housekeeping, health and safety, and spill prevention requirements.

Any concerns or issues that arise in relation to environmental performance/requirements of the EP will be recorded and communicated through:

- Personnel related issues/concerns raised are to be communicated with the Vessel Master or SLB Onboard Representative, and are communicated/recorded in daily meetings if required; and
- Infield stakeholder engagement with fishing and shipping activities is managed by the vessel master/crew and recorded on the vessel log (i.e. stakeholders in field must follow mariners' warnings and navigational requirements and/or agreed controls under this EP).

Consultation with relevant stakeholders identified in this EP throughout the Seismic Survey will be managed and maintained and all records of communications with external stakeholders (i.e. calls, emails, meetings etc.) will be recorded.

10.3 Training, Competencies and Awareness

The correct selection, placement, training and ongoing assessment of employees and contractors is a key component of any offshore activity in order to ensure that operations meet all business, statutory and environmental requirements.

This process is guided by SLB internal standards including Training and Competency (*SLB-QHSE-S005*), Contracting (*SLB-QHSE-S012)* and Newcomer Employee (*Green Hat*) Program Guideline (*SLB-QHSE- S017-G001*). The basis of recruitment relies on a position description that details the necessary qualifications, experience and skill levels required to undertake the defined and the HSEQ responsibilities of that position.

10.3.1 Environmental Inductions

All vessel-based SLB employees and contractors will be required to attend a survey-specific environmental induction prior to the commencement of operations in line with SLBs Marine Induction Procedure (*M3MAQ/P007*). This environmental induction will include awareness and compliance aspects of the approved EP, including:

- Environmental regulatory requirements;
- Environmental sensitivities within the Bonaparte Basin, and the key impacts/risks associated with the Seismic Survey;
- The control measures and relevant EPSs, EPOs and measurement criteria, including but not limited to:
    - The relevant requirements of the EPBC Policy Statement 2.1;
    - Megafauna sighting procedures;
    - Environmental incident reporting;
    - Waste segregation, containment and disposal;
    - Housekeeping and spill prevention; and
    - Spill preparedness and response.

Responsibilities under the MoC process will also be communicated to all personnel involved in the Seismic Survey and SLB staff managing the survey (either shore-based or onboard the vessel). This will include reiterating the requirements for individuals being vigilant of potential changes to the Seismic Survey with the potential for affecting the risk and impact profile, or which may cause deviation from the accepted EP.

Induction attendance records will be retained; made available on request (i.e. SLB internal audits and inspections). The SLB Onboard Representative is responsible for ensuring personnel receive this induction with all personnel being required to sign an attendance sheet to confirm their participation in and understanding of the induction.

10.3.2 MMOs and PAM Operators

The EPBC Act Policy Statement 2.1 requires MMOs to have '*proven experience in whale observation, distance estimation and reporting*'. SLB will employ experienced trained MMOs, as identified by their professional CVs and records of relevant past experience. In particular, given the sensitivity towards mammals in the OA and the extended 2 km Shut-down Zone for baleen whales that will be implemented throughout the OA for the entire duration of the survey (**Section 3.4**), SLB will require the following minimum level of experience or the MMOs:

- MMO's must have logged a minimum of 20 weeks' relevant sea-time engaged in MSS operations in Australian waters as an MMO or MFO. In particular, MMOs will need to be able to demonstrate competency in identifying the species that have been identified as likely to be present during the Seismic Survey (as stated in this EP). Competency will also need to be demonstrated in assessing behaviour and estimating distance.

Likewise, PAM Operators employed during the Seismic Survey will need to be experienced in the use of PAM for the detection and monitoring of cetacean vocalisations. This experience will be identified by their professional CVs and records of relevant past experience. In particular, SLB will require that the following minimum level of experience is required for the PAM Operators:

- PAM Operators must have logged a minimum of 20 weeks' relevant sea-time engaged in MSS operations in Australian waters as a PAM Operator (following the recommendation of the Marine Mammal Observer Association (MMOA, 2019)). In particular PAM Operators will need to be able to demonstrate competency in the acoustic identification of the species that are likely to be present during the Seismic Survey (as stated in this EP); noting that the ability to acoustically detect some species (e.g. blue whales) is limited. PAM Operators will also need to demonstrate competency in interpreting acoustic software and estimating distance to any whale calls detected.

All contracted MMOs and PAM Operators will be aware of the requirements of the EPBC Act Policy Statement 2.1 Part A procedures and adopted Part B procedures. MMOs and PAM Operators will also have experience with the preparation of compliance and sighting reports (see **Section 10.6.2**).

10.4 Review of Environmental Performance

The development of this EP resulted in a number of control measures, EPOs, EPSs and relevant measurement criteria to ensure the control measures are operating to reduce the impacts and risks to **ALARP** and **Acceptable Levels**. These provisions have been based on several pieces of legislation (outlined throughout **Section 2**) to provide a suite of control measures (outlined throughout **Section 7** and **8** for the planned and unplanned activities respectively) that ensures that levels of environmental performance specifically defined in the EP are being met.

SLB will continue to monitor the environmental performance of the control measures during the Seismic Survey in line with the Bonaparte Basin HSE Plan and as per Regulation 14(6) of the Environment Regulations to ensure that:

- The EPOs and the associated EPSs are being met through a review process. This process will ensure that, where necessary, the EPOs and/or EPSs can be amended to maintain the management of impacts and risks to the receiving environment to **ALARP** and an **Acceptable Level**;
- Any opportunities for improvement are identified promptly to further reduce potential impacts and risks, and any non-conformances are identified to allow appropriate corrective action is undertaken; and
- All required monitoring requirements have been undertaken prior to the completion of the Seismic Survey.

The suite of control measures will be incorporated into the key requirements to review SLBs environmental performance during the Seismic Survey, including:

- Ensuring sufficient monitoring and recording is undertaken (discussed in **Section 10.4.1**);
- Maintenance of accurate records as required within the Environment Regulations (discussed within **Section 10.4.2);**
- Undertaking auditing to ensure the processes and systems adopted are effective (discussed in **Section 10.4.3**);
- The management of non-conformances (discussed in **Section 10.4.4**); and
- The review of the EP to continuously look for ways to improve operations during the Seismic Survey (discussed in **Section 10.4.5**).

10.4.1 Monitoring and Recording

As required by Regulation 14(7), each vessel operating as part of the Seismic Survey will prepare a daily report and carry out a weekly inspection (which will be included within the end-of-week daily report) to ensure that:

- Environmental issues and/or concerns raised through the MoC (**Section 10.4.5**) process are communicated to SLB management and recorded for future learnings;
- Any issues arising from SOPEP testing (**Section 10.9.1**) are reported;
- Monitoring of key parameters (**Table 107**) are recorded for when a review of the EP is undertaken including an evaluation of environment performance based on the potential impacts and risks associated with the Seismic Survey; and

- The performance of key equipment as described in this EP is checked at least weekly to ensure ongoing reduction of risks and impacts to **ALARP** and **Acceptable Levels**, and any potential issues (i.e. observations of poor operating condition/performance or non-conformances) are continually monitored and raised as soon as practicable.

The results will be reported in the end-of-survey EP performance report submitted to NOPSEMA (**Section 10.6.1**).

Table 107 Summary of Routine Environmental Monitoring

Environment Aspect/Activity	Parameter Measured	Reporting to be Maintained
Physical presence of Seismic Vessel and towed equipment		
Negative interactions with marine fauna	Marine fauna ship strike or entanglement incidents	Incident records of location, time, type of marine fauna, expected injury. DoEE Ship Strike Database.
Negative interactions with other marine users	Incident or near miss involving the Seismic Vessel and other marine users	Report provided to AMSA on any incidents or near misses that threaten the safety of the Seismic Vessel and/or requires remedial action by the Support Vessel. Bridge logs.
Acoustic disturbance to the marine environment		
Impacts on whales through acoustic disturbance	Whales	Daily report summaries any adaptive measures required to be applied due to whales. Weekly checklist confirms that whales sighting datasheets are correctly filled out and maintained.
	Adherence to EPBC Policy Statement 2.1	Bridge Logs. MMO Report. PAM Logs. Whale Observation Report.
	Application of defined Shut-down Zone	MMO Report.
	Restrictions of acoustic release outside of OA	Bridge Logs and digital records such as AIS.
	Crew training	Induction and training records for crew, MMOs and PAM Operators.
Routine permissible waste discharges		
Grey water and sewage discharge	Liquid waste discharges	Weekly inspection record confirms that recordable discharge records are maintained. Discharge logs confirm discharges occurred outside of AMPs. Maintenance records confirm equipment/machinery functioned correctly.
Atmospheric emissions		
Refuelling	MGO volume	The daily record will record the day of bunkering and provide sufficient detail to confirm the bunker notes/records are maintained, the refuelling checklist is completed, and no incidents occurred.

Environment Aspect/Activity	Parameter Measured	Reporting to be Maintained
Minimisation of atmospheric emissions	MGO usage	Weekly inspection records the volume of MGO used.
No deliberate discharge of ODS	ODS discharges	ODS Record Book confirms no deliberate discharge of ODS.
Incineration of approved substances	Substances incinerated	Incineration Log confirm only wastes approved by the Garbage Management Plan is incinerated and at a distance greater than 12 NM from shore.
Artificial light emissions		
Light generation from Seismic Vessel	Directional lighting and minimisation of unnecessary lighting	Pre-mobilisation audit and inductions. Bridge logs.
	Separation distances from shore maintained	Digital records, such as AIS tracking, showing separation distance of at least 3 NM from shore maintained.
Invasive marine species		
Introduction of invasive marine species	Ballast water exchange	Weekly checklist confirms that ballast records maintained in accordance with the Ballast Water Management Plan. Ballast Water Logbook detailing all ballast water exchanges. Certification of approved ballast water treatment system. Biosecurity clearance using the Maritime Arrivals Reporting system.
	Vessel hull biofouling	Inspection certificate and dry-dock and/or anti-fouling application certification. Biofouling Risk Assessment Report. Incident reporting form for any sighting or suspicion of any IMS on vessel(s), in niche areas, and in ports/harbours.
Streamer Loss		
Physical damage to benthic environment from loss of streamer	Location, equipment type, duration of incident and response option taken	Vessel incident report outlining details of equipment loss.
Vessel Collision and Associated Hydrocarbon Spill		
Vessel collision	Location, volume, duration, type of spill and response option taken	Vessel incident report outlining details of incident. AMSA Report Notification. NOPSEMA Reports. POLREP.
Vessel refuelling	Refuelling operations	Bunker documentation showing refuelling operations undertaken at sea and port.
Hydrocarbon Spill Response		
Secondary impacts from response options	Implementation of response options	Vessel incident report outlining 'first-strike' response options undertaken. NEBA Report.

Environment Aspect/Activity	Parameter Measured	Reporting to be Maintained
Accidental Release of Hazardous and Non-Hazardous Materials		
Hazardous and non-hazardous solid waste management	Solid waste generation	Weekly inspection records confirm waste tracking certificates or garbage record books are up to date. Waste Transfer Certificate issued by licensed facility of carrier for onshore transfers.
Accidental release of hazardous and/or non-hazardous material	Location, volume, and duration of incident, and response option taken	Vessel incident report detailing the release. Notice to Mariners lodged for objects unable to be found/retrieved.

10.4.2 Record Management

As required by Regulations 27 and 28 of the Environment, SLB will maintain all documents and reports relevant to the Seismic Survey for a minimum of five years following the completion of the survey which will be made available upon request. Documents and reports to be kept by SLB include:

- The Seismic Survey EP and associated documents, including any reviews or revisions;
- Records of emissions and discharges into the environment made in accordance with the EP;
- End-of-survey EP performance report;
- Stakeholder consultation records;
- Daily vessel operation reports;
- Personnel training and induction records; and
- Records of reportable and recordable incidents.

In addition to the above, the Vessel Master will keep copies of all operation records as required, such as fuel consumption records, oil record book, IOPP/IAPP/ISPP Certificates etc.

10.4.3 Auditing

A pre-survey audit and inspection of the survey vessels will be carried out prior to the commencement of the Seismic Survey to ensure that the vessels are fit for purpose and to ensure that all procedures are in place in order to ensure compliance with the measures outlined in the EP.

This pre-survey audit/inspection will also ensure that the vessel HSE management systems are in accordance with SLB’s internal HSE management systems and policies. This audit will review the risk of the establishment of an IMS, including for IMS inspection certification and dry-dock and/or anti-fouling application certification, to ensure that the vessel does not pose an unacceptable risk for the establishment of an IMS. In addition to the above, the on-board spill response capability of the vessel will be audited against its SOPEP, and the respective control measures outlined within this EP to ensure appropriate preparedness for the unlikely event of a spill occurring.

SLB’s Auditing Standard (*SLB-QHSE-S007*) outlines audit scheduling and the measurements that must be taken during each audit. An audit will be carried out within two months of the commencement of Seismic Survey, with the purpose of assessing the implementation of requirements under the EP. Compliance with the EP will also be continuously audited by the Onboard SLB Representative as part of daily activities.

These audits will include ensuring the EPOs, EPSs and the measurement criteria are being implemented and reviewed to keep impacts and risks to **ALARP** and **Acceptable Levels**. Any non-compliance identified through this auditing process will follow the process outlined within **Section 10.4.4**.

Any findings and recommendations obtained through the auditing process will be distributed to the relevant parties in order to undertake the appropriate actions.

10.4.4 Management of Non-Conformances

A breach of the any of the EPSs detailed in the EP will be considered a 'non-conformance'. Non-conformances may be identified by any crew member during routine observations, during an inspection or audit, or as a consequence of an unplanned activity. All crew are required to report any non-conformance they observe.

Following identification of a non-conformance, remedial actions will be required in order to resolve the issue and to prevent recurrence. Affected parties will be notified and follow-up actions will be communicated to all relevant crew and affected parties. Follow-up actions will be tracked to closure in accordance with the Reports of Non-Conformities, Accidents, Incidents and Hazardous Occurrences Procedure (*M3MISM/P015*)S.

An internal risk assessment will be undertaken when any non-conformances are identified to determine whether any changes are required to operational procedures ensure the impacts and risks are maintained or reduced to **ALARP** and **Acceptable Levels**. Should a change be identified during this risk assessment process, a MoC process will be undertaken as per **Section 10.4.5**.

All non-compliances and remedial actions taken will be recorded by the Onboard SLB Representative and included in the Post-Survey Review Report (**Section 10.6.1**).

10.4.5 Environment Plan Revision and Improvement

Following submission of the EP, SLB will continuously look for ways to improve operations during the Seismic Survey. Regulation 17 of the Environment Regulations requires the resubmission of the EP to NOPSEMA due to a change or proposed change to circumstances or operations. The following criteria will trigger the requirement for a review/resubmission of the EP:

- Any significant modification or new stage of the Seismic Survey that is not provided for in the EP currently in force;
- The occurrence of any significant new environmental impact or risk, or significant increase in an existing environmental impact or risk that is not provided for in the EP;
- The occurrence of a series of new environmental impacts or risks, or a series of increases in existing environmental impacts or risks, which, taken together, amount to the occurrence of a significant new environmental impact or risk, or a significant increase in an existing environmental impact or risk that is not provided for in the EP;
- Identification of recent scientific publications that may have an influence on the risk assessment and increase the environmental risk of the survey;
- Identification of any changes to the biological (including the presence of threatened species not already considered under the EP), physical, and socio-economic environment which may have an influence on the risk assessment and increase the environmental risk of the survey;
- The existing suite of control measures are no longer considered suitable to reduce the environmental risk of the survey to **ALARP** and **Acceptable Levels**;

- During operations the number of sightings and/or power-downs of whales are higher than anticipated during the planning of the survey; and/or
- As requested by NOPSEMA.

Following any non-compliance incident, SLB will review the EP and implemented control measures to identify any potential shortfalls in the EP, any additional mitigation/control measures that could be implemented to prevent such an occurrence from arising again, and to further investigate the cause of the non-compliance.

10.4.6 Management of Change

The MoC process is utilised when there is a change to the proposed activity, or in the circumstances under which it is being undertaken, which may have the potential to increase or change the level of impact or risk of the Seismic Survey that is not currently detailed within an accepted EP. MoC is a transparent process used for the identification, assessment, control and documentation of any such change.

On 30 March 2016, NOPSEMA issued an Environment Alert regarding the proper application of the MoC process. This alert was a result of inspections undertaken by NOPSEMA which found that titleholders manage change through partial or simplistic environmental assessments which differ to the assessments undertaken during the EP process. This alert requested better consideration of changes and a more robust MoC procedure that is in accordance with the procedures for impact and risk assessment within an accepted EP to confirm that these impacts and risks are **ALARP** and at an **Acceptable Level** throughout the life of the EP.

The MoC procedure that would be implemented by SLB for the proposed activity is consistent with this Environment Alert and is further detailed in the sub-sections below. SLBs comprehensive MoC procedure is also consistent with its own internal risk assessment procedure (*SLB-QHSE-S020* a *Hazard Analysis and Risk Control Standard*). This MoC procedure will implement a sound process of change identification, risk and impact assessment, establishment of modified or new controls if required, re-assessment of the risk and impact profile following the same risk assessment procedures as used in this EP, and documentation of the process, rationale and outcomes of the assessment.

10.4.6.1 Triggers for Management of Change

Three regulations under the Environment Regulations require changes to be assessed and managed; these include:

- Regulation 7 – Operations must comply with the accepted EP. This requires that titleholders do not undertake an activity in a way that is contrary to the EP that is in force for that activity. This means that any changes to the Seismic Survey, or the conditions under which it is being enacted, must be assessed for potential divergence from the accepted EP and possible increase in the environmental impact or risk profile;
- Regulation 8 – Operations must not continue if new or increased environmental risk is identified. This makes it an offence for the titleholder to undertake an activity after the occurrence of any significant new environmental impact or risk arising from the Seismic Survey; or any significant increase in an existing environmental impact or risk arising from the Seismic Survey; and the new impact or risk, or increase in the impact or risk, is not provided for in the EP in force for the Seismic Survey; and
- Regulation 17 – Revision because of a change, or proposed change, of circumstances or operations. This requires a titleholder to submit a proposed revision of the EP for an activity before, or as soon as practicable after:

- The occurrence of any significant new environmental impact or risk, or significant increase in an existing environmental impact or risk, not provided for in the EP in force for the Seismic Survey; or
- The occurrence of a series of new environmental impacts or risks, or a series of increases in existing environmental impacts or risks, which, taken together, amount to the occurrence of a significant new environmental impact or risk, or a significant increase in an existing environmental impact or risk, that is not provided for in the approved EP for the Seismic Survey.

The Environment Alert issued by NOPSEMA contained a number of deficiencies that were identified in managing change through the implementation of EPs. Specifically, the following points are relevant to the proposed Seismic Survey which will be regularly considered under this MoC process prior to, and during, the Seismic Survey:

- Extending the duration of a Seismic Survey;
- Consideration of a series of increases, or new, impacts and/or risks, arising from changes to the Seismic Survey over time which additively creates a significant increase in impacts or risk;
- Alteration or removal of an environmental performance standard in the accepted EP, including changes to the wording which may materially degrade or diminish the level of performance;
- Reporting of breaches to environmental performance standards after realising that the standard does not, or cannot, monitor the level of performance set in the EP; and
- Greater discharge to the marine environment than predicted in the EP.

If any of the following types of changes are identified, the MoC process will be implemented:

- Identification of new impacts or risks, such as a stakeholder raises a new issue or concern prior to, or during, the implementation of the EP;
- Increase in impact or risk, such as if the seismic source volume is required to be increased to improve quality of imagery;
- A new stage of the Seismic Survey is required, e.g. if a significant extension of timeline is required to complete the acquisition;
- Reduced ability to effectively implement the EP to meet its stated environmental performance standards, such as if an MMO is taken ill and demobilised; and
- Any incremental change in the Seismic Survey increasing the risk of significant impact.

SLB will undertake regular reviews of the currency of the list of relevant stakeholders and may need to initiate MoC if new stakeholders raise new issues which have potential to significantly increase the risk of interference with the stakeholders' interests.

10.4.6.2 Originator of Management of Change

Throughout the Seismic Survey all personnel involved with the survey, including the Seismic Vessel operator's staff, along with SLB staff managing the survey, are required to keep a lookout for any potential changes to the Seismic Survey which have the potential for changing the impact and/or risk profile, or which may cause deviation from the EP. Any personnel in charge of work functions will be required to report any changes within their area of work, e.g. the Vessel Master will be required to report changes to the functionality of pollution control equipment on the vessel as they become aware of such changes. Similarly, the SLB Onboard Representative will be required to report any potential changes to the seismic activity before they are implemented. Potential MoC triggers shall be reported immediately to the SLB Project Manager. These responsibilities will be reinforced to all personnel during the induction process.

This EP will be reviewed as per the discussion in **Section 10.4** so that any changes to the Seismic Survey, occurrence of a new environmental impact or risk, scientific publications or changes to the existing environment are taken into account during the Seismic Survey. This review will ensure that the impacts and risks of the Seismic Survey remain **ALARP** and at an **Acceptable Level**.

10.4.6.3 Management of Change Process

If potential changes to the Seismic Survey activity are identified which trigger a MoC as identified above, the following steps will be initiated and documented:

- Stop work if the survey has started, or delay commencement of new activity;
- Establish a risk assessment team and advise the SLB Project Manager;
- Assess the need for SLB MoC (*SLB-QHSE-S010 Management of Change and Exemption Standard*);
- Initiate a risk and impact assessment by the risk assessment team, using the same procedures as outlined in **Section 6** of this EP. This process will determine if the increase in risk is significant and would therefore trigger a requirement to revise and resubmit the EP under Regulation 17 of the Environment Regulations;
- If resubmission of the EP is required, the work or the new activity is to be suspended until revised EP is accepted by NOPSEMA;
- If resubmission is not required, conduct and document detailed risk and impact assessment;
- Consultation with stakeholders if changes may affect their activities or interests (based on previous feedback discussed throughout **Section 5** and **Appendix I**);
- Develop any additional controls required to reduce risks and impacts to **ALARP** and to an **Acceptable Level**;
- Develop an EP Addendum which documents the following:
  - The MoC process followed;
  - Risk and impact assessment process undertaken;
  - Rationale for conclusions on residual risk;
  - Stakeholder feedback;
  - Additional controls to be implemented;
  - Demonstration of **ALARP** and justification for acceptability;

- Revised performance standards, measurement criteria, responsibilities for each revised or new control; and
- Confirmation that all sections of EP have been checked to ensure any potential deviations from the accepted plan have been captured and addressed.

10.4.6.4 Approver of Management of Change Outcomes

Should the MoC procedure not trigger Regulation 17 resubmission (and hence approval from NOPSEMA), any work on new or modified activities will only commence on the authority of the SLB Project Manager.

10.5 Support Vessel and Chase Vessel Management Plan

One Support Vessel and one Chase Vessel will be present in close proximity to the Seismic Vessel for the duration of the Seismic Survey. The primary role of these vessels is to manage any possible interactions between the Seismic Vessel and the seismic array (i.e. acoustic source and streamer) with any other vessels or maritime activities occurring in the area. The Support Vessel and Chase Vessel will assist with informing any other vessels in the path of the approaching Seismic Vessel that cannot be raised on VHF radio or any other means. In addition, the Chase Vessel will also be utilised as an additional platform for marine mammal observations while acquisition occurs inside the blue whale migratory BIA and 17 km buffer. Within this area, an extended (5 km) observation zone will be implemented and two dedicated and trained MMOs will be stationed on the Chase Vessel to support the MMO efforts from the Seismic Vessel.

While the presence of the Support Vessel and Chase Vessel in the OA does pose additional risk to marine mammals in the area, the Vessel Master of these vessels will be operating in accordance with the EPBC Regulations Part 8, Division 8.1 in regards to the minimum approach distances and vessel speed for "other craft" and follow the prescribed actions when adult cetaceans and/or calves are present within the caution zone (defined by these regulations as a 150 m radius around a dolphin, and 300 m radius around a whale).

The following procedures will be implemented onboard the Support Vessel and Chase Vessel:

Communications:

- The Support Vessel and Chase Vessel will be in close contact with the Seismic Vessel on VHF radio at all times to ensure clear communications are maintained;
- The Support Vessel and Chase Vessel will be able to receive and transmit communications via VHF radio at all times with all maritime traffic in the area; and
- The MMOs on the Chase Vessel will maintain direct communication with the MMOs and PAM Operators onboard the Seismic Vessel at all times throughout their observational shift.

Maintenance of distance to Seismic Vessel:

- The Support Vessel and Chase Vessel will be present around the Seismic Vessel at all times unless an intervention with another marine user is necessary;
- In the case that the Support Vessel or Chase Vessel is unable to maintain such a presence (e.g. it is undertaking intervention actions), the Masters of the survey vessels will maintain radio contact.
- While the Seismic Vessel has an active source within the blue whale migratory BIA and the 17 km buffer, the Chase Vessel will have an MMO on watch during daylight hours observing for marine mammals;

- During this time the Chase Vessel will travel c. 3 km ahead of the Seismic Vessel (Defined as an 180° arc ahead of the Seismic Vessel, noting that the Chase Vessel should focus on the portion of the arc closest to the blue whale migratory BIA and buffer) and will conduct visual surveillance for marine mammals during daylight hours; and
- The Support Vessel and Chase Vessel will be equipped with radar, ARPA and AIS, allowing the exact position and distance between the survey vessels to be continuously monitored.

Use of Chase Vessel as a secondary observational platform for marine mammals:

- Two trained and experienced MMOs will be on the Chase Vessel to provide additional visual observational capabilities while the Seismic Vessel has an active source within the blue whale migratory BIA and the 17 km buffer;
- The on-duty MMO will be stationed on the bridge of the Chase Vessel during day light hours to assist the Seismic Vessel detect marine mammals;
- If the MMOs on the Chase Vessel observe a marine mammal, the lead MMO on the Seismic Vessel will be notified immediately;
- The MMOs on the Chase Vessel will have the same roles and responsibilities as those on the Seismic Vessel, including the full authority to direct control measures such as shut-down/power-down of the acoustic source if a whale is observed within a relevant shutdown/low power zone; and
- After the Seismic Vessel has been notified by the Chase Vessel of a shutdown/power-down requirement, the appropriate control measure will be implemented immediately by the Seismic Vessel (including any required adaptive management procedure, see Section **7.2.2.2.5**).

10.6 Reporting

SLB has internal requirements for the recording and reporting of incidents, as outlined in the Reports of Non-Conformities, Accidents, Incidents and Hazardous Occurrences Procedure (*M3ISM/P015*). There are legal obligations under the Environment Regulations to report incidents to NOPSEMA within a specified time period. The legislative requirements for recording and reporting are described in further detail below.

The Environment Regulations requires a number of notifications for starting and ending an activity, and ending of an EP. SLB will comply with these notification requirements, as per the below:

- Start of Activity Notification – At least 10 days before the commencement of the Seismic Survey, SLB must provide written notification to NOPSEMA of the date of intention to commence the activities approved under the EP;
- End of Activity Notification - At least 10 days following the completion of the Seismic Survey, SLB must provide written notification to NOPSEMA of the date of the completion of the activities approved under the EP; and
- End of EP Notification – As soon as practicable on the completion of the last activity covered under the survey, SLB must provide written notification to NOPSEMA informing that all of the activities and obligations covered under the EP have been completed. Following acceptance of the notification by NOPSEMA, the EP is no longer in force.

In addition to the above notifications, further pre-survey and post-survey notifications will be undertaken to the relevant parties outlined within **Section 5.4.9** and **5.4.10**.

10.6.1 Environmental Performance Reporting

Under Regulation 14(2) of the Environment Regulations, SLB are required to submit an Annual Report that provides a review of compliance with the EP's EPOs and EPSs. Regulation 26C also requires submission of a review report following the completion of the Seismic Survey. The Annual Report and post-survey review report will be combined and submitted together.

The Post-Survey Review Report/Annual Report will be submitted to NOPSEMA within two months of the completion of the survey. The content of this report will include the following:

- A review of routine activities and incident records, including:
  - Whale sighting records, and any other interactions with whales requiring start-up delays;
  - Records of any interaction between marine fauna and vessels of towed equipment used during the survey; and
  - Records of any unplanned activities, such as accidental discharges of hazardous and non-hazardous substances, vessel collisions or negative interactions with commercial operators in the Bonaparte Basin (fishing, shipping etc.);
- An assessment of compliance with requirements set out in the EP (i.e. compliance with the EPOs and EPSs);
- An assessment of compliance with the SLB HSE Management Systems and Policies; and
- A review of all recordable and reportable incidents.

10.6.2 Marine Mammal Reporting

As required by the EPBC Policy Statement 2.1, a report on all whale interactions will be provided to the DoEE within two months of survey completion. The report will contain the following information as a minimum:

- The location, date and start time of the survey;
- Name, qualifications and experience of any MMOs (or research scientists) involved in the survey;
- The location, times and reasons when observations were hampered by poor visibility or high winds;
- The location and time of any start-up delays, power downs or stop work procedures instigated as a result of whale sightings;
- The location, time and distance of any whale sighting including species where possible; and
- The date and time of survey completion.

This information will be recorded using the 'Cetacean Sightings Application' software as outlined in the EPBC Act Policy Statement 2.1. Upon completion of the survey the information entered into this application will be exported as a text file and emailed to sightingsdata@aad.gov.au.

The following additional information may also be collected during the Seismic Survey. Note that this additional information includes sightings of all marine mammals (i.e. dolphins and pinnipeds, as well as whales):

- The location, time and distance of any marine mammal sighting including species where possible;
- Method of detection (visual or PAM);
- Observation platform;
- Water depth at time of each whale sighting;
- Sea condition (Beaufort scale) at time of each marine mammal sighting;
- Number of animals involved in each marine mammal sighting (total);
- Number of juveniles involved in each marine mammal sighting (if present);
- Description of behaviour for each marine mammal sighting;
- Description of any injuries, mortality, entanglement or other interactions;
- Distance from seismic source at first sighting;
- Closest subsequent distance to seismic source;
- Behaviour at first sighting (travelling, feeding, milling etc.); and
- Subsequent behaviours (avoidance, attraction and other changes in behaviour).

10.6.3 Reportable and Recordable Incident Reporting

10.6.3.1 Reportable Incidents

Regulation 26 of the Environment Regulations requires SLB to report all 'reportable incidents' that occur in relation to the Seismic Survey. Under the Environment Regulations, a reportable incident is defined as '*an incident relating to the activity that has caused, or has the potential to cause, moderate to significant environmental damage*'.

NOPSEMA must be provided with an oral notification (phone 1300 674 472) of any reportable incident as soon as practicable after the reportable incident, and no later than two hours after the first occurrence of the reportable incident, or after first becoming aware of a reportable incident.

Notification of the Reportable Incident must be oral and must include the following:

- All facts and circumstances concerning the incident that SLB knows, or is able to find out with reasonable effort;
- Actions taken to avoid, or mitigate impacts arising from the reportable incident; and
- Any corrective actions that were taken, or have been proposed to be taken to stop, control, or remedy the reportable incident.

Following oral notification of the reportable incident, a written record of the notification must be provided to the following as soon as practicable:

- NOPSEMA (via submissions@nopsema.gov.au);
- National Offshore Petroleum Titles Administrator (via resources@nopta.gov.au); and
- Department of the responsible State Minister or the responsible Northern Territory Minister.

For the purpose of the Seismic Survey, reportable incidents have been identified as:

- Any incident involving a collision between the survey vessels and marine megafauna;
- Any incident involving the entanglement of megafauna in towed equipment;
- Any incident involving a negative interaction between other marine users (i.e. those identified in the EP) such as a collision or whereby intervention by the Support Vessel is required; and
- Any incident that results in a hydrocarbon spill of > 80 L into the surrounding marine environment.

DMIRS will, as soon as practicable, be notified of any environmental incidents that could potentially impact on any land or water in WA state jurisdiction, and any notifications or reports will be sent to petroleum.environment@dmirs.wa.gov.au.

10.6.3.2 Recordable Incidents

Recordable incidents are breaches of EPOs or EPSs (as outlined in this EP) that do not meet the definition of a reportable incident. A written report must be provided to NOPSEMA as soon as practicable, but not later than 15 days, after the end of the calendar month. If no recordable incidents occur, a monthly 'nil incident' report is required to be submitted to NOPSEMA (via submissions@nopsema.gov.au). The monthly Recordable Incident Report must include the following:

- A record of all recordable incidents that occurred during the calendar month;

- All facts and circumstances concerning the incident that SLB knows, or is able to find out with reasonable effort;
- Actions taken to avoid, or mitigate impacts arising from the recordable incident;
- Any actions that were taken, or have been proposed to be taken to stop, control, or remedy the recordable incident; and
- Any actions that were taken, or have been proposed to be taken, to avoid a similar incident occurring in the future.

10.7 Emergency Response

Health and safety to all personnel on the vessels and all aspects of the marine environment are of the highest importance to SLB and have been considered very seriously throughout the planning and development phase of the Seismic Survey EP. Safety plans, control measures, operational procedures and management plans have been developed by SLB to minimise the potential risk of any emergency that could result in any injury to personnel onboard the vessels or lead to the loss of hydrocarbons exposing marine life within the Bonaparte Basin to hazardous substances. All of these control measures, operational procedures and management plans have been detailed throughout this EP.

As identified in **Section 8.3**, bunkering operations are considered to be the greatest risk for a release of hydrocarbons; however, the greatest consequence from a release of MGO into the marine environment is in relation to a vessel collision or rupture of the hull of the Seismic Vessel. Nevertheless, with the extensive control measures in place and operational procedures, the risks associated with this have been reduced to **ALARP** and an **Acceptable Level**. This is also further supported by the fact that there have been no vessel collisions or groundings with survey vessels recorded in Australian waters in over the last 30 years.

The emergency response procedures that SLB require the active commitment to, and accountability for from all employees and contractors during the Seismic Survey are included in the QHSE Policy (**Figure 2**). The QHSE Policy is regularly reviewed and will be incorporated as part of the crew induction process. Of relevance to the emergency response procedures, the QHSE Policy contains SLBs commitment to:

- Protect and strive for improvement of the health, safety and security of personnel at all times;
- Eliminate any HSE accidents;
- Plan for, respond to and recover from any emergency, crisis and business disruption; and
- Minimise disruption on the environment through pollution prevention.

The following sub-sections provide further details of how SLB are prepared for emergency response, primarily in regard to approaching adverse weather conditions or hydrocarbon spill through the Oil Pollution Emergency Plan. These procedures and plans detail the processes SLB will undertake in the event of an approaching adverse weather system or a hydrocarbon spill. SLB has developed a detailed OPEP which is aligned with the statutory plans of both Commonwealth and State agencies for oil spill response. The roles and responsibilities are clearly defined, in particular who will be the Control Agency in the event of a hydrocarbon release, and likewise, the role of SLB in supporting the relevant Control Agency to achieving the best environmental outcome.

In the event of any emergency occurring during the Seismic Survey, the Master of the Seismic Vessel will assume overall onsite command of all vessels and crew and will take on the role as the Emergency Response Coordinator. The Seismic Vessel will have suitable equipment onboard to respond to any emergencies should they arise, and suitably trained crew will be sufficient in the use of such equipment, they will be familiar with where the equipment is stored, and all crew will undertake regular exercises, which will be documented and recorded.

The emergency response equipment onboard the survey vessels is for first response and will include medical equipment/supplies, firefighting equipment and oil spill response equipment. However, as mentioned some of these items will be limited, such as any serious medical injury or illness would require a medivac to the nearest hospital. In addition, the intention of the oil spill response equipment on the survey vessels is for the purpose of containing and cleaning any spills onboard the vessel, and preventing discharges of hydrocarbons into the ocean, the equipment will not be carried for spill response of hydrocarbons in the ocean.

10.8 Adverse Weather Procedures

Damage to survey equipment, risks to health and safety of survey personnel and increased risks of hazardous material spills can all occur during severe weather events. To mitigate these potential risks, SLB will operate in accordance with the Seismic Vessel contractor’s marine *Adverse Weather Procedures*, which will define a set of controls for managing risks of adverse weather whilst undertaking marine offshore operations, as well as the roles and responsibilities of the key personnel onboard the survey vessels. However, SLB has not finalised the selection of a seismic contractor for the Seismic Survey and consequently the *Adverse Weather Procedures* document is not currently available for submission with this EP. SLB will ensure that a suitable *Adverse Weather Procedures* document of the successful seismic contractor is in place and that it is aligned with SLBs QHSE Policy (**Figure 2**) as part of contract negotiations and prior to commencing the Seismic Survey.

In addition to the *Adverse Weather Procedures* that will be in place, SLB will subscribe to a weather monitoring service that will provide forecasts that update regularly throughout the day. This monitoring service will provide information on wind, waves/seas and currents, primarily to plan the movements and operations to occur when and where in the OA the weather is safest and operationally feasible to acquire the survey safely. The benefit of this service will provide SLB prior warning of any severe weather event forming within, or approaching, the OA. If this were the case, the Vessel Master on-board the survey vessels will make decisions relevant to their authority to ensure safety of the vessel, personnel and the environment. In a worst-case scenario, and a large storm event approach, the Seismic Vessel may retrieve the seismic equipment, and retreat from the area to more sheltered waters.

10.9 Oil Pollution Emergency Plan

The following OPEP provides an overview of SLB's arrangements for responding to a hydrocarbon spill event during the Seismic Survey. It is important to note that SLB's response arrangements do not negate the requirements for a SOPEP (Shipboard Oil Pollution Emergency Plan). Once contracting has been completed with the successful Seismic Vessel, the SOPEP for this vessel will be reviewed, tested, and incorporated into the OPEP arrangements as part of this EP.

This OPEP does not describe spills for petroleum operator infrastructure as the Seismic Survey will have no interactions with offshore infrastructure, thus is out of scope for this EP.

10.9.1 Vessel Shipboard Oil Pollution Emergency Plan

MARPOL Annex I require a SOPEP to be carried on all vessels greater than 400 gross tonnes. In general, a SOPEP describes the steps to be taken:

- In the event that a hydrocarbon spill has occurred;
- If a vessel is at risk of a hydrocarbon spill occurring, and
- For notification procedures in the event of a hydrocarbon spill occurring and provides all important contact details.

The Vessel Master is the overall in charge of the SOPEP and ensuring that all crew comply with the plan.

Although Support Vessels are not required under MARPOL Annex I to have a SOPEP, SLB will require the Support Vessel, Seismic Vessel and Chase Vessel hold a SOPEP.

Each SOPEP will be specific to the vessel that holds it (i.e. separate SOPEPs will be held by the survey vessels and will contain vessel-specific details). The SOPEP will provide the following:

- A description of all actions to be taken by onboard personnel to reduce or control the discharge following a hydrocarbon spill incident;
- A detailed description of all spill response equipment held onboard the vessel including what equipment is available and its stored location;
- Detailed diagrams of the vessel, including locations of drainage systems, location of spill response equipment, and general layout of the vessel;
- An outline of the roles and responsibilities of all onboard personnel with regard to hydrocarbon spill incidents;
- A description of the procedures and contacts required for the co-ordination of hydrocarbon spill response activities with the relevant National and Local Authorities; and
- Requirements for testing of the SOPEP and associated drills.

The SOPEP also includes specific emergency procedures including steps to control discharges for bunkering spills, hull damage, grounding and stranding, fire and explosions, collisions, tank failure, sinking and vapour release.

In accordance with the control measures that will be implemented during the Seismic Survey (**Section 8.3.5**), each vessel involved in the Seismic Survey will have:

- An IMO certified SOPEP;

- A SOPEP drill conducted prior to the Seismic Survey commencing (i.e. within three months). A SOPEP drill is normally every three months; however, due to the proposed duration of the Seismic Survey, with this measure in place a SOPEP drill will be performed at least once during the Seismic Survey;
- The spill kits will be kept fully stocked (to vessel class requirements) and any items will be replaced if they are used; and
- In the event of a hydrocarbon spill, the Vessel Master will implement available controls and resources of the SOPEP.

10.9.2 Statutory Plans

10.9.2.1 Commonwealth Waters

If an oil spill occurs within Commonwealth waters the National Plan will apply and integrates with the relevant State response plans (discussed in **Section 10.9.2.2**). Initial actions would be undertaken immediately by the Vessel Master, with any further actions determined following immediate contact with AMSA.

The National Plan integrates the response from both the Commonwealth and relevant State Governments to ensure an effective response to marine pollution incidents. The National Plan provides for AMSA to be the Control Agency when responding to a spill event who works closely with the relevant State Governments, emergency services and industry to ensure a robust response capability.

10.9.2.2 State Waters

Should a spill occur during the Seismic Survey which originates within, or is likely to move into, State/Territory waters, the relevant statutory plans are as follows (depending on the location and trajectory of the spill):

- The Western Australia (WA) state plan is the WA Department of Transport (**DoT**) Offshore Petroleum Industry Guidance Note – Marine Oil: Response and Consultation Arrangements[16]. Under this plan, the DoT Maritime Environmental Emergency Response (**MEER**) unit is the Control Agency;
- The Northern Territory (**NT**) territory plan is the NT Department of Environment, Parks and Water Security (**DEPWS**) NT Oil Spill Contingency Plan. The NT DEPWS is the Control Agency for Territory waters.

10.9.3 Hydrocarbon Spill Response Framework

SLB utilise the incident classification as outlined in the National Plan (AMSA, 2019) for hydrocarbon spills to provide direction on the potential consequence and impact of the incident and to provide guidance for preparedness, incident notifications and response actions.

Two levels of incident are possible for the Seismic Survey:

- **Level 1:** Incidents are generally able to be resolved through the application of local or initial resources only (e.g. first-strike capacity); and
- **Level 2:** Incidents are more complex in size, duration, resource management and risk and may require deployment of jurisdiction resources beyond the initial response.

[16] https://www.transport.wa.gov.au/mediaFiles/marine/MAC_P_Westplan_MOP_OffshorePetroleumIndGuidance.pdf

The division of the responsibilities in the event of a hydrocarbon spill that affects State and Commonwealth Waters is provided in **Table 108**.

Table 108 State and Commonwealth Hydrocarbon Spill Responsibilities

Location	Spill Source	Statutory Authority	Control Agency	
			Level 1	Level 2
Commonwealth waters	Shipping sourced spill	NOPSEMA	AMSA	AMSA
Western Australia state waters		WA DoT	WA DoT	WA DoT
Northern Territory waters		NT DEPWS	NT DEPWS	NT DEPWS

10.9.3.1 Control Agency

AMSA is the designated Control Agency if a hydrocarbon spill occurs from a ship associated with the Seismic Survey within Commonwealth waters. AMSA will assume control of the incident and respond in accordance with the National Plan. SLB will assume a Support Agency role and provide all available assistance to AMSA during their Control Agency responsibilities.

10.9.3.2 Cross Jurisdictional Coordination

As stated in the National Plan, maritime environmental emergencies have the potential to impact upon the interests of two or more Australian jurisdictions, where both jurisdictions have legitimate administrative and regulatory interests in the incident. In this case, the National Plan addresses these complexities through the *Guidance on the Coordination of Cross Border Incidents* which provides for the establishment of an incident coordination process and the determination of a 'lead' jurisdiction, if appropriate.

10.9.4 Nature and Scale of Preparedness

10.9.4.1 Maximum Credible Scenario

As described in **Section 8.3** it is considered that either a vessel collision or refuelling at sea are the only credible scenarios in which a hydrocarbon spill could occur during the Seismic Survey. As the vessel collision, and associated hydrocarbon spill, would result in the greatest impact on the receiving environment, this scenario is considered here. Based on AMSAs "*Technical Guidelines for Preparing Contingency Plans for Marine and Coastal Facilities*" (AMSA, 2015), the largest fuel tank is adopted as the worst-case Maximum Credible Scenario (**MCS**) that may result from a vessel collision. In the absence of vessel specifications, a spill of 1,000 m^3 of MGO from the Seismic Vessel (through vessel collision) is considered to be the MCS. This MCS is considered to be very conservative, as it is assumed vessel fuel tanks will be at smaller capacity than 1,000 m^3, fuel will be compartmentalised into separate tanks, and while the survey is underway it is likely that the tank will not be 100% full. In addition, there is a hierarchy of controls in place to avoid this MCS from occurring.

10.9.4.2 Hydrocarbon Characteristics and Behaviour

The fuel to be used during the Seismic Survey is MGO which is a light petroleum distillate. This would undergo rapid dispersion and evaporation if it was released into the high energy offshore marine environment of the Bonaparte Basin. DNV (2011) estimates that the half-life of MGO is 2.5 hours in wind speeds of 10 m/s, 1 hour at 20 m/s and approximately 12 minutes in storm conditions with wind speeds over 30 m/s.

Based on outcomes of scenario modelling (summarised in **Section 8.3.2**, and **Appendix B**) for the Bonaparte Basin, the MGO will initially be present longer on the surface; but then undergo partitioning to vapour (i.e. to air), water (as dissolved and dispersed fractions), with a small fraction expected to be beached. The worst-case scenario, whilst predicting that under calm weather and the most proximate release point to result in up to 13% of a 1,000 m^3 spill to be beached, is considered highly conservative. It is highly unlikely given the hierarchy of controls in place to prevent this occurrence.

10.9.4.3 Spatial Extent of Maximum Credible Scenario

Hydrocarbon spill modelling has been summarised in **Section 8.3** to inform the development of this EP and risk assessments. In case the unlikely event that a vessel collision occurs, real-time modelling is also proposed to confirm any assumptions about the EMBA, and level of response required. The extent of the MCS has been based on stochastic modelling using the opensource OpenOil modelling software, modified to include dissolution processes.

Outputs of the scenario modelling were used to define the extent of the EMBA and identification of intersections with potential impacts on sensitive receptors which have the potential to be subjected to surface-oiling (assessed in **Section 4.1**)

10.9.5 Hydrocarbon Spill Response Arrangements

10.9.5.1 Hydrocarbon Spill Resources

SLB will ensure that the vessels used for the Seismic Survey will have on-site response equipment for the prevention and minimisation of loss of oil to the sea. This equipment will include the on-board spill containment and recovery kits which includes absorbent material to meet the flag state and class requirements. All crew onboard will be trained in the use of this spill response equipment and know the location of the response kits. However, this response equipment that will be onboard will not be suitable for deployment to sea for any spills.

For Level 2 spills, the equipment needed (such as booms – although this is not likely needed for MGO) will come from AMSA stockpiles (either from the Perth (Western Australia), Darwin (Northern Territory) stockpile dependant on location of the spill) deployed through the National Plan arrangements. AMSA also has access to stockpiles in other states which are managed by the Australian Marine Oil Spill Centre.

10.9.5.2 Spill Response Options

An assessment of the hydrocarbon spill response options was undertaken within **Section 8.4**. These options include:

- Source control including securing cargo and trimming;
- Natural weathering relating to monitoring and evaluating the spill via vessel/aerial surveillance and trajectory modelling;
- Physical break-up via vessel prop-washing;
- Application of dispersants;
- Containment and recovery through booms and skimmers;
- Protection and deflection utilising booms in the intertidal area;
- Shoreline clean-up through physical removal, surf washing, flushing and natural dispersion; and

- Oiled wildlife response via capture and rehabilitation.

This assessment concluded that source control and natural weathering are the preferred options when dealing with a hydrocarbon spill during the Seismic Survey due to the location of the OA and the likely break-up of MGO.

Source control will be undertaken as part of a Level 1 response in accordance with the vessels SOPEP. For Level 2 responses, SLB will assist where required by the Control Agency, including provision of up-to-date monitoring information from visuals from the available vessels, and trajectory modelling.

10.9.5.3 Notifications

The Vessel Master has the responsibility for notification and reporting of any spills into the marine environment (via POLREP Form contained in the vessel's SOPEP) to the AMSA Response Coordination Centre. Once this initial report has been undertaken, further reports will be sent at regular intervals to keep relevant parties (such as AMSA, SLB, NOPSEMA, etc.) informed.

The SLB On-board Representative is responsible for advising the SLB Project Manager of the spill incident. The SLB Project Manager is then responsible for notifying NOPSEMA.

The Notification and associated timeframes for both Level 1 and 2 responses are outlined in **Table 109**.

Table 109 Hydrocarbon Spill Response Notifications and Timeframes

Incident Classification	Notification Timing	Authority/Company	Contact Number	Instructions
Level 1 and Level 2	Immediately	SLB Project Manager	(08) 9420 4801	Verbally notify SLB of event and estimated volume and hydrocarbon type.
	Within 2 hours	NOPSEMA	(08) 6461 7090	Verbally notify NOPSEMA for spills > 80 L Record notification using Initial Verbal Notification Form or equivalent and send to NOPSEMA as soon as practicable
	Within 3 days			Provide a written NOPSEMA Incident Report Form as soon as practicable (no later than 3 days after notification)
	Within 1 day	NOPTA	(08) 6424 5317	Provide a verbal or written incident summary
	As soon as possible	DNP	(04) 19 293 465	Provide titleholder details, time and location of incident, name of marine park likely to be affected, proposed response arrangements (as per OPEP), confirmation of providing access to relevant monitoring and evaluation reports when available, and contact details for the response coordinator.

Incident Classification	Notification Timing	Authority/Company	Contact Number	Instructions
Level 2	Within 2 hours	AMSA	1800 641 792	Verbally notify AMSA Response Coordination Centre of the hydrocarbon spill. Follow up with a written POLREP as soon as practicable following verbal notification.
	As soon as possible if spill affects Western Australia state waters	WA DoT MEER	(08) 9480 9924	Verbally notify WA DoT MEER. Follow up with a written POLREP as soon as practicable following verbal notification.
	As soon as possible if spill affects Northern Territory waters	NT DEPWS	(08) 8999 5511	Verbally notify NT DEPWS. Follow up with a written POLREP as soon as practicable following verbal notification.
	Within 2 hours	Type II Monitoring Service Provider	To be confirmed prior to commencement	Verbally notify the nominated emergency contact person for the Type II Monitoring service provider (see **Section 10.9.6.2**). Note that the initial notification may not be able to provide key details (i.e. meeting the scientific monitoring program initiation criteria); however, will allow the service provider to commence planning activities to be at the ready. Follow up with more formal notification (includes written documentation), if and when a scientific monitoring program initiation criterion is met (see **Section 10.9.6.3**)

10.9.5.4 Control Measures for Hydrocarbon Spill Response

SLB has developed a number of control measures that are necessary to ensure timely response to an emergency that result, or may result, in hydrocarbon pollution. These control measures are described in **Section 8.4.2**.

10.9.5.5 Capability and Training Requirements

As part of the basic introductory and technical training, all staff will also receive environmental awareness training. As stated within the SLB Environmental Standard (*SLB-QHSE-S008*), SLBs environmental training programme also provides addition training where required, such as for site-specific environmental exposures etc. as all employees are responsible for environmental protection and to minimise the potential impacts on the environment.

10.9.5.6 Arrangements for Testing the OPEP

Prior to the commencement of the Seismic Survey the OPEP will be tested. A summary of arrangements for testing the response arrangements is provided in **Table 110**.

Table 110 Testing Requirements of the Response Arrangements

Environment Regulations	Description
Regulation 14(8B) of the Environment Regulations requires the arrangements for testing the response arrangements to include:	
A statement of the objectives of testing:	The objectives of testing are to provide an opportunity for crew to gain confidence in using the onboard spill equipment and implementing the incident response procedures. The result of this will increase efficiency in the event of an emergency, review the efficiency of procedures and detect any failures in equipment.
A proposed schedule of tests:	Three-monthly drills and exercise will be carried out on all vessels associated with the Seismic Survey in line with IMO/SOPEP. The timing of the drills will be scheduled to coincide at the start of the Seismic Survey. These drills will include, but not be limited to: • Spill response; • Collision and grounding; • Fire and explosion; and • Helicopter emergency.
Mechanisms to examine the effectiveness of response arrangements against the objectives of testing:	Refer to **Section 10.4**, **i**n particular: • Issues raised (if any) will be described in daily report; • Weekly checklists will ensure that spill monitoring equipment is in place and fully stocked; • Requirements described for the review of the EP and OPEP; and • Requirements described for testing below.
Mechanisms to address recommendations arising from tests:	As mentioned above, any issues raised resulting from testing will be described in the daily report. Also, the Vessel Master is made aware that any change to this OPEP and EP is managed through MoC described in **Section 10.4.5**.
Regulation 14(8C) of Environment Regulations states that proposed schedule of tests must provide for the following:	
Testing the response arrangements when they are introduced:	As outlined in **Section 10.9.1**, SOPEP drill conducted prior to the Seismic Survey (within three months) and at least every three months during the Seismic Survey if it proceeds that long.
Testing the response arrangements when they are significantly amended:	The MoC process described in **Section 10.4.6** details the process for any changes to be introduced to the OPEP and EP. Where these changes reasonably affect the arrangements in place, the changed arrangements will be tested prior to finalising the MoC.
Testing the response arrangements, no later than 12 months after the most recent test:	As discussed above, and in **Section 10.9.1**, testing will occur every three months during the Seismic Survey. If this is longer than the duration of the survey, the testing will occur when the survey starts.

Environment Regulations	Description
If a new location for the activity is added to the EP after the response arrangements have been tested, and before the next test is conducted — testing the response arrangements in relation to the new location as soon as practicable after it is added to the plan:	SLB will not be undertaking work outside of the OA described within **Section 3.2.1**.
If a facility becomes operational after the response arrangements have been tested and before the next test is conducted—testing the response arrangements in relation to the facility when it becomes operational:	Not applicable to the Seismic Survey.

10.9.6 Operational and Scientific Monitoring Plan

The Operational and Scientific Monitoring Plan (**OSMP**) is set out in **Appendix L**. This sets out the framework for developing a specific OSMP following an oil spill based on the parameters of the spill, including the location, nature and scale of the spill, and any potentially impacted values including sensitive resources.

As part of the initial response, SLB and the Seismic Vessel operator will provide a first-strike response (i.e. local or initial resources to stop or contain spill) at the direction of the Control Agency and provide ongoing response and monitoring arrangements where requested.

10.9.6.1 Type I Operational Monitoring

As outlined in the OSMP and within **Section 8.3**, Type I 'Operational Monitoring' will be implemented where safe to do so and when there is a net benefit in doing so (as agreed with the Control Agency). This monitoring will be implemented to:

- Determine the extent and character of a spill;
- Visual tracking of the movement/ trajectory of surface slicks;
- Identify areas/ resources potentially affected by surface slicks; and
- Determine sea conditions/ other constraints.

This monitoring will enable the Vessel Master to provide the necessary information to the relevant Control Agency, via a POLREP form, to determine and plan appropriate response actions under the National Plan and the relevant State plan. Operational monitoring and observation in the event of a spill will inform an adaptive spill response and scientific monitoring of relevant key sensitive receptors

Ongoing situational awareness information is provided to the Control Agency through the use of a Marine Pollution Situation Report.

For a Level 2 spill, SLB will undertake real-time spill trajectory modelling to provide assurances that response options can be tailored to the specific spill situation. The modelling will be based on continuous weather monitoring which will be utilised in conjunction with hindcast data to predict any potential beaching locations of the hydrocarbon, if any exist. This real-time spill trajectory modelling will be utilised to focus any potential scientific monitoring if it were to be required (and directed by the Control Agency) in order to monitor the impacts from a spill occurrence. Further discussion on scientific monitoring is detailed within the OSMP and summarised in **Section 10.9.6.2**.

Field-based monitoring, including vessel and/or aerial surveillance, will be undertaken immediately following a spill event. This monitoring will enable the Vessel Master to provide up-to-date information to the relevant Control Agency via the POLREP form to appropriate plan any response options. This field-based monitoring will be utilised further in the development of any scientific monitoring of key sensitive receptors if scientific monitoring is required and requested by the Control Agency. Field-based monitoring has its limitations in that it can only be conducted during daylight hours when the surface slick is visible.

SLB will assist with further operational monitoring (including funding if required) as directed by the Control Agency.

10.9.6.2 Type II Scientific Monitoring

In consultation with the Control Agency, SLB will commit to scientific monitoring dependent on the circumstances of the spill, and the sensitivities at risk. The proposed approach to any detailed scientific monitoring is set out in the OSMP. For the purpose of this EP, it is not considered that more detailed Scientific Monitoring Plans are required to be developed or environmental baseline monitoring is required prior to the Seismic Survey commencing due to the potential risks associated with the Seismic Survey and a hydrocarbon spill through vessel collision are considered very low with all of the associated control measures in place. The identified potential risks are assessed as short term, transient and in the very unlikely even that it did occur, it is unlikely to cause significant impact on the marine environment given the likely volumes and nature of the MGO onboard the Seismic Vessel. It is considered that this proposed approach is reasonable for the Seismic Survey as existing control measures, including meeting all of the legislative requirements and industry standards, will reduce the risk or a hydrocarbon spill to the marine environment.

As discussed in **Section 10.9.4**, it is recognised that there is a remote chance of shoreline contact depending on the location of a hydrocarbon spill. Therefore, SLB commit to having a service agreement with a service provider prior to the commencement of the Seismic Survey. This agreement will ensure SLB has a capability to undertake Type II monitoring if required and also enable the chosen service provider to act (in a capacity as agreed with all parties), to either assist the Control Agency or to undertake key Type II monitoring activities on SLBs behalf (if initiation criteria are triggered).

10.9.6.2.1 Type II – Scientific Monitoring Services Agreement

As outlined above, prior to the commencement of the Seismic Survey, SLB will commit to having a service agreement with a service provider who have demonstrated capability to undertake Type II Monitoring. Prior to agreement with a third-party service provider, they must demonstrate they have the following capabilities:

- Emergency manned mobile telephone number;
- Capacity to prioritise and deploy qualified personnel to execute each scientific monitoring plan (**Section 10.9.6.3**);
- Qualifications and capacity to prepare detailed supporting sampling analytical plans/ monitoring plans for each of the scientific monitoring plans described in **Section 10.9.6.3**;
- The ability to prioritise and mobilise resources to the region (i.e. logistics are in place); or resources are located within the region; and
- Capacity to mobilise personnel and resources to the region as soon as practicable.

After agreeing to a services agreement, should the service provider suggest amendments of **Section 10.7**, this will be managed through the MoC process outlined in **Section 10.4.5**.

A notification will be provided to the service provider within two hours of a known spill event, so the service provider can be 'at the ready', even in the event initiation criteria are not yet triggered.

10.9.6.2.2 Situational Awareness

In the event of a hydrocarbon spill, details that will be exchanged between SLB and the service provider describing situational awareness will include:

- Hydrocarbon type and size of spill;
- Is the spill under control;
- Potential environmental or external influences that may impact a monitoring response;
- Predicted behaviour and predicted trajectory of the spill;
- Potential sensitivities at risk;
- Any ongoing safety concerns; and
- Protection priorities.

10.9.6.3 Scientific Monitoring Plans

The framework for implementing SMPs is set out in the OSMP Document, **Appendix L**. The service provider will develop and implement a variety of scientific monitoring plans if and when the initiation criteria are met (**Table 111**). The monitoring plan(s) required in the event of a Level 2 hydrocarbon spill are assessed based on the nature and scale of the MCS and the situational awareness at the time of any spill.

Due to the potential beaching of a hydrocarbon spill as identified by modelled scenarios, a number of monitoring plans may be required to monitor the potential impacts of a hydrocarbon spill. **Table 111** provides rationale for the various monitoring plans that would be developed.

Any monitoring plans that are implemented are required to be adaptive to allow key sensitivities at risk to be identified. Such as, if a Control Agency makes a reasonable request for monitoring to be undertaken on a receptor which isn't specified here, any service agreement will provide SLB with the capacity to react to these requests.

Table 111 Scientific Monitoring Plan Aims, Objectives and Rationale

Scientific Monitoring Plan	Key Receptor(s)	Aim	Objective	Rationale
Marine water quality	Background water quality	To monitor the hydrocarbons in marine waters to support assessment of impacts and recovery of sensitivities and to verify hindcast modelling	Assess and document the extent and severity of hydrocarbon contamination utilising observations and/or in-water measurements made during operational monitoring. Provide data to inform further scientific monitoring plans.	Reductions in water quality are likely to result due to aromatic hydrocarbons being entrained within the water column. Subsequent partitioning, including to the water column, is expected. Impacts on the water quality from a hydrocarbon spill are important to understand and evaluate as this will potentially impact a range of other receptors, and data will be used to inform other monitoring plans described below.
Intertidal and shoreline sediment quality	Background sediment quality, particularly focused on sensitive locations	Gain an understanding of the characteristics, persistence, and fate of spilled hydrocarbons within sediments exposed to beached oil	Estimate spilled hydrocarbon concentrations within sediment exposed to beached oil. Monitor changes over time in hydrocarbon concentrations. Provide data to assist assessment of impacts on benthic communities. Establish necessary response options.	Should a spill of hydrocarbons reach the shoreline it has the potential to impact on the sediment quality, and as such impact on intertidal biota (described below) which may be exposed to chronic toxicity levels of hydrocarbons.
Intertidal and shoreline habitats and benthos	Invertebrates, filter feeders, benthic primary producers, demersal fish, shorelines and intertidal habitats	Determine the impacts of spilled hydrocarbons on intertidal benthos and habitats	Monitor impacts on intertidal and shoreline habitats from beached hydrocarbon contamination. Define recovery parameters for benthos. Monitor benthos recovery to hydrocarbon contamination. Establish necessary response options.	Shoreline habitats can be impacted from a spill through stranded floating hydrocarbons, or droplets entrained within the water column, with hydrocarbons becoming increasingly entrained within the nearshore waters. Aquatic organisms utilising these habitats can be exposed to elevated levels of hydrocarbons over their thresholds which will ultimately impact the organism.

Scientific Monitoring Plan	Key Receptor(s)	Aim	Objective	Rationale
Seabirds and shorebirds population and recovery	Foraging seabirds and coastal shorebird populations	Assess impacts on seabird and shorebird populations.	Quantify foraging, nesting or breeding seabird and shorebird populations potentially impacted by spilled hydrocarbons. Quantify oiled avifauna, including mortalities. Establish necessary response options.	Seabirds and shorebirds can be impacted by hydrocarbons spills through the presence of hydrocarbons on the surface of the water and from hydrocarbons entrained within the water column. This can lead to potential behavioural, physiological and physical impacts such as deviation from migratory routes, disruption to their indigestion and/or coating their feathers resulting in the inability to fly.
Marine fauna (excluding avifauna)	Marine mammals, marine reptiles, bony fish, elasmobranchs	Assess impacts on non-avian marine fauna potentially impacted by a hydrocarbon spill.	Quantify oiled marine fauna, including mortalities.	Hydrocarbon spills resulting in a surface slick or entrained within the water column has the potential for long-term impacts to marine fauna. Contact between marine fauna and a surface slick or in-water concentrations of hydrocarbon has the potential to elicit lethal and sub-lethal impacts, including behavioural (avoidance of foraging habitats or migratory routes), physiological (inability to digest) and/or physical effects.
Socio economic impact monitoring (fisheries and tourism)	Target species or areas of importance for fishing/tourism	Assess impacts on fisheries (including aquaculture) and tourism activities	Monitor hydrocarbon concentration within tissue of species targeted by commercial fisheries. Identify potential impacts on human health as a result of hydrocarbon contamination. Assess recovery of tourism operations in area affected.	Commercial fishing operations for pelagic fish, prawn fisheries, shellfish can be impact from a hydrocarbon spill which can include lethal and sub-lethal physiological and physical effects. Any exposure to commercial and recreational target species can result in the tainting of flesh and increase in toxicity above human consumption thresholds. In terms of tourism, a hydrocarbon spill can result in a negative perception on the environment impacted by the spill.

10.9.6.3.1 Development of Detailed Scientific Monitoring Plans

The agreed service provider will develop detailed scientific monitoring plans after receiving the initial notification in the event of a spill, and when the initiation criteria outlined in **Table 111** have been met. A draft scientific monitoring plan will be provided to SLB as soon as practicable, but within 24 hours after receiving the initial notification that a hydrocarbon spill has occurred. A final proposed monitoring plan will then be provided to the relevant Control Agency for review as soon as practicable, but within 24 hours of initial notification.

The monitoring plans will include, as a minimum:

- Objectives and rationale of the monitoring plan: Each plan developed will outline the key objectives, rationale and focus of the plan;
- Baseline information: It is important for each monitoring plan to specify the details of the baseline to be applied, or a method for selection of suitable reference/control sites. If possible, previous monitoring from published studies and findings is to be utilised;
- Spatial awareness: It is important for any scientific monitoring plan to provide information and outcomes obtained from the operational monitoring (such as real-time spill trajectory modelling) to support the proposed design;
- Methodology: The proposed survey methodology should consider the statistical methods and sampling effort required to achieve the objectives of the scientific monitoring plan. If sampling is proposed as part of the monitoring plan, industry recognised methods for collection and analysis of the samples must be used. This includes utilising accredited laboratories and following best practice guidelines and applicable legislation where applicable. The methodology should include, as a minimum:
    - Details of any permits or approvals required to undertake the work, including whether there are any exemptions;
    - Collection and analysis requirements (i.e. permits);
    - Personnel proposed to undertake the monitoring, including appropriate qualifications and skills;
    - Equipment required to complete the proposed monitoring;
    - HSSE requirements to complete the survey;
    - QA/QC requirements if appropriate;
- Initiation criteria: The criteria used to initiate the proposed scientific monitoring plan;
- Termination criteria: Each monitoring plan will include a termination date at which time the monitoring can stop which is consistent with the objectives of the monitoring plan. These criteria must be adaptive and be able to change based on the actual circumstances of the impacts and/or risks of assessment;
- Management of change: The monitoring plans must be adaptive to ensure the impacts and risks are managed appropriately. As such, if a monitoring plan is required to change to adapt to these circumstances, then a process for change needs to be detailed so that any revision is provided to SLB and the relevant Control Agency for acceptance as soon as practicable. Any revisions undertaken must be tracked to clearly communicate the current status of the monitoring requirements; and

- Reporting: Each monitoring plan is required to detail the reporting of results during and post monitoring. This reporting will include ongoing situation reports during the implementation of monitoring; the timing of these situation reports will be based on the nature and scale of the impacts/risks. Post monitoring, a draft report and third-party peer reviewed report will be provided to SLB, the Control Agency and NOPSEMA which will include any recommendations resulting from the monitoring plan.

10.9.6.3.2 Implementation of Scientific Monitoring Plans

During the development of the monitoring plan(s) outlined in **Section 10.9.6.3** above, the service provider will undertake all planning actions required to mobilise to the site. This will include providing a brief proposal to SLB which will outline the resources and personnel required, transport arrangements and timeframes for implementation. The service provider will undertake all reasonable measures to mobilise to the site as soon as practicable. The ability for the service provider to mobilise within 24 hours will be required under the service agreement.

Due to the low likelihood of a spill occurring, it is not considered reasonable to have these resources on standby during the Seismic Survey. It would require considerable financial investments over and above the significant control measures implemented to reduce the risks of a vessel collision to **ALARP** and **Acceptable Levels**. Therefore, SLB consider the approach outlined above to be reasonably practicable based on the nature and scale of the risks associated with the Seismic Survey.

10.9.6.3.3 Initiation Criteria for Scientific Monitoring Plan

The initiation criteria (**Table 112**) for each monitoring plan is broadly applied to enact the response described within this EP. However, it is important to note that the final decision to commence each monitoring plan will be based on the net environmental benefit in which the environmental sensitivities should be avoided if the monitoring proposed may reasonably result in further impacts and offer no net benefit.

Table 112 Scientific Monitoring Plan Initiation Criteria

Plan	Initiation Criteria
Marine water quality	Notification of a Level 2 or greater hydrocarbon spill.
Intertidal and shoreline sediment quality	Notification of a Level 2 or greater hydrocarbon spill. and Where modelling and/or Operational Monitoring indicates likely exposure to intertidal and/or shoreline sediments. or Reports are received of shoreline and/or shoreline contact from hydrocarbon spill.
Intertidal and shoreline habitats and benthos	Notification of a Level 2 or greater hydrocarbon spill. and Where modelling and/or Operational Monitoring indicates likely exposure to intertidal and/or shoreline habitats or benthos. or Reports are received of shoreline and/or shoreline contact from hydrocarbon spill.
Seabirds and shorebirds population and recovery	Notification of a Level 2 or greater hydrocarbon spill. and Where modelling and/or Operational Monitoring indicates likely exposure to seabird and/or shorebird populations. and/or Reports are received of contact with avifauna from hydrocarbon spill. and/or Reports of oiled or dead avifauna are received.
Marine fauna (excluding avifauna)	Notification of a Level 2 or greater hydrocarbon spill. and Where modelling and/or Operational Monitoring indicates likely exposure to non-avian marine fauna. and/or Reports are received of contact with non-avian marine fauna from hydrocarbon spill. and/or Reports of oiled or dead non-avian marine fauna are received.
Socio economic impact monitoring (fisheries, aquaculture and tourism)	Notification of a Level 2 or greater hydrocarbon spill. and Where modelling and/or Operational Monitoring indicates likely exposure to aquaculture operations. and/or Reports are received of commercial fisheries closures due to hydrocarbon contamination. and/or Reports are received of tourism operation closures due to hydrocarbon contamination.

10.9.6.3.4 Termination Criteria for Scientific Monitoring Plan

Each scientific monitoring plan that is undertaken as part of a response operation will continue until certain termination criteria have been met (**Table 113**), in consultation with the relevant Control Agency.

Table 113 Scientific Monitoring Plan Termination Criteria

Plan	Termination Criteria
Marine water quality	Hydrocarbon spill has ceased, there are no visible sheens present and no further sheens are predicted by the modelling. Monitoring data of in-water concentrations of hydrocarbons have been compiled and analysed. Data confirm water concentrations are at background/reference levels. Reporting on sampling has been completed detailing extent and severity of spilled hydrocarbons which can enable further analysis of impacts on other receptors in any further scientific monitoring plans.
Intertidal and shoreline sediment quality	Hydrocarbon spill has ceased, there are no visible sheens present and no further sheens/beaching are predicted by the modelling. Any monitoring undertaken confirms concentrations of hydrocarbons present within sediments fall below relevant receiving guidelines (e.g. ANZG, 2018), and pose low to negligible ecological risk. Reporting on the sampling has been completed detailing the extent and severity of spilled hydrocarbons which can enable further analysis of impacts on benthic communities.
Intertidal and shoreline habitats and benthos	Hydrocarbon spill has ceased, there are no visible sheens present and no further sheens/beaching are predicted by the modelling. Impacts from hydrocarbon spill on benthos are quantified and recovery evaluated. Reporting on the monitoring has been completed detailing the extent and severity of spilled hydrocarbon impacts on benthos.
Seabirds and shorebirds population and recovery	Hydrocarbon spill has ceased, there are no visible sheens present and no further sheens/beaching are predicted by the modelling. Objectives and values associated with any relevant avian species recovery plans and/or conservation advice's have been met. Impacts from hydrocarbon spill on avifauna quantified and recovery evaluated. Reporting on the monitoring has been completed detailing the extent and severity of spilled hydrocarbon impacts on avifauna.
Marine fauna (excluding avifauna)	Hydrocarbon spill has ceased, there are no visible sheens present and no further sheens are predicted by the modelling. Objectives and values associated with any relevant species recovery plans and/or conservation advice have been met. Impacts from hydrocarbon spill on marine fauna (excluding avifauna) quantified and recovery evaluated. Reporting on the monitoring has been completed detailing the extent and severity of spilled hydrocarbon impacts on marine fauna (excluding avifauna).
Socio economic impact monitoring (fisheries, and tourism)	Hydrocarbon spill has ceased, there are no visible sheens present and no further sheens are predicted by the modelling. Impacts to important commercial fisheries quantified and recovery evaluated. Impacts to seafood quality and secondary impacts on human health evaluated. Impacts on tourism ventures quantified and evaluated. Reporting on the monitoring has been completed detailing the extent and severity of spilled hydrocarbon impacts on commercial fisheries, and tourism operations.

10.9.7 OPEP Review and Revision

In accordance with subregulation 14(8) of the Environment Regulations, the OPEP will be reviewed, updated and resubmitted to NOPSEMA should a change to the existing OPEP be required. It is considered, such changes to the OPEP could arise due to:

- A change to the EP that may impact spill response capabilities or coordination, such as an increase to the potential risk of a spill or release of hydrocarbons;
- When a significant change to the activities currently included within this EP has occurred, which could have implications on spill response or coordination;
- During routine testing of the OPEP, where improvements or corrections of the current OPEP are identified; and
- Any learnings from the result of a Level 1 or Level 2 spill or incident.

Any changes made to the OPEP, and any subsequent resubmission will be informed by the Environment Regulations or any other relevant Commonwealth regulations. If a change to the OPEP is required, SLB will undertake this in accordance with the MOC procedures defined in **Section 10.4.6**.

The SLB Project Manager will be responsible for the OPEP and ensuing that any relevant updates are made to the OPEP, and should any amendments be required, that the revised plan is submitted to NOPSEMA.

11 Conclusion

SLB has prepared this EP to support the application process for the Seismic Survey which may commence as early as September 2022 and will be completed before 30 June 2024, taking between 120 and 190 days to acquire the 12,000 km^2.

As part of developing the EP, an EMBA was derived utilising stochastic hydrocarbon dispersion and fate modelling (**Appendix B**) which provides a conservative area that may be impacted by the Seismic Survey. A comprehensive description of the key physical, biological, socio-economic and cultural characteristics of the existing environment and the sensitivities and receptors has focused on the EMBA.

This EP assesses the potential risks and associated impacts from the Seismic Survey on the biological and socioeconomic values of the EMBA, employing three key methods: 1) an extensive literature review; 2) project specific UAM to examine the spatial spread and magnitude of acoustic outputs from the Seismic Survey and to predict how this would affect various receptors; and 3) extensive stakeholder engagement.

UAM (**Appendix A**) was undertaken to predict received SELs and spread of noise emissions, or the 'footprint' of acoustic emissions generated from the Seismic Survey. The UAM involved three key components: array source modelling; underwater acoustic propagation modelling; and animat modelling. The results from the UAM were then compared with a variety of noise criteria and sound levels identified in scientific research to cause the onset of PTS and TTS.

Through the development of the EP, SLB has undertaken an extensive stakeholder engagement programme with those stakeholders considered as 'relevant persons', including commercial and recreational fishers, industry bodies and associations, marine park authorities, tourism operators etc. The stakeholder engagement process has provided SLB with a deep level of understanding with regard to the potential impacts (both real and perceived) from interested parties. The nature of responses varied; some included requests for further information, to be kept informed and some noted that the proposed survey was not relevant for their interest in the area. Only one objection to the Seismic Survey was reported throughout the stakeholder engagement programme which concluded that detailed consideration be given to the protection of BIAs and their corresponding receptors areas of cultural heritage significance. These claims were considered to be adequately addressed through the development of this EP.

One of the key sensitivities identified through the preparation of the EP was the proximity of the OA to the blue whale migratory BIA. SLB recognises that the potential to encounter whales increases as the Seismic Survey approaches and overlaps the blue whale migratory BIA. In addition to Standard and Additional Control Measures, the following control measures are proposed in relation to acquisition within the blue whale migratory BIA to minimise the potential for behavioural disturbance within this sensitive area:

- A 17 km buffer will be established around the blue whale migratory BIA where it overlaps with the OA;
- The Seismic Vessel will not activate the acoustic source(s) within the blue whale migratory BIA or buffer from mid-April (14th) to mid-January (14th) which represents the period during which most migrations whales are expected to pass through the Timor Sea;
- Outside of this period (15 Jan to 13 April), any seismic operations inside the blue whale migratory BIA or buffer will:
  - Implement an extended observation zone of 5 km;

- The extended observation zone in the BIA and buffer will be monitored using the Chase Vessel as an additional observation platform with two MMO's onboard. The Chase Vessel will travel c. 3 km ahead of the Seismic Vessel and will conduct visual surveillance for marine mammals during daylight hours. Trained and experienced MMOs will be required to undertake these observations. Note: 'ahead of the Seismic Vessel is defined as an 180° arc ahead of the Seismic Vessel, noting that the Chase Vessel should focus on the portion of the arc closest to the blue whale migratory BIA and buffer.
- Limit soft start procedures to conditions that allow visual inspection of the 5 km Observation Zone; and
- If species identity is uncertain at any location inside the blue whale migratory BIA or buffer, any unidentified whale will be assumed to be a blue whale.

In addition to the above control measures tailored to the blue whale migratory BIA, SLB has developed a suite of control measures to ensure that the impacts and risks from the planned and unplanned activities associated with the Seismic Survey are reduced as far as practicable. In light of the extensive suite of proposed controls, the overall conclusion from the environmental risk assessment is that the impacts from the Seismic Survey have been reduced to **ALARP** and **Acceptable Levels**. The survey will fully comply with all relevant legislation and industry best practice.

12 References

Abbriano, R.M., Carranza, M.M., Hogle, S.L., Levin, R.A., Netburn, A.N., Seto, K.L., Snyder, S.M., Franks, P.J.S., 2011. '*Deepwater Horizon oil spill: a review of the planktonic response*'. Oceanography, 24(3): 294 – 301.

AFMA, 2018a. '*Southern bluefin tuna*'. www.afma.gov.au/fisheries-management/species/southern-bluefin-tuna.

AFMA, 2018b. *About 'AFMA'*. https://www.afma.gov.au/about/about-afma.

AFMA, 2018c. '*Petroleum industry consultation with the commercial fishing industry*'. https://www.afma.gov.au/sustainability-environment/petroleum-industry-consultation.

Aguilar de Soto, N., Atkins, J., Howard, S., Williams, J., Johnson, M., 2013. '*Anthropogenic noise causes body malformations and delays development in marine larvae*'. Scientific Report 3.

Aguilar Soto, N., Johnson, M., Madsen, P.T., Tyack, P.L., Bocconcelli, A., Borsani, J.F., 2006. '*Does intense ship noise disrupt foraging in deep-diving Cuvier's beaked whales (Ziphius cavirostris)?*' Marine Mammal Science, 22(3): 690 – 699.

Aicher, B., Markl, H., Masters, W.M., Kirschenlohr, H.L., 1983. '*Vibration transmission through the walking legs of the fiddler crab, Uca pugilator (Brachyura, Ocypodidae) as measured by Laser Doppler Vibrometry'*. Journal of Comparative Physiology, 150: 483-491.

AIMS (Australian Institute of Marine Science), 2016. '*The Barracouta, Goeree and Vulcan Shoals Survey 2016'*. Report for PTTEP Australasia (Ashmore Cartier) Pty Ltd 53. Australian Institute of Marine Science, Townsville. (53 pp).

ALA, 2022. '*Atlas of Living Australia field guide*'. http://biocache.ala.org.au, download generated March 2022

Allen, G.R., 1993. '*Fishes of Ashmore Reef and Cartier Island.* **In:** *Marine and Faunal Surveys of Ashmore Reef and Cartier Island North-western Australia'*. Edited by P.F. Berry. Western Australian Museum, Perth, Western Australia. Pp. 67 – 91.

Allen, J.K., Peterson, M.L., 2012. '*Radiated noise from commercial ships in the Gulf of Maine: implications for whale/vessels collisions'*. The Journal of the Acoustical Society of America, 132: EL229.

Almeda, R., Connelly, T.L., Buskey, E.J, 2016. How much crude oil can zooplankton ingest? Estimating the quantity of dispersed crude oil defecated by planktonic copepods. Environmental Pollution, Volume 208, Part B, Pages 645-654. https://doi.org/10.1016/j.envpol.2015.10.041

Almeida, J.R., Gravato, C., Guilhermino, L., 2012. '*Challenges in assessing the toxic effects of polycyclic aromatic hydrocarbons to marine organisms: a case study on the acute toxicity of pyrene to the European seabass (Dicentrarchus labrax L.)*'. Chemosphere, 86(9): 926 – 937.

Alonso-Alvarez, C., Munilla, I., Lopez-Alonso, M., Velando, A., 2007. '*Sublethal toxicity of the Prestige oil spill on yellow-legged gulls*'. Environment International, 33(6): 773 – 781.

AMSA, 2015. '*Technical guidelines for preparing contingency plans for marine and coastal facilities*'. AMSA guidance document, 64p. Australian Government.

AMSA, 2019. '*National Plan for Maritime Environmental Emergencies – 2019 Edition'*. AMSA, Australian Government.

AMSA, 2021**.** Marine Traffic Density. Available at: https://www.marinetraffic.com/en/ais/home/, accessed March 2022.

Andre, M., Soler, M., Lenoi, M., Dufrot, M., Quero, C., Alex, M., Antoni, L., Van Der Schar, M., Lopez-Bejar, M., Morell, M., Zaugg, S., Houegnigan, L, 2011. '*Low-Frequency Sounds Induce Acoustic Trauma In Cephalopods*'. Frontiers in Ecology and the Environment, 9:489-493.

Andrews, K.S., Williams, G.D., Levin, P.S., 2010. *'Seasonal and ontogenetic changes in movement patterns of sixgill sharks'.* PLoS One, 5(9): e12549.

Ansari, Z.A., Desilva, C., Badesab, S., 2012. '*Total petroleum hydrocarbon in the tissue of some commercially important fishes of Bay of Bengal*'. Marine Pollution Bulletin, 64: 2564 – 2568.

AP Science, 2015. '*Investigating the impact of seismic surveys on threatened sea snakes in Australia's North West Shelf* '(APSF 12-5). Project description and summary, available online at: http://www.apscience.org.au/apsf_12_5/

APPEA, 2015. '*Reference document: Seismic surveys*'. https://www.appea.com.au/wp-content/uploads/2015/03/15-02-Ref-Doc_Seismic-V5.pdf

Aroyan, J.L., McDonald, M.A., Webb, S.C., Hildebrand, J.A., Clark, D., Laitman, J.T, Reidneberg, J.S., 2000. '*Acoustic Models Of Sound Production And Propagation*'. In: Hearing by Whales and Dolphins, Ed: W.W.L. Au, A.N. Popper & R.N. Fay", 409-469 p. Springer, New York, U.S.

ATSB, 2018. '*Marine Safety Investigations & Reports*'. http://www.atsb.gov.au/publications/safety-investigation-reports/?mode=Marine&q=seismic

Au, W.W.L., Floyd, R.W., Penner, R.H., Murchison, A.E., 1974. '*Measurement of Echolocation Signals of the Atlantic Bottlenose Dolphin, Tursiops truncatus Montagu in Open Waters*'. J. Acoust. Soc. Am., 56(4), 1280-1290.

Aulich, M.G, McCauley, R.D., Saunders, B.J., Miles J. G. Parsons, M.J.G, 2019. Fin whale (Balaenoptera physalus) migration in Australian waters using passive acoustic monitoring. Nature, Scientific Reports (2019) 9:8840. Available at: https://doi.org/10.1038/s41598-019-45321-w.

Austin, D. and Pollom, R., 2019. '*The IUCN Red List of Threatened Species 2019*'. http://www.iucnredlist.org/, viewed April 2019.

Australian and New Zealand guidelines for fresh and marine water quality (2018). https://www.waterquality.gov.au/anz-guidelines.

Australian Bureau of Statistics, 2016. Census data, in lieu of 2021 Census data (to be released July 2022).

Australian Government, 2022. '*Whale of a recovery brings hope for threatened species*'. Media Release by The Hon Sussan Ley (MP), Minister of the Environment. 26 Feb 2022. https://minister.awe.gov.au/ley/media-releases/whale-recovery-brings-hope-threatened-species.

Bahmanpour, M.H., Pattiaratchi, C., Wijeratne, E.M.S, Steinbers, C., D'Adamo, N., n.d. '*The Holloway current along northwest Australia*'. Coastal Oceanography. Retrieved from: http://imos.org.au/fileadmin/user_upload/shared/IMOS%20General/ACOMO/ACOMO_2014/presentations/posters/Holloway_ACOMO.pdf

Baird, R.W. 2018. Pseudorca crassidens (errata version published in 2019). '*The IUCN Red List of Threatened Species 2018*': e.T18596A145357488. http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T18596A145357488.en.

Baird, R.W., Gorgone, A.M., McSweeney, D.J., Webster, D.L., Salden, D.R., Deakos, M.H., Ligon, A.D., Schorr, G.S., Barlow, J., Mahaffy, S.D., 2008. '*False killer whales (Pseudorca crassidens) around the main Hawaiian Islands: long-term site fidelity, inter-island movements, and association patterns*'. Marine Mammal Science 24, 591-612.

Baker, C., Potter, A., Tran, M., Heap, A.D., 2008. '*Geomorphology and sedimentology of the North-west Marine Region of Australia*'. Record 2008/07, Geoscience Australia, Canberra.

Balcioglu, E.B., 2016. '*Potential effects of polycyclic aromatic hydrocarbons (PAHs) in marine foods on human health: a critical review*'. Toxin Reviews, 35(3-4): 98 – 105.

Baldwin, R., G. Hughes, Prince, R., 2003. '*Loggerhead turtles in the Indian Ocean*'. **In:** Bolten, A. & B. Witherington, eds. *Loggerhead sea turtles*. Washington: Smithsonian Books.

Balsiero, A., Espi, A., Marquez, I., Perez, V., Ferreras, M.C., Garcia Marin, J.F., Prieto, J.M., 2005. '*Pathological features in marine birds affected by the Prestige's oil spill in the north of Spain*'. Journal of Wildlife Diseases, 41 (2): Pp 371 – 378.

Ban, N., Hussein, A., Ardron, J. 2010. '*Cumulative impact mapping: Advances, relevance and limitations to marine management and conservation, using Canada's Pacific waters as a case study*'. Marine Policy. Vol 34, Issue 5. pp 876-886.

Bannister, J.L., Kemper, C.M., Warneke, R.M., 1996. '*The Action Plan for Australian Cetaceans*'. Canberra: Australian Nature Conservation Agency. Available from: http://www.environment.gov.au/resource/action-plan-australian-cetaceans.

Bass, A.H., Ladich, F., 2008. '*Vocal-Acoustic Communication: From Neurons To Behaviour*'. In: Webb JF, Fay RR, Popper AN, editors. Springer handbook of auditory research. Vol. 32. New York: Springer. Pages 253–278.

Basson, M., Hobday, A.J., Eveson, J.P., Patterson, T.A., 2012. '*Spatial interactions among juvenile southern bluefin tuna at the global scale: a large scale archival tag experiment*'. FRDC Report 2003/002.

Baumgartner, M.F., Van Parijs, S.M., Wenzel, F.W., Tremblay, C.J., Esch, H.C., Warde, A.M., 2008. '*Low frequency vocalizations attributed to sei whales (Balaenoptera borealis)*'. Journal of the Acoustical Society of America, 124(2):1339-1349.

Bax, N., Williamson, A., Aguero, M., Gonzalez, E., Geeves, W., 2003. '*Marine Invasive Alien Species: A Threat To Global Biodiversity*'. Marine Policy, 27:313-323.

Beasley, I.L., Arnold, P.W., Heinsohn, G.E., 2002. '*Geographical variation in skull morphology of the Irrawaddy dolphin, Orcaella brevirostris*'. Raffles Bulletin of Zoology. 10:15-24.

Benson, S.R., P.H., Dutton, C. Hitipeuw, B. Samer, J. Bakarbessy, D. Parker, 2007. '*Post-Nesting Migrations of Leatherback Turtles (Dermochelys coriacea) from Jamursba-Medi, Bird's Head Peninsula, Indonesia*'. Chelonian Conservation and Biology. 6(1):150-154. Chelonian Research Foundation. Available from: http://www.bioone.org/doi/pdf/10.2744/1071-8443%282007%296%5B150%3APMOLTD%5D2.0.CO%3B2.

Benson, S.R., T. Eguchi, D.G. Foley, K.A. Forney, H. Bailey, C. Hitipeuw, B.P. Samber, R.F. Tapilatu, V. Rei, P. Ramohia, J. Pita, P.H. Dutton, 2011. '*Large-scale movements and high-use areas of western Pacific leatherback turtles, Dermochelys coriacea*'. *Ecosphere*. 2(7): art84.

Berthou, F., Balouët, G., Bodennec, G., Marchand, M., 1987. '*The occurrence of hydrocarbons and histopathological abnormalities in oysters for seven years following the wreck of the Amoco Cadiz in Brittany (France)*'. Marine Environ Res, 23:103-133.

BHP Billiton, 2005. '*Draft Environmental Impact Statement*'. Report No. WA-255-P (2), Stybarrow Development, Melbourne, Australia.

BirdLife International, 2022. '*Species factsheet: Lesser Frigatebird (Fregata ariel)*'. Downloaded March 2022 from http://www.birdlife.org.

Bjorndal, K.A, Bolten, A.B, Martins, H.R., 2000. '*Somatic growth model of juvenile loggerhead sea turtles Caretta caretta: duration of pelagic stage*'. Marine Ecology Progress Series. 202:265-272. Available from: http://www.seaturtle.org/PDF/Bjorndal_2000_MarEcolProgSer.pdf.

Blaber, S.J.M., Dichmont, C.M., Buckworth, R.C., Badrudin, Sumiono, B., Nurhakim, S., Iskandar, B., Fegan, B., Ramm, D.C., Salini, J.P., 2005. '*Shared stocks of snappers (Lutjanidae) in Australia and Indonesia: integrating biology, population dynamics and socio-economics to examine management scenarios*'. Reviews in Fish Biology and Fisheries, 15:111-27.

Black, A., 2005. '*Light induced seabird mortality on vessels operating in the Southern Ocean: incidents and mitigation measures*'. Antarctic Science 17:67-68.

Blackwell, S.B., Nations, C.S., McDonald, T.L., Thode, A.M., Mathias, D., Kim, K.H., Greene, C.R., Macrander, A.M., 2015. '*Effects of airgun sounds on bowhead whale calling rates: evidence for two behavioural thresholds*'. PLoS One. 10(6): doi: 10.1371/journal.pone.0125720.

Blair, H.B., Merchant, N.D., Friedlaender, A.S., Wiley, D.N., Parks, S.E., 2016. '*Evidence for ship noise impacts on humpback foraging behaviour*'. Biology Letters, 12: 20160005/.

Boeger, W., Pei, M., Ostrensky, A., Cardaso, M., 2006. '*The effect of exposure to seismic prospecting on coral reef fishes*'. Brazilian Journal of Oceanography, 54:235-239.

BoM, 2022a. Climatology of Tropical Cyclones in Western Australia. Available at: http://www.bom.gov.au/cyclone/climatology/, accessed January 2022.

BoM, 2022b. Climate Statistics for Australian Locations. Available at: http://www.bom.gov.au/climate/data/index.shtml accessed January 2022.

Booman, C., Dalen, J., Leivestad, H., Levsen, A., van der Meeren, T., og Toklum, K., 1996. '*Effekter av luftkanonskyting på egg, larver og yngel*'. Undersøkelser ved Havforskningsinstituttet og Zoologisk Laboratorium, UiB. (English summary). Havforskningsinstituttet, Bergen. *Fisken og Havet,* nr. 3. 83 s.

Bowlay, A. and Whiting, A., 2007. Uncovering Turtle Antics. *Landscope*. 23 (2). Western Australia Department of Environment and Conservation.

Bowles, A.E., Smultea, M., Würsig, B., DeMaster, D.P. & Palka, D., 1994. '*Relative abundance and behaviour of marine mammals exposed to transmissions from the Heard Island Feasibility Test*'. Journal of the Acoustical Society of America 96, 2469–2484.

Branch, T.A., Stafford, K.M., Palacios, D.M., Allision, C., Bannister, J.L., Burton, C.L.K., Cabrera, E., Carlson, C.A., Galletti Vernazzani, B., Gill, P.C., Hucke-Gaete, R., Jenner, K.C.S., Jenner, M-N.M., Matsuoka, K., Mikhalev, Y.A., Miyashita, T., Morrice, M.G., Nishiwaki, S., Sturrock, V.J., Tormosov, D., Anderson, R.C., Baker, A.N., Best, P.B., Borsa, P., Brownell Jr, R.L., Childerhouse, S., Findlay, K.P., Gerrodette, T., Ilangakoon, A.D., Joergensen, M., Kahn, B., Ljunglad, D.K., Maughan, B., McCauley, R.D., McKay, S., Norris, T.F., Oman Whale and Dolphin Research Group, Rankin, S., Samaran, F., Thiele, D., Van Waerbeek, K., Warneke, R.M., 2007. '*Past and present distribution, densities and movements of blue whales Balaenoptera musuclus in the Southern Hemisphere and northern Indian Ocean*'. Mammal Rev., 37(2):116-175.

Bray, D.J. and Thompson, V.J., 2022. '*Fishes of Australia*'. http://fishesofaustralia.net.au/home/species/, viewed March 2022.

Brewer, D. Lyne, V. Skewes, T., Rothlisberg, P., 2007. '*Trophic Systems of the Northwest Marine Region*'. Report to the Department of the Environment and Water Resources, CSIRO Marine and Atmospheric Research, Cleveland.

Broker, K. 2019. '*An overview of potential impacts of hydrocarbon exploration and production on marine mammals and associated monitoring and mitigation measures*'. Aquatic Mammals 2019, 45(6), 576-611, DOI 10.1578/AM.45.6.2019.576.

Brown, A.M., Bejder, L., Pollock, K.H., Allen, S.J., 2014. *Abundance of coastal dolphins in Roebuck Bay, Western Australia: Updated results from 2013 and 2014 sampling periods*. Report to WWF-Australia. Murdoch University Cetacean Research Unit, Murdoch University, Western Australia.

Bruce, B.D., 2008. '*The Biology and Ecology of the White Shark, Carcharodon carcharias*'. In: Camhi, M.D, E.K. Pikitch and E.A Babcock, eds. Sharks of the Open Ocean. Page(s) 69-76. Oxford, UK: Blackwell Publishing.

Brumm, H., Slabbekoorn, H., 2005. '*Acoustic communication in noise*'. Adv. Study. Behav., 35:151-209.

Buck, B.M., Chalfant, D.A., 1972. '*Deep water narrowband radiated noise measurement of merchant ships*'. Delco TR72-28, Rep. from Delco Electronics, Santa Barbara, CA, for U.S. Navy Off. Naval Res., Arlington, VA.

Buscaino, G., Filiciotto, F., Buffa, G., Bellante, A., Di Stefano, V., Assenza, A., Fazio, F., Caola, G., Mazzola, S., 2010. '*Impact of an acoustic stimulus on the motility and blood parameters of European sea bass (Dicentrarchus labrax L.) and gilthead sea bream (Sparus aurata L.)*'. Marine Environmental Research, 69:136-142.

Calypso Science, 2022. '*Oil spill trajectory modelling arising from a vessel collision in the Bonaparte Basin*'. Report prepared for Schlumberger Australia Pty Ltd.

CarbonNet, 2018. '*Executive Summary of the CarbonNet Pelican 3D Marine Seismic Survey (MSS) Offshore Habitat Assessments Final Report*'. Accessed from: http://earthresources.vic.gov.au/earth-resources/victorias-earth-resources/carbon-storage/the-carbonnet-project/marine-seismic-survey-habitat-impact-assessment-outcomes

Carey, W.M., 2009. '*Lloyd's Mirror-Image Interference Effects*'. Acoustics Today, 5(2):14-20.

Carroll, A.G., Przeslawski, R., Duncan, A., Gunning, M., Bruce, B., 2017. '*A critical review of the potential impacts of marine seismic surveys on fish & invertebrates*'. Marine pollution bulletin, 114(1):9-24.

Castellote, M., Clark, C.W., Lammers, M.O., 2012. '*Acoustic and behavioural changes by fin whales (Balaenoptera physalus) in response to shipping and airgun noise*'. Biological Conservation, 147(1): 115 – 122.

Castro, J.I., Woodley, C.M., Brudek, R.L., 1999. '*A preliminary evaluation of the status of shark species*'. FAO Fisheries Technical Paper 380. FAO, Rome.

Cato, D.H. and McCauley, R.D. 2002. '*Australian research into ambient sea noise*'. Journal of Australian Acoustics, 30(1):13-20.

Caton, A.E., 1991. '*Review of aspects of southern bluefin tuna biology, population and fisheries*'. In: World Meeting on Stock Assessment of Bluefin Tuna: Strengths and Weaknesses, Deriso, R.B.m, Bayliff, W.H. (Eds). IATTC, La Jolla, CA, Special Report 7, pp. 181-357.

CBD, 2018. '*Convention on Biological Diversity – Introduction*'. https://www.cbd.int/intro/default.shtml.

Ceccarelli, D.M., Richards, Z.T., Pratchett, M.S., and Cvitanovic, C., 2011. '*Rapid increase in coral cover on an isolated coral reef, the Ashmore Reef National Nature Reserve, North-western Australia*'. Marine and Freshwater Research 62(10):1214.

Cerchio, S., Stindberg, S., Collins, T., Bennett, C., Rosenbaum, H., 2014. '*Seismic surveys negatively affect humpback whales singing activity off northern Angola*'. PLoS ONE, 9(3): e86464, doi:10.1371/journal.pone.0086464.

Cerchio, S., Yamada, T.K., Brownell, R.L. Jr., 2019. '*Global Distribution of Omura's Whales (Balaenoptera omurai) and Assessment of Range-Wide Threats*'. Front. Mar. Sci. 6:67. doi: 10.3389/fmars.2019.00067.

Chaloupka, M., Limpus, C., Miller, J., 2001. '*Green Turtle somatic growth dynamics in a spatially disjunct Great Barrier Reef metapopulation*'. Coral Reefs. 23:325-335.

Chapuis, L., Kerr, C., Collin, S., Hart, N., Sanders, K., 2019. '*Underwater hearing in sea snakes (Hydrophiinae): first evidence of auditory evoked potential thresholds*'. Journal of Experimental Biology 222: jeb198184. doi:10.1242/jeb.198184.

Chatto, R. and Baker B., 2008. '*The distribution and status of marine turtle nesting in the Northern Territory-Technical Report 77/2008*'. Parks and Wildlife Service, Department of Natural Resources, Environment, The Arts and Sport. Northern Territory Government. Available from: http://hdl.handle.net/10070/203056.

Chatto, R. and Warneke, R.M., 2000. '*Records of cetacean strandings in the Northern Territory of Australia*'. The Beagle, Records of the Museums and Art Galleries of the Northern Territory. 16:163-175.

Chatto, R., 2001. '*The distribution and status of colonial breeding seabirds in the Northern Territory*'. Technical report 70, Parks and Wildlife Commission of the Northern Territory, Palmerston.

Chatto, R., 2003. '*The distribution and status of shorebirds around the coast and coastal wetlands of the Northern Territory*' - Parks and Wildlife Commission of the Northern Territory, Palmerston.

Chilvers, B.L., Delean, S., Gales, N., Holley, D., Lawler, I., Marsh, H., Preen, A., 2004. '*Diving behaviour of dugongs, Dugong dugon*'. Journal of Experimental Marine Biology and Ecology 304:203-224.

Chou, E., Southall, B., Robards, M., Rosenbaum, H. 2021. '*International policy, recommendations, actions, and mitigation efforts of anthropogenic underwater noise*'. Ocean and Coastal Management202: 105427.

Christian, J.R., Mathieu, A., Thompson, D.H., White, D., Buchanan, R., 2003. '*Effect of Seismic Energy on Snow Crab (Chionoecetes opilio)*'. Report No. SA694 to the Canadian National Energy Board (Calgary, Alberta) by LGL Ltd (King City, Ontario) and Oceans Ltd (St John's, Newfoundland). 106 pp.

Clark, M.R., Rouse, H., Lamarche, G., Ellis, J., Hickey, C., 2017. '*Preparation of environmental impact assessments: general guidelines for offshore mining and drilling with particular reference to New Zealand*'. NIWA Science and Technology Series, NIWA Project EMOM163, 105p.

Clarke, R.H., 2010. '*The status of seabirds and shorebirds at Ashmore Reef, Cartier Island and Browse Island: monitoring program for the Montara well release – pre-impact assessment and first post-impact field survey*'. Prepared on behalf of PTTEP Australasia and the Department of the Environment, Water, Heritage and the Arts, Australia.

Clifton, J., Tonts, M., Boruff, B., 2007. *A Socio-Economic Overview of the Coastal Communities Adjacent to the North-West Marine Region*. Institute of Regional Development, The University of Western Australia. Report prepared for the Department of the Environment, Water, Heritage and the Arts.

CMS (Convention on the Conservation of Migratory Species), 2016. '*Proposal for Inclusion of species on the appendices of the Convention on the Conservation of Migratory Species of wild animals*'. Proposal ii/2: https://www.cms.int/sites/default/files/document/CMS_COP6_II_02_Tursiops_aduncus-Australia-E.pdf.

Cogger, H.G., 2000. '*Reptiles and Amphibians of Australia*' - 6th edition. Sydney, NSW: Reed New Holland.

Colman, J. G., Grebe, C. C., Hearn, R. L., 2008. '*The challenges and complexities of impact assessment for a seismic survey in a remote coral reef environment*'. IAIA08 Conference Proceedings, The Art and Science of Impact Assessments 28th Conference of the International Association for Impact Assessments, 4 – 10 May 2008, Perth Convention Exhibition Centre, Perth, Australia.

Commonwealth Government, 2005. '*Blue fin and sei whale recovery plan 2005-2010*'. https://cdn.environment.sa.gov.au/environment/docs/pa-rec-bluewhale.pdf.

Commonwealth of Australia, 2012. '*Conservation Management Plan for the Southern Right Whale – a Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999, 2011-2021*'. 72pp.

Commonwealth of Australia, 2015. '*Conservation Management Plan for the Blue Whale 2015-2025 - a Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999*'. 57pp.

Commonwealth of Australia, 2017a. '*National strategy for reducing vessel strike on cetaceans and other marine megafauna*'. 35pp.

Commonwealth of Australia, 2017b. '*Recovery plan for Marine Turtles in Australia: 2017 – 2027*'. 154pp.

Commonwealth of Australia, 2018. '*Threat Abatement Plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans*'. 53pp.

Commonwealth of Australia, 2020. '*National Light Pollution Guidelines for Wildlife, including marine turtles, seabirds and migratory shorebirds*'. 111pp.

Commonwealth of Australia, 2021. '*Indigenous Protected Areas Map*'. Geospatial & Information Analytics Branch (ERIN), Department of Agriculture, Water and Environment. Published 30/07/2021.

Compagno, L.J.V., 1984. FAO species catalogue. '*Sharks of the world. An annotated and illustrated catalogue of shark species known to date*'. FAO Fisheries Synopsis No. 125, Volume 4, Part 1.

Condie, S., Andrewartha, J., Mansbridge, J., Waring, J., CSIRO, 2006. '*Modelling circulation and connectivity on Australia's Northwest Shelf*'.

Connell, S.C., K.E. Zammit, M.J. Weirathmueller, M.W. Koessler, A. M. Muellenmeister, C.R McPherson, 2022. '*Bonaparte Basin Marine Seismic Survey: Acoustic Modelling for Assessing Marine Fauna Sound Exposures*'. Document 02724, Version 1.0. Technical report by JASCO Applied Sciences for SLR.

Conoco Phillips Australia, 2018. Barossa area development - Offshore project proposal. Document number: BAA-00-EN-RPT-00001.

Corkeron, P.J., 1995. '*Humpback whales (Megaptera novaeangliae) in Hervey Bay, Queensland: behaviour and responses to whale-watching vessels*'. Can. J. Zool., 73: 1290 – 1299.

Couturier, L.I., Jaine, F.R., Townsend, K.A., Weeks, S.J., Richardson, A.J., Bennett, M.B., 2011. '*Distribution, site affinity and regional movements of the manta ray, Manta alfredi (Krefft, 1868), along the east coast of Australia*'. Marine and Freshwater Research, 62(6):628-637.

CSIRO, 2005. '*Collation and Analysis of Oceanographic Datasets for National Marine Bioregionalisation*'. The Northern Large Marine Domain. Available at: https://www.environment.gov.au/system/files/resources/51abf1da-40b7-4513-8fad-b4537e1fac62/files/nmb-northern-domain.pdf.

CSIRO, 2015. '*Marine Benthic Substrate Database*' – CAMRIS – Marsed v1. CSIRO. Data Collection. https://doi.org/10.4225/08/551485612CDEE.

Culik, B., 2005. Pseudorca crassidens. '*Review on Small Cetaceans: Distribution, Behaviour, Migration and Threats*'. Compiled for the Convention on Migratory species (CMS). Available from: http://www.cms.int/reports/small_cetaceans/data/P_crassidens/p_crassidens.htm.

Cummings, W.C., Thompson, P.O 1971. '*Underwater sounds from the blue whale, Balaenoptera musculus*'. Journal of the Acoustical Society of America 50: 1193-1198.

David, A., 2011. '*Underwater environmental impact assessments on marine mammals and fish by high power anthropogenic radiated sound*'. Paper Number 27, Proceedings of Acoustics. 2-4 November 2011, Gold Coast, Australia. https://acoustics.asn.au/conference_proceedings/AAS2011/papers/p27.pdf.

Davies, T.W., Duffy, J.P., Bennie, J., Gaston, K.J., 2014. '*The nature, extent, and ecological implications of marine light pollution*'. Ecological Environment, 12(6), 347-355. doi: 10.1890/130281.

DAWE, 2012. '*Key Threatening Process Nomination Form – 2012 Assessment Period*'. https://www.environment.gov.au/system/files/pages/87ef6ac7-da62-4a45-90ec-0d473863f3e6/files/nomination-marine-seismic.pdf

DAWE, 2021. '*Continental shelf and demersal fish communities*'. Commonwealth of Australia 2021. Available at: https://www.environment.gov.au/sprat, accessed March 2022.

DAWE, 2022. '*Species Profile and Threats Database: Thunnus maccoyii – Southern bluefin tuna*'. http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=69402, accessed March 2022.

DAWE, 2022a. Protected Matters Search Tool https://www.awe.gov.au/environment/epbc/protected-matters-search-tool, accessed March 2022.

DAWE, 2022b. '*Biologically important areas of regionally significant marine species*'. Available at: https://www.awe.gov.au/environment/marine/marine-species/bias, accessed February 2022.

Day, R.D., Fitzgibbon, Q.P., McCauley, R.D. and Semmens, J.M., 2021. '*Examining the potential impacts of seismic surveys on octopus and larval stages of southern rock lobster, Part A: southern rock lobster*'. FRDC project 2019-051. The Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania.

Day, R.D., McCauley, R.D., Fitzgibbon, Q.P., Hartmann, K., Semmens, J.M., 2016. '*Assessing the impact of marine seismic surveys on southeast Australian scallop and lobster fisheries*'. Report to the Fisheries Research and Development Corporation. Report prepared by the University of Tasmania, Hobart. 159 pp.

Day, R.D., McCauley, R.D., Fitzgibbon, Q.P., Hartmann, K., Semmens, J.M., 2017. '*Exposure to seismic air gun signals causes physiological harm and alters behavior in the scallop Pecten fumatus*'. Proceedings of the National Academy of Sciences of the United States of America 114(40): E8537-E8546. https://doi.org/10.1073/pnas.1700564114.

Day, R.D., McCauley, R.D., Fitzgibbon, Q.P., Hartmann, K., Semmens, J.M., 2019. '*Seismic air guns damage rock lobster mechanosensory organs and impair righting reflex*'. Proceedings of the Royal Society B 286(1907). https://doi.org/10.1098/rspb.2019.1424.

Day, R.D., McCauley, R.D., Fitzgibbon, Q.P., Semmens, J.M., 2016a. Seismic air gun exposure during early-stage embryonic development does not negatively affect spiny lobster Jasus edwardsii larvae (Decapoda: Palinuridae). Scientific Reports 6: 1-9. https://doi.org/10.1038/srep22723.

Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, and J.M. Semmens. 2016. '*Seismic air gun exposure during early-stage embryonic development does not negatively affect spiny lobster Jasus edwardsii larvae (Decapoda:Palinuridae)*'. *Scientific Reports* 6: 1-9. https://doi.org/10.1038/srep22723.

DBCA, 2022. '*Western Australia's Marine Parks and Reserves*'. https://www.dpaw.wa.gov.au/management/marine/marine-parks-and-reserves, accessed March 2022.

Deda, P., Elbertzhagen, I., Klussmann, M., 2007. '*Light pollution and the impacts on biodiversity, species and their habitats*'. In C. o. M. S. o. W. A. (UNEP-CMS) (Ed.), (pp. 133-139): Conservation of Migratory Species of Wild Animals (UNEP-CMS).

DEH, 2005. '*Issues paper for six species of marine turtles found in Australian waters that are listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999*'. Commonwealth Department of Environment and Heritage: Canberra. Available from: http://www.environment.gov.au/biodiversity/threatened/publications/recovery/marine-turtles/pubs/issues-paper.pdf.

DEH, 2005a. '*Whale shark (Rhincodon typus) Recovery Plan 2005-2010*'. Available from: https://www.awe.gov.au/sites/default/files/documents/rhincodon-typus.pdf accessed April 2022.

Department of Fisheries biofouling risk assessment tool. Available at: https://vesselcheck.fish.wa.gov.au/.

DEPWS, 2022. '*Threatened species of the Northern Territory – Plains Death Adder*'. Available from: https://nt.gov.au/data/assets/pdf_file/0014/206402/plains-death-adder.pdf, accessed March 2022.

DEPWS, 2022a: '*Threatened species of the Northern Territory - Great knot*'. (https://nt.gov.au/environment/animals/threatened-animals) accessed March 2022.

DEPWS, 2022b. '*Threatened species of the Northern Territory - Gouldian finch*'. Available from: https://nt.gov.au/environment/animals/threatened-animals, accessed March 2022.

DEPWS, 2022c. '*Threatened species of the Northern Territory - Abbott's booby*'. Available from: https://nt.gov.au/environment/animals/threatened-animals, accessed March 2022.

DEPWS, 2022d. '*Threatened species of the Northern Territory - Lesser sand plove*r'. Available from: https://nt.gov.au/environment/animals/threatened-animals, accessed March 2022.

DEPWS, 2022e. '*Threatened species of the Northern Territory - Grey Falcon*'. Available from: https://nt.gov.au/environment/animals/threatened-animals, accessed March 2022.

DEPWS, 2022f. '*Threatened species of the Northern Territory - Bar-tailed Godwit, (Western Alaskan)*'. Available from: https://nt.gov.au/environment/animals/threatened-animals, accessed March 2022.

DEPWS, 2022g. '*Threatened species of the Northern Territory - Red Goshawk*'. Available from: https://nt.gov.au/environment/animals/threatened-animals, accessed March 2022.

DEPWS, 2022h. '*Threatened species of the Northern Territory - Masked owl (northern mainland)*'. Available from: https://nt.gov.au/environment/animals/threatened-animals, accessed March 2022.

DEPWS, 2022i. '*Threatened species of the Northern Territory - Crested Shrike-tit (northern)*'. Available from: https://nt.gov.au/environment/animals/threatened-animals, accessed March 2022.

DEPWS, 2022j. '*Threatened species of the Northern Territory - Greater Sand Plover*'. Available from: https://nt.gov.au/environment/animals/threatened-animals, accessed March 2022.

Dethmers, K.M., Broderick, D., Moritz, C., FitzSimmons, N.N., Limpus, C.J., Lavery, S., Whiting, S., Guinea, M., Prince, R.I.T., Kennett, R., 2006. '*The genetic structure of Australasian green turtles (Chelonia mydas): exploring the geographical scale of genetic exchange*', Molecular Ecology, 15:3931-3946.

DEWHA, 2008. '*EPBC Act Policy Statement 2.1 - Interaction Between Offshore Seismic Exploration and Whales*'. In: Australian Government - Department of the Environment, Water, Heritage and the Arts. 14 pp. http://www.environment.gov.au/resource/epbc-act-policy-statement-21-interaction-between-offshore-seismic-exploration-and-whales.

DEWHA, 2007. '*Characterisation of the marine environment of the north marine region: outcomes of an expert workshop convened in Darwin'.,* Northern Territory, 2-3 April 2007, DEWHA, Canberra. http://www.environment.gov.au/resource/characterisation-marine-environment-north-marine-region-outcomes-expert-workshop-2-3-april

DEWHA, 2008a. '*The North Marine Region Bioregional Plan Bioregional Profile'*. Commonwealth of Australia.

DEWHA, 2008b. '*The North-west Marine Region Bioregional Plan Bioregional Profile'*. Commonwealth of Australia.

DFO (Fisheries and Oceans Canada). 2017. '*Action Plan for the Northern and Southern Resident Killer Whale (Orcinus orca) in Canada'*. Species at Risk Act Action Plan Series. Fisheries and Oceans Canada, Ottawa. v + 33 pp.

Di lorio, L., Clark, C.W., 2010. '*Exposure to seismic survey alters blue whale acoustic communication*'. Biol. Lett. 6: 51 – 54.

DNP (Director of National Parks), 2018a. '*North-west Marine Parks Network Management Plan 2018'*. Commonwealth of Australia, 2018.

DNP, 2018b. '*North Marine Parks Network Management Plan 2018*'. Commonwealth of Australia, 2018.

DNV, 2011. '*Assessment of the Risk of Pollution from Marine Oil Spills in Australian Ports and Waters*'. Prepared for Australian Maritime Safety Authority, Report No. PP002916.

DoAWR (Department of Agriculture and Water Resources), 2002. '*National Competition Policy Review of Commonwealth Fisheries Legislation*'. Available at: http://www.agriculture.gov.au/fisheries/domestic/review-comm-fishleg.

DoAWR, 2018. '*Department of Agriculture and Water Resources – The Australian Fishing Zone*'. http://www.agriculture.gov.au/fisheries/domestic/zone, accessed March 2022.

Dobbs, K.A., Miller, J.D., Limpus, C.J., Landrey, A.M. Jr., 1999. '*Hawksbill turtle, Eretmochelys imbricata, nesting at Milman Island, northern Great Barrier Reef, Australia'*. Chelonian Conservation and Biology. 3(2):344-361.

DoD, 2022. Unexploded Ordnance (UXO) Mapping Application. Available at: https://defence.gov.au/UXO/Where/Default.asp, accessed March 2022.

DoE (Department of the Environment), 2014. '*Approved Conservation Advice for Glyphis garricki (northern river shark)*'. Canberra: Department of the Environment.

DoE, 2022a. '*Aipysurus apraefrontalis'* in Species Profile and Threats Database, Department of the Environment, Canberra. Available from: https://www.environment.gov.au/sprat, accessed March 2022.

DoE, 2022b. '*Lepidochelys olivacea'* in Species Profile and Threats Database, Department of the Environment, Canberra. Available from: https://www.environment.gov.au/sprat, accessed March 2022.

DoE, 2022c. '*Caretta caretta'* in Species Profile and Threats Database, Department of the Environment, Canberra. Available from: https://www.environment.gov.au/sprat, accessed March 2022.

DoE, 2022d. '*Chelonia mydas'* in Species Profile and Threats Database, Department of the Environment, Canberra. Available from: https://www.environment.gov.au/sprat, accessed March 2022.

DoE, 2022e. '*Eretmochelys imbricata'* in Species Profile and Threats Database, Department of the Environment, Canberra. Available from: https://www.environment.gov.au/sprat accessed March 2022.

DoE, 2022f. '*Crocodylus porosus'* in Species Profile and Threats Database, Department of the Environment, Canberra. Available from: https://www.environment.gov.au/sprat, accessed March 2022.

DoE, 2022g. '*Balaenoptera borealis'* in Species Profile and Threats Database, Department of the Environment, Canberra. Available from: https://www.environment.gov.au/sprat, accessed March 2022.

DoE, 2022h. '*Tursiops aduncus'* in Species Profile and Threats Database, Department of the Environment, Canberra. Available from: https://www.environment.gov.au/sprat, accessed March 2022.

DoE, 2022i. '*Orcaella heinsohni'* in Species Profile and Threats Database, Department of the Environment, Canberra. Available from: https://www.environment.gov.au/sprat, accessed March 2022.

DoE, 2022j. '*Dugong dugon'* in Species Profile and Threats Database, Department of the Environment, Canberra. Available from: https://www.environment.gov.au/sprat, accessed March 2022.

DoEE, 2018a. '*The Ramsar Convention on Wetlands'*. Available at: http://www.environment.gov.au/water/wetlands/ramsar.

DoEE, 2018b. '*Australian Marine Mammal Centre – Vessel/Whale Collisions (ship strike)*'. https://data.marinemammals.gov.au/report/shipstrike.

DoEE, 2019. Draft Wildlife Conservation Plan for Seabirds, Commonwealth of Australia 2019.

DoEE, 2022. SPRAT Profile, Multiple species. Available at: http://www.environment.gov.au/cgi-bin/sprat/public/sprat accessed March 2022.

DoEE, n.d.c. '*Marine Bioregional Plans'*. Commonwealth of Australia. Canberra. Available at: https://www.environment.gov.au/marine/marine-bioregional-plans.

Donovan, A., Brewer, D., van der Velde, T., Skewes, T., 2008. '*Scientific descriptions of four selected key ecological features (KEFs) in the north-west bioregion'*: draft report, a report to the Australian Government Department of the Environment, Water, Heritage and the Arts by CSIRO Marine and Atmospheric Research, Cleveland.

Double, M.C., Andrews-Goff, V., Jenner, K.C.S., Jenner, M.-N., Laverick, S.M., Branch, T.A., Gales, N.J., 2014. '*Migratory Movements of Pygmy Blue Whales (Balaenoptera musculus brevicauda) between Australia and Indonesia as Revealed by Satellite Telemetry'*. PLOS ONE 9: e93578.

DPAW, 2013. '*Whale shark management with particular reference to Ningaloo Marine Park, Wildlife management program no. 57'*. Perth, Western Australia. 99 pp.

DPAW, 2016a. '*Proposed North Kimberley Marine Park indicative joint management plan 2016*'. Department of Parks and Wildlife, Perth.

DPAW and AMOSC, 2014. '*Western Australian Oiled Wildlife Response Plan'*. Available at: https://www.dpaw.wa.gov.au/images/documents/conservation-management/marine/wildlife/West_Australian_Oiled_Wildlife_Response_Plan_V1.1.pdf, accessed April 2022.

DPAW, 2016b. '*North Kimberley Marine Park joint management plan 2916 Uunguu, Balanggarra, Miriuwug and Wilinggin management areas'*. Plan No. 89, Department of Parks and Wildlife, Perth. Available at: https://www.dpaw.wa.gov.au/management/marine/marine-parks-and-reserves, accessed March 2022.

DPIRD, 2022. '*Management of Marine Protected Areas'*. Available at: https://www.fish.wa.gov.au/Sustainability-and-Environment/Aquatic-Biodiversity/Marine-Protected-Areas/Pages/default.aspx, accessed March 2022.

DSEWPC, 2012a. '*Marine bioregional plan for the North-west Marine Region*'. Commonwealth of Australia. Canberra.

DSEWPC, 2012b. '*Marine Bioregional Plan for the North Marine Region*'. Commonwealth of Australia. Canberra.

DSEWPC, 2012c. '*Species group report card – seabirds and migratory shorebirds*'. Commonwealth of Australia.

DSEWPC, 2012d. '*Species group report card, marine reptiles: supporting the marine bioregional plan for the North-West Marine Region*'. Commonwealth of Australia. Canberra.

Dubovskaya, O.P., Tang, K.W., Gladyshev, M.I., Kirillin, G., Buseva, Z., Kasprzak, P., Tolomeev, A.P. and Grossart, H-P. 2015. '*Estimating in situ zooplankton non-predation mortality in an oligo-mesotrophic lake from sediment trap data: caveats and reality check*.' PLoS ONE 10(7): e0131431.

Duncan, A. J., Gavrilov, A. N, McCauley R. D., Parnum, I., 2013. '*Characteristics of sound propagation in shallow water over an elastic seabed with a thin cap-rock layer*.' J. Acoust. Soc. Am., 134(1):207-215.

Dunlop, R.A., Cato, D.H., Noad, M.J., 2010. '*Your attention please: increasing ambient noise levels elicits a change in communication behaviour in humpback whales (Megaptera novaeangliae*)'. Proc. R. Soc. London, Ser. B, 277:2521-2529.

Dunlop, R.A., Noad, M.J., Cato, D.H., Stokes, D., 2007. '*The social vocalization repertoire of east Australian migrating humpback whales (Megaptera novaeangliae)*'. Journal of the Acoustical Society of America, 122(5):2893 – 2905.

Dunlop, R.A., Noad, M.J., McCauley, R.D., Kniest, E., Paton, D., Cato, D.H., 2015. '*The behavioural response of humpback whales (Megaptera novaeangliae) to a 20 cubic inch air gun'*. Aquatic Mammals, 41(4): 412 – 433.

Dunlop, R.A., Noad, M.J., McCauley, R.D., Kniest, E., Slade, R., Paton, D., Cato, D.H., 2016. '*Response of humpback whales (Megaptera novaeangliae) to ramp-up of a small experimental air gun array'*. Marine Pollution Bulletin, 103: 72 – 83.

Dunlop, R.A., Noad, M.J., McCauley, R.D., Kniest, E., Slade, R., Paton, D., Cato, D.H., 2017. '*The behavioural response of migrating humpback whales to a full seismic airgun array*'. Proc. R. Soc. B., 284: 20171901. http://dx.doi.org/10.1098/rspb.2017.1901.

Dyndo, M., Wisniewska, D.M., Rojano-Donate, L., Madsen, P.T., 2015. '*Harbour porpoises react to low levels of high frequency vessel noise*'. Scientific Reports, 5: 11083, DOI:10/1038/srep11083.

ECMWF, 2019. "ERA5: Fifth Generation of ECMWF Atmospheric Reanalyses of the Global Climate." https://cds.climate.copernicus.eu/cdsapp#!/home.

Edmonds, N.J., Firmin, C.J., Goldsmith, D., Faulkner, R.C., Wood, D.T., 2016. '*A review of crustacean sensitivity to high amplitude underwater noise: Data needs for effective risk assessment in relation to UK commercial species*'. Marine Pollution Bulletin. 108: 5-11.

Ehmann, H., 1992. '*Reptiles*'. **In:** Strahan, R., ed. *Encyclopedia of Australian Animals*. Sydney: Angus & Robertson.

Ellison, W.T., Racca, R., Clark, C.W., Streever, B., Frankel, A.S., Fleishman, E., Angliss, R., Berger, J., Ketten, D., Guerra, M., Leu, M., McKenna, M., Stormo, T., Southall, B., Suydam, R., Thomas, L., 2016. '*Modelling the aggregated exposure and responses of bowhead whales Balaena mysticetus to multiple sources of anthropogenic underwater sound'*. Endangered Species Research, 30:95-108.

Engas, A., Lokkeborg, S., Ona, E., Soldal, A., 1996. '*Effects of seismic shooting on local abundance and catch rates of cod (Gadus morhua) and haddock (Melanogrammus aeglefinus)'*. Canadian Journal of Fisheries and Aquatic Sciences, 53:2238-2249.

Environment Australia, 2003. '*Recovery Plan for Marine Turtles in Australia'*. Prepared by the Marine Species Section, Approvals and Wildlife Division, Environment Australia in consultation with the Marine Turtle Recovery Team. Available from: http://www.environment.gov.au/coasts/publications/turtle-recovery/index.html. In effect under the EPBC Act from 21-Jul-2003.

EPA, 2010. '*Environmental Assessment Guideline for Protecting Marine Turtles from Light Impacts (pp. 130)*'. Perth: Environmental Protection Authority, Western Australia.

Erbe, C., Dunlop, R., Dolman, S. 2018. '*Effects of noise on marine mammals*'. In: Effects of Anthropogenic Noise on Animals Eds: Slabbekoorn, H., Dooling, R., Popper, A., Fay, R. (eds). Springer Handbook of Auditory Research. Chapter 10.

Erbe, C., Reichmuth, C., Cinningham, K., Lucke, K., Dooling, R., 2016. '*Communication masking in marine mammals: a review and research strategy*'. Marine Pollution Bulletin, 103:15-38.

Eriksen R.S., Davies, C.H., Bonham, P., Coman, F.E., Edgar, S., McEnnulty, F.R., McLeod, D., Miller, M.J., Rochester, W., Slotwinski, A., Tonks, M.L., Uribe-Palomino, J., Richardson, A.J., 2019. '*Australia's Long-Term Plankton Observations: The Integrated Marine Observing System National Reference Station Network*'. Front. Mar. Sci. 161(6).

ERM, 2011. '*Marine Baseline Survey and Ecological Assessment*'. Report prepared for GDF SUEZ LNG, Perth, Western Australia.

ERM, 2012. '*Marine environmental baseline study*'. Field Survey Report Rev 1. Report prepared for PTTEP AA, July 2012.

Evans, G.W., Lercher, P., Meis, M., Ising, H., Kofler, W.W., 2001. '*Community noise exposure and stress in children*'. J. Acoust. Soc. Am., 109(3): 1023 – 1027.

Evans, P.G.H., 1987. '*The Natural History of Whales and Dolphins*'. Christopher Helm/Academic Press, London.

Fall, J., Fields, L., 1996. '*Subsistence uses of fish and wildlife before and after the Exxon Valez oil spill*'. In "Proceedings of the Exxon Valdez oil spill symposium". Eds. Rice, S., Spies, R., Wolfe, S., Wright, B., 819-836. Bethesda, MD: American Fisheries Society.

Fay, R.R., Popper, A.N., 2000. '*Evolution of hearing in vertebrates: the inner ears and processing*'. Hearing Research, 149:1-10.

Fewtrell, J.L., 2003. '*The response of marine finfish and invertebrates to seismic survey noise*'. Doctoral dissertation, Curtin University.

Fewtrell, J.L., McCauley, R.D., 2012. '*Impact of air gun noise on the behaviour of marine fish and squid*'. Marine pollution bulletin, 64(5):984-993.

Fiedler, P.C., Reilly, S.B., Hewitt, R.P., Demer, D.A., Philbrick, V.A., Smith, S., Armstrong, W., Croll, D.A., Tershy, B.R., Mate, B.R., 1998. '*Blue whale habitat and prey in the California Channel Islands*'. Deep Sea Research Part II: Topical Studies in Oceanography, 45.

Fields, D. M., Handegard, N. O., Dalen, J., Eichner, C., Malde, K., Karlsen, Ø., Skiftesvik, A. B., Durif, C. M. F., and Browman, H. I. '*Airgun blasts used in marine seismic surveys have limited effects on mortality, and no sublethal effects on behaviour or gene expression, in the copepod* Calanus finmarchicus'. ICES Journal of Marine Science, doi:10.1093/icesjms/fsz126.

Fine, M.L., Thorson, R.F., 2008. '*Use of Passive Acoustics for Assessing Behavioural Interactions in Individual Toadfish*'. Trans. Am. Fish. Soc., 137:627-637.

Finneran, J.J., 2015. '*Noise induced hearing loss in marine mammals: A review of temporary threshold shift studies from 1996 to 2015*'. The Journal of Acoustical Society of America 138, 1702 (20015). https://asa.scitation.org/doi/full/10.1121/1.4927418.

Finneran, J.J., Carder, D.A., Schlundt, C.E. and Dear, R.L. 2010. '*Temporary threshold shift in a bottlenose dolphin (Tursiops truncatus) exposed to intermittent tones*'. J. Acoust. Soc. Am. 127, 3267-3272.

Finneran, J.J., Henderson, E.E., Houser, D.S., Jenkins, K., Kotecki, S., Mulsow, J., 2017. '*Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III)*'. Technical report by Space and Naval Warfare Systems Center Pacific (SSC Pacific). 183 pp. https://nwtteis.com/portals/nwtteis/files/technical_reports/Criteria_and_Thresholds_for_U.S._Navy_Acoustic_and_Explosive_Effects_Analysis_June2017.pdf.

Finneran, J.J., Jenkins, A.K., 2012. '*Criteria and thresholds for U.S. Navy acoustic and explosive effects analysis*'. SPAWAR Systems Center Pacific, San Diego, CA, USA. 64 pp.

Finneran, J.J., Schlundt, C.E., Branstetter, B. and Dear, R.L. 2007. '*Assessing temporary threshold shift in a bottlenose dolphin (Tursiops truncatus) using multiple simultaneous auditory evoked potentials*'. J. Acoust. Soc. Am. 122, 1249-1264.

Fitzgibbon, Q.P., Day, R.D., McCauley, R.D., Simon, C.J., Semmens, J.M., 2017. '*The impact of seismic air gun exposure on the haemolymph physiology and nutritional condition of spiny lobster, Jasus edwardsii*'. Marine Pollution Bulletin, 2017.08.004, doi.org/10.1016.

Fletcher, L.M., Zaiko, A., Atalah, J., Richter, I., Dufour, C.M., Pochon, X., Wood, S.A., Hokpins, G.A., 2017. '*Bilge Water as a Vector for the Spread of Marine Pests: A Morphological, Metabarcoding and Experimental Assessment*'. Biological Invasions, DOI 10.1007/s10530-017-1489-y.

Froese, R. and Pauly, D. (eds.), 2022. FishBase. Available at: http://www.fishbase.org/, accessed March 2022.

Fuiman, L. A., & Werner, R. G. 2002. '*Fishery science: The unique contributions of early life stages*.' Oxford, UK: Blackwell Science.

Gales, N., Double, M., Robinson, S., Jenner, C., Jenner, M., King, E., Gedamke, J., Childerhouse, S., Paton, D., 2010. '*Satellite tracking of Australian humpback whales (Megaptera novaeangliae) and pygmy blue whales (Balaenoptera musculus brevicauda)*'. Report for the International Whaling Commission 2010. SC/62/SH21.

Garcia-Rojas, M.I., Jenner, K.C.S., Gill, P.C., Jenner, M-N.M., Sutton, A.L., McCauley, R.D., 2018. '*Environmental evidence for a pygmy blue whale aggregation area in the Subtropical Convergence Zone south of Australia*'. Marine Mammal Science, 34:901-923.

Gausland, I., 2000. '*Impact of seismic surveys on marine life*'. The Leading Edge, 19: 903 – 905.

Gavrilov, A.N., McCauley, R.D., Salgado-Kent, C., Tripovich, J., Burton, C., 2011. '*Vocal characteristics of pygmy blue whales and their change over time*'. Journal of the Acoustical Society of America, 130(6):3651-3660.

Geoscience Australia, 2021. '*Ashmore and Cartier Islands*'. Australian Government, 2021. Available at: https://www.ga.gov.au/scientific-topics/national-location-information/dimensions/remote-offshore-territories/ashmore-and-cartier-islands, accessed March 2022.

Gerstein, E. R. 2002. '*Manatees, bioacoustics, and boats*'. American Scientist 90:154–163.

Giles, J., R.D. Pillans, M.J. Miller, J.P., Salini, 2006. '*Sawfish Catch Data in Northern Australia: A Desktop Study*'. Internal CSIRO Report for FRDC. 2002/064:74.

Gill, P., 2002. '*A blue whale (Balaenoptera musculus) feeding ground in a southern Australian coastal upwelling zone*'. J. Cetacean Res. Manage., 4(2):179-184.

Gill, P.C., Morrice, M.G., Page, B., Pirzl, R., Levings, A.H., Coyne, M., 2011. '*Blue whale habitat selection and within-season distribution in a regional upwelling system off southern Australia*'. Marine Ecology Progress Series, 421:243-263.

Gillespie, A., 2005. '*The Dugong Action Plan for the South Pacific: an evaluation based on the need for international and regional conservation of Sirenians*'. Ocean Development and International Law, 36(2):135-158.

Gleiss, A., Wright, S., Liebsch, N., Wilson, R., 2013. '*Contrasting diel patterns in vertical movement and locomotor activity of Whale sharks at Ningaloo Reef*'. Marine Biology.

Glen, K. and Collins, D., 2005. '*Ashmore Reef's sedimentological and morphological response to the Holocene sea level rise*'. **In**: Understanding the Cultural and Natural Heritage Values and Management Challenges in the Ashmore Region, Proceedings of a Symposium organised by the Australian Marine Sciences Association and the Museum and Art Gallery of the Northern Territory, Darwin, 4-6 April 2001. *Edited by* B. Russel, H. Larson, C.J. Glasby, R.C. Wilan, and J. Martin. Museum and Art Galleries of the Northern Territory & Australia Marine Sciences Association, Darwin, Northern Territory. pp. 13-29.

Golder, A., 2007. '*Literature review, synthesis, and design of monitoring of ambient artificial light intensity on the OCS regarding potential effects on resident marine fauna*'. Prepared for: U.S. Department of the Interior, Minerals Management Service. (pp. 1-96). Anchorage, Alaska.

Gomez, C., Lawson, J., Wright, A., Buren, A., Tollit, D., Lesage, V. 2016. '*A systematic review on the behavioural responses of wild marine mammals to noise: the disparity between science and policy*'. Canadian Journal of Zoology. DOI: 10.1139/cjz-2016-0098.

Goodall, C., Chapman, C., Neil, D., 1990. '*The acoustic response threshold of the Norway lobster, Nephrops norvegicus (L.) in a free sound field'*. In: Wiese K, Krenz WD, Tautz J, Reichert H, Mulloney B (eds) Frontiers in crustacean neurobiology. Birkha È user, Basel, pp 106±113 *(PDF) Acoustic detection and communication by decapod crustaceans*. Available from: https://www.researchgate.net/publication/8196581_Acoustic_detection_and_communication_by_decapod_crustaceans.

Goold, J.C., 1996. '*Acoustic assessment of populations of common dolphins Delphinus delphis in conjunction with seismic surveying'*. J. Mar. Biol. Ass. UK., 76:811-820.

Gordon, J., Gillespie, D., Potter, J., Frantzis, A., Simmonds, M.P., Swift, R., Thompson, D., 2003. '*A Review of the Effects of Seismic Surveys on Marine Mammals'*. Marine Technology Society Journal, 37(4):16-34.

Gordon, J., Moscrop, A., 1996. '*Underwater noise pollution and its significance for whales and dolphins*'. In Simmonds, M.P. and Hutchinson, J.D. (Eds.), The conservation of whales and dolphins. John Wiley and Sons, Ltd.

Goudie, R.I., Ankney, C.D., 1986. '*Body Size, Activity Budgets, and Diets Of Sea Ducks Wintering In Newfoundland*'. Ecology, 67:1475-1482.

Graham, A.L., Cooke, S.J., 2008. '*The effects of noise disturbance from various recreational boating activities common to inland waters on the cardiac physiology of a freshwater fish, the largemouth bass (Micropterus salmoides)*'. Aquatic Conservation and Freshwater Ecosystems 18, 1315-1324.

Gray, H., van Waerebeek, K., 2011. '*Postural instability and akinesia in a panspotted tropical dolphin Stenella attenuata, in proximity to operating airguns of a geophysical seismic vessel*'. Journal for Nature Conservation 19(6): 363 – 367.

Gray, M.D., Rogers, P.H., Popper, A.N., Hawkins, A.D., Fay, R.R., 2016. *'Large tank acoustics: how big is big enough?'.* The Effects of Noise on Aquatic Life II., pages 363-370. Springer + Business Media, New York.

Griffith, J.K., 1997. *The Corals Collected During September/October at Ashmore Reef, Timor Sea*. Parks Australia.

Guinea, M., 2008. *An Assessment of Seasnake Abundance at Ashmore Reef National Nature Reserve, Ashmore Reef and Cartier Island Territory, Stage Three*. Charles Darwin University, Darwin, Northern Territory.

Guinea, M.L., 1993. '*Reptilia, Aves and Mammalia*'. **In:** Russell, B.C. & J.R. Hanley, eds. Survey of Marine Biological and Heritage Resources of Cartier and Hibernia Reefs, Timor Sea. Page(s) 74 - 83. Darwin: Northern Territory Museum of Arts and Sciences.

Guinea, M.L., 1995. '*The sea turtles and sea snakes of Ashmore Reef Nature Reserve'*. Page(s) 67. Darwin: Northern Territory University.

Guinea, M.L., 2007. '*Survey March 16 - April 2 2007: Sea snakes of Ashmore Reef, Hibernia Reef and Cartier Island with comments on Scott Reef'.* Final Report to the Department of the Environment and Water Resources, Canberra. Darwin: Charles Darwin University.

Guinea, M.L., Whiting, S.D., 2005. '*Insights into the distribution and abundance of sea snakes at Ashmore Reef*'. The Beagle Supplement 1, 199–205.

Gurjao, L.D., Freitas, J.P., Araújo, D.S., 2005. '*Observations of Marine Turtles During Seismic Surveys off Bahia, North-eastern Brazil*'. Marine Turtle Newsletter No. 108, 2005.

Hale, J. and Butcher, R., 2013. *Ashmore Reef Commonwealth Marine Reserve Ramsar Site Ecological Character Description*. Report prepared for the Department of the Environment, Canberra.

Hale, P.T., Barreto, A.S., Ross. G.J.B., 2000. '*Comparative Morphology and Distribution of the aduncus and truncates forms of Bottlenose Dolphin Tursiops in the Indian and Western Pacific Oceans'*. Aquatic Mammals, 26(2):101-110.

Halfwerk, W., Holleman, L.J.M., Lessells, C.M., Slabbekoorn, H., 2011. '*Negative impact of traffic noise on avian reproductive success*'. J. Appl. Ecol., 48:210-219.

Hamann, M., Limpus, C.J., Read, M., 2007. Vulnerability of marine reptiles to climate change in the Great Barrier Reef. **In:** Johnson, J. & P. Marshal, eds. *Great Barrier Reef Marine Park Authority and The Australian Greenhouse Office: Climate change and the Great Barrier Reef*.

Handegard, N., Tronstad, T., Hovem, J., Jech, J., 2013. '*Evaluating the Effect of Seismic Surveys on Fish – The Efficacy of Different Exposure Metrics to Explain Disturbance*'. Canadian Journal of Fisheries and Aquatic Sciences, 70:1271 – 1277.

Handegard, N.O., Michalsen, K., Tjostheim, D., 2003. '*Avoidance behaviour in cod (Gadus morhua) to a bottom-trawling vessel*'. Aquatic Living Resources, 16(3):265-270.

Harland, E.J., Jones, S.A., Clarke, T. 2005. '*SEA 6 Technical report: Underwater ambient Noise*'. Produced by QinetiQ as part of the UK Department of Trade and Industry's offshore energy Strategic Environmental Assessment programme. QINETIQ/S&E/MAC/CR050575.

Harrington, J. J., McAllister, J., Semmens, J.M., 2010. *'Assessing the short-term impact of seismic surveys on adult commercial scallops (Pecten fumatus) in Bass Strait'*. Tasmanian Aquaculture and Fisheries Institute, University of Tasmania.

Harris, P., Heap, A., Passlow, V., Sbaffi, L. Fellows, M., Porter-Smith, R., Buchanan, C., Daniell, J.,2005. Geomorphic Features of the Continental Margin of Australia. Geoscience Australia, Record 2003/30, 142pp.

Hartline, P.H., Campbell, H.W., 1969. '*Auditory and vibratory responses in the midbrains of snakes'*. Science. 163, 1221-1223. doi:10.1126/science.163.3872.1221.

Hassel, A., Knutsen, T., Dalen, J., Skaar, K., Lokkeborg, S., Misund, O., Ostensen, O., Fonn, M., Haugland, E., 2004. *'Influence of seismic shooting on the lesser sandeel (Ammodytes marinus)*'. ICES Journal of Marine Science, 61:1165-1173.

Hastings, M.C., Reid, C.A., Grebe, C.C., Hearn, R.L., Colman, J.G., 2008. '*The effects of seismic airgun noise on the hearing sensitivity of tropical reef fishes at Scott Reef, Western Australia. Underwater noise measurement, impact and mitigation'*. Proc. Inst. Acoust., 30(5).

Hatch, L., Wahle, C., Gedamke, J., Harrison, J., Laws, B., Moore, S., Stadler, H., Van Parijs, S. 2016. '*Can you hear me here? Managing acoustic habitat in US waters'*. Endangered Species Research. 30, 171–186.

Hawkins, A. D., Pembroke, A., Popper, A., 2015. '*Information gaps in understanding the effects of noise on fishes and invertebrates*'. Reviews in Fish Biology and Fisheries, 25: 39–64.

Hayes, D., Lyne, V., Condie, S., Griffiths, B., Pigot, S., Hallegraeff, G. 2005. '*Collation and analysis of oceanographic datasets for national marine bioregionalisation'*. A report to the Australian Government, National Oceans Office, Canberra, ACT. CSIRO Marine Research.

Hazel, J., Gyuris, E., 2006. '*Vessel-related mortality of sea turtles in Queensland, Australia*'. Wildlife Research, 33(2):149-154.

Hazel, J., Lawler, I.R., Marsh, H., Robson, S., 2007. '*Vessel speed increases collision risk for the Green turtle Chelonia mydas*'. Endangered Species Research, 3:105-113.

Heyward, A., Colquhoun, J., Cripps, E., McCorry, D., Stowar, M., Radford, B., Miller, K., Miller, I., Battershill, C., 2018. '*No evidence of damage to the soft tissue or skeletal integrity of mesophotic corals exposed to a 3D marine seismic survey*'. Marine Pollution Bulletin 129(1):8-13. https://doi.org/10.1016/j.marpolbul.2018.01.057.

Heyward, A., Jones, R., Meeuwig, J., Burns, K., Radford, B., Colquhoun, J., Cappo, M., Case, M., O'Leary, R., Fisher, R., Meekan, M., Stowar, M. 2011. '*Montara: 2011 Offshore Banks Assessment Survey*'. Monitoring Study S5. Final Report prepared by the Australian Institute of Marine Science for PTTEP Australasia (Ashmore Cartier).

Heyward, A., Radford, B., Cappo, M., Wakeford, M., Fisher, R., Colquhoun, J., Case, M., Stowar and Miller, K. 2017. '*Barossa Environmental Baseline Study, Regional Shoals and Shelf Assessment 2015 Final Report'*. A report for ConocoPhillips Australia Exploration Pty Ltd by the Australian Institute of Marine Science, Perth 2017. 143pp.

Higgins, P.J. and Davies, S.J.JF. (eds.), 1996. '*Handbook of Australian, New Zealand and Antarctic Birds*'. Volume Three - Snipe to Pigeons, Melbourne, Victoria, Oxford University Press.

Hoenner, X., Whiting, S.D., Enever, G., Lambert, K., Hindell, M.A., McMahon, C.R., 2016. '*Nesting ecology of hawksbill turtles at a rookery of international significance in Australia's Northern Territory*'. Wildlife Research, 43:461-473.

Holliday, D., Beckley, L.E., Weller, E., Sutton, A.L., 2011. '*Natural variability of macro-zooplankton and larval fishes off the Kimberley, north-western Australia: Preliminary findings'*. Journal of the Royal Society of Western Australia, 94:181-195.

Holloway, P.E., 1983. '*Tides on the Australian North-West Shelf*'. Aust. J. Mar. Freshwat. Res., 34:213-230.

Holloway, P.E., 1984. '*On the semidiurnal internal tide at a shelf break region on the Australian North West Shelf'*. J. Phys. Oceanogr., 14:1787-1799.

Holloway, P.E., 1987. '*Internal hydraulic jumps and solitons at a shelf break region on the Australian North West Shelf*'. J. Geophys. Res., 92:5405-5416.

Holt, M.M., Noren, D.P., Veirs, V., Emmons, C.K., Veirs, S., 2008. '*Speaking up: Killer whales (Orcinus orca) increase their call amplitude in response to vessel noise*'. Journal of the Acoustical Society of America, 125(1): EL27 – EL32.

Hook, S., Batley, G., Holloway, M., Irving, P., Ross, A., 2016. '*2016 Oil Spill Monitoring Handbook*'. CSIRO Publishing Melbourne.

Horwood, J., 2009. '*Sei whale Balaenoptera borealis'.* In, W. F. Perrin and B. Würsig and J. G. M. Thewissen (Ed.), Encyclopedia of marine mammals, pp. 1001-1003. Academic Press, United States.

Hosack, G.R. and Dambacher, J.M., 2012. '*Ecological indicators for the Exclusive Economic Zone of Australia's South-east Marine Region*'. A report prepared for the Australian Government Department of Sustainability, Environment, Water, Population and Communities, CSIRO Wealth from Oceans Flagship, Hobart.

Houde, E.D. and Zastrow, C.E. 1993. '*Ecosystem- and taxon-specific dynamic and energetics properties of larval fish assemblages.*' Bulletin of Marine Science 53(2): 290-335.

Houghton, J., Doyle, T., Wilson, M., Davenport, J., Hays, G., 2006. '*Jellyfish aggregations and leatherback turtle foraging patterns in a temperate coastal environment*'. Ecology, 8:1967-1972.

Houghton, J.D.H., Doyle, T.K., Davenport, J., Wilson, R.P., Hays, G.C., 2008. '*The role of infrequent and extraordinary deep dives in leatherback turtles (Dermochelys coriacea)*'. The Journal of Experimental Biology, 211:2566-2575.

How, J., Coughran, D., Double, M., Rushworth, K., Hebiton, B., Smith, J., Harrison, J., Taylor, M., Paton, D., McPherson, G., McPherson, C., Recalde Salas, A., Salgado-Kent, C., de Lestang, S., 2020. '*Mitigation measures to reduce entanglements of migrating whales with commercial fishing gear FRDC 2014-004'*. Fisheries Research Report No. 304 Department of Primary Industries and Regional Development, Western Australia. 118pp.

Howard, M., Howard, M., McLeod, P., Marine Tourism WA, 2021. '*The Western Australian Charter Fishing Industry: A Survey Based Study of Operators and Customers. Research Report for the Recreational Fishing Initiatives Fund*'. Department of Primary Industries and Regional Development.

IAGC, 2017. '*Review of Recent Study Addressing Potential Effcts of Seismic Surveys on Zooplankton*'. Letter to Mr Gary Goeke, Chief Environmental Assessment Section, Office of Environment, Bureau of Ocean Energy management and Ms Jolie Harrison, Chief Permits and Conservation Division, Office of Protected Resources, National Marine Fisheries Service from the International Association of Geophysical Contractors and API.

IAP2, 2016. http://iap2.org.au/resources/iap2-published-resources/ accessed 10 May 2022.

IOGP, 2017. '*Seismic Surveys & Marine Mammals'*. Joint IOGP/IAGC position paper, Report 576, 12p.

Irvine, L.G., Thums, M., Hanson, C.E., McMahon, C.R., Hindell, M.A., 2018. '*Evidence for a widely expanded humpback whale calving range along the Western Australian coast*'. Marine Mammal Science, 34(2):294-310.

ISO, 2016.' *Environmental management systems - Requirements with guidance for use'*. AS/NZS ISO 14001:2016. Australian & New Zealand International Standard.

ISO, 2017. '*Standard for acoustic terminology*', ISO/DIS 18405:2017. Australian & New Zealand International Standard.

ISO, 2018. '*Risk Management – Guidelines*'. AS/NZS ISO 31000:2018. Australian & New Zealand International Standard.

ITOPF, 2011. '*Effects of Oil Pollution on the Marine Environment*'. Technical Information Paper. Technical paper No. 13. The International Tank Owners Pollution Federation Limited.

IWC, 2007. '*Report of the Scientific Committee Annex K*'. Report of the Stranding Working Group on Environmental Concerns. Journal of Cetacean Research and Management Supplement 9: 227-296.

Jackson, J.A., Steel, D.J., Beerli, P., Congdon, B.C., Olavarria, C., Leslie, M.S., Pomilla, C., Rosenbaum, H., Baker, C., 2014. '*Global diversity and oceanic divergence of humpback whales (Megaptera novaeangliae)*'. Proceedings of the Royal Society B, 281:20133222.

Jacobs Group Australia Pty Ltd (Jacobs), 2017. *Montara Environmental Monitoring – Produced Formation Water Toxicity and Potential Effects on the Receiving Environment Rev 2.* Report prepared for PTTEP AA. December 2017.

Jefferson, T.A. and Rosenbaum, H.C., 2014. '*Taxonomic revision of the humpback dolphins (Sousa spp.), and description of a new species from Australia'. Marine Mammal Science*, 30(4):1494-1541.

Jenner, C., Jenner, M., Burton, C., Sturrock, V., Salgado Kent, C., Morrice, M., Attard, C., Möller, L., Double, M.C., 2008. '*Mark recapture analysis of pygmy blue whales from the Perth Canyon, Western Australia 2000–2005*'. Paper SC/60/SH16 presented to the IWC Scientific Committee (unpublished).

Jensen, A.S., Silber, G.K., Calambokidis, J., 2004. '*Large Whale Ship Strike Database*'. Washington, DC: US Department of Commerce, National Oceanic and Atmospheric Administration.

Jensen, F.H., Bejder, L., Wahlberg, M., Aguilar Soto, N., Johnson, M., Madsen, P.T., 2009. '*Vessel noise effects on delphinid communication'*. Marine Ecology Progress Series, 395: 161 – 175.

Jenssen, B.M., 1994. '*Effects of oil pollution, chemically treated oil, and cleaning on the thermal balance of birds*'. Environmental Pollution, 86(2): 207 – 215.

Jochens, A., Biggs, D., Engelhaupt, D., Gordon, J., Jaquet, N., Johnson, M., Leben, R., Mate, B., Miller, P., Ortega-Oritz, J., Thode, A., Tyack, P., Wormuth, J., Wűrsig, B., 2016. '*Sperm whale seismic study in the Gulf of Mexico; summary report, 2002 – 2004'*. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2006-034, 352p.

Johnson, M., Soto, N., Madsen, P., 2009. '*Studying the behaviour and sensory ecology of marine mammals using acoustic recording tags: a review*'. Marine Ecology Progress Series, 395: 55-73.

Johnstone, R.E. and Storr, G.M., 1998. '*Handbook of Western Australian Birds, Non-passerines (Emu to Dollarbird)'*. Vol. 1, Perth, Western Australia: West Australian Museum.

Jones, I.T., Stanley, J.A., Mooney, T.A., 2020. 'Impulsive pile driving elicits alarm responses in squid (*Doryteuthis pealeii*)'. Marine Pollution Bulletin, Volume 150, January 2020.

Kaifu, K., Segawa, S., Tsuchiya, K., 2007. '*Behavioural responses to underwater sound in the small benthic octopus Octopus ocellatus*'. The Journal of the Marine Acoustics Society of Japan, 34(4):266-273.

Kashiwagi, T., Marshall, A.D., Bennet, M.B., Ovenden, J.R., 2011. '*Habitat segregation and mosaic sympatry of the two species of manta ray in the Indian and Pacific Oceans: Manta alfredi and M. birostris'*. Marine Biodiversity Records, 4: e53.

Kastelein, R., Helder-Hoek, L., Covi, J., Gransier, R., 2016. '*Pile driving playback sounds and temporary threshold shift in harbour porpoises (Phocoena phocoena): effect of exposure duration*'. Journal of the Acoustical Society of America 139(5): 2842-2851.

Kato, H., 2002. 'Bryde's Whales *Balaenoptera edeni* and *B. brydei'*. **In:** Perrin W.F., B. Wrsig & H.G.M. Thewissen, eds. Encyclopedia of Marine Mammals. Pages 171-177. Academic Press.

Kavanagh, A., Nykanen, M., Hunt, W., Richardson, N., Jessopp, M. 2019. '*Seismic surveys reduce cetacean sightings across a large marine ecosystem'*. Scientific Reports 9: 19164.

Keevin, T.M., Hempen, G.L., 1997. '*The environmental effects of underwater explosions with methods to mitigate impacts'*. Corps of Engineering St Louis MO St Louis District.

Kent, C.S., McCauley, R.D., Duncan, A., Erbe, C., Gavrilov, A., Lucke, K., Parnum, I., 2016. '*Underwater Sound and Vibration from Offshore Petroleum Activities and their Potential Effects on Marine Fauna*': An Australian Perspective.

Ketos Ecology, 2009. '*Turtle Guards: A method to reduce the marine turtle mortality occurring in certain seismic survey equipment*.' Ketos Ecology Report, 14 pp.

Kimberley Bird Watching, 2018. '*Ashmore Reef*'. Retrieved from: http://kimberleybirdwatching.com.au/tours/ashmore-reef/. Accessed March 2020.

Kirillin, G., Grossart, H-P. and Tang, K.W. 2012. '*Modelling sinking rate of zooplankton carcasses: Effects of stratification and mixing*.' Limnology and Oceanography 57(3): 881–894.

Kirkendale, L., Hosie, A.M., Richards, Z., 2019. '*Defining biodiversity gaps for North west Shelf marine invertebrates'*. Journal of the Royal Society of Western Australia, 102: 1-9, 2019.

Klimley, A.P., Myrberg, J.A.A., 1979. '*Acoustic stimuli underlying withdrawal from a sound source by adult lemon sharks, Negaprion brevirostris (Poey)*'. Bulletin of Marine Science, 29:447–458.

Komak, S., Boal, J.G., Dickel, L., Budelmann, B.U., 2005. '*Behavioural responses of juvenile cuttlefish (Sepia officinalis) to local water movements*'. Marine and Freshwater Behaviour and Physiology, 38(2):117-125.

Kospartov*, M.,* Beger, M., Ceccarelli, D., Richards, Z., 2006. *An Assessment of the Distribution and Abundance3 of Sea Cucumbers, Trochus, Giant Clams, Coral, Fish and Invasive Marine Species at Ashmore Reef National Nature Reserve and Cartier Island Marine Reserve*. UniQuest Pty Ltd.

Kostyuchenko, L., 1973. *'Effects of elastic waves generated in marine seismic prospecting on fish eggs in the Black Sea'*. Hydrobiol. J., 9:45–48.

Lacroix, D.L., Lanctot, R.B., Reed, J.A., McDonald, T.L., 2003. '*Effect of underwater seismic surveys on molting male long-tailed ducks in the Beaufort Sea, Alaska'*. Can. J. Zool., 81:1862-1875.

Ladich F., Collin S.P., Moller P., Kapoor B.G., 2006. '*Fish Communication'*. Enfield (CT): Science Publisher.

Laist, D.W., 1987. '*Overview of the biological effects of lost and discarded plastic debris in the marine environment'*. Marine Pollution Bulletin 18(6): 319 – 326.

Last, P.R. and Stevens, J.D., 1994. '*Sharks and Rays of Australia'*. Melbourne, Victoria: CSIRO.

Last, P.R. and Stevens, J.D., 2009. '*Sharks and Rays of Australia (Second Edition)*'. Collingwood, Victoria: CSIRO Publishing.

Law, R.J., Hellou, J., 1999. '*Contamination of fish and shellfish following oil spill incidents'*. Environmental Geosciences, 6(2): 90-98.

Law, R.J., Kirby, M.F., Moore, J., Barry, J., Sapp, M. and Balaam, J., 2011. PREMIAM – Pollution Response in Emergencies Marine Impact Assessment and Monitoring: Post-incident monitoring guidelines. Science Series Technical Report, Cefas, Lowestoft, 146: 164p.

Lee, R.F., Page, D.S., 1997. '*Petroleum hydrocarbons and their effects in subtidal regions after major oil spills*'. Marine Pollution Bulletin, 34(11): 928 – 940.

Lenhardt, M.L., 1994. '*Seismic and very low frequency sound induced behaviors in captive loggerhead marine turtles (Caretta caretta). In Proceedings of the fourteenth annual symposium on sea turtle biology and conservation*' (KA Bjorndal, AB Bolten, DA Johnson & PJ Eliazar, eds.) NOAA Technical Memorandum, NMFSSEFC-351, National Technical Information Service, Springfield, Virginia (pp. 238-241).

Leonard, M.L., Horn, A.G., 2012. '*Ambient noise increases missed detections in nestling birds*'. Biol. Lett., 8:530-532.

Lewis, P. '*Resource Assessment Report No. 19 – Statewide Large Pelagic Resource in Western Australia*'. Department of Primary Industries and Regional Development, Government of Western Australia.

Lewis, P., Blay, N., Watt, M., 2021. 'Statewide Large Pelagic Finfish Resource Status Report 2020'. In: Status Reports of the Fisheries and Aquatic Resources of Western Australia 2019/20: The State of the Fisheries (eds). D.J. Gaughan and K. Santoro. Department of Primary Industries and Regional Development, Western Australia. pp. 241-247.

Limpus, C.J, 1997. '*A biological review of Australian marine turtle species. 6. Olive Ridley Turtle,* Lepidochelys olivacea *(Eschscholtz)'*. Queensland Environment Protection Agency.

Limpus, C.J. and MacLachlin, N., 1994. '*The conservation status of the Leatherback Turtle, Dermochelys coriacea, in Australia'*. **In:** James, R, ed. Proceedings of the Australian Marine Turtle Conservation Workshop, Gold Coast 14-17 November 1990. Page(s) 63-67. Queensland Department of Environment and Heritage. Canberra: ANCA.

Limpus, C.J., 1985. '*A study of the Loggerhead Turtle, Caretta caretta, in eastern Australia'*. Ph.D. Thesis. Brisbane, Department of Zoology, University of Queensland.

Limpus, C.J., 1992. '*The hawksbill turtle, Eretmochelys imbricata, in Queensland: population structure within a southern Great Barrier Reef feeding ground'*. Wildlife Research.

Limpus, C.J., 1995. '*Conservation of marine turtles in the Indo-Pacific region'*. Brisbane: Queensland Department of Environment and Heritage.

Limpus, C.J., 2007. '*A biological review of Australian marine turtle species. 5. Flatback turtle, Natator depressus (Garman)'*. Queensland Environmental Protection Agency.

Limpus, C.J., 2008. '*A biological review of Australian Marine Turtles. 1. Loggerhead Turtle Caretta caretta (Linneaus)'*. Queensland Environment Protection Agency. Available from: http://www.epa.qld.gov.au/publications/p02785aa.pdf/A_Biological_Review_Of_Australian_Marine_Turtles_1_Loggerhead_Turtle_emCaretta_Caretta/em_Linnaeus.pdf.

Limpus, C.J., 2009. '*A biological review of Australian marine turtle species: 6. Leatherback turtle, Dermochelys coriacea (Vandelli)'*. Environmental Protection Agency, Queensland.

Limpus, C.J., MacLachlin, N.C., Miller, J.D., 1984. '*Further observations on breeding of Dermochelys coriacea in Australia*'. Australian Wildlife Research, 11:567-571.

Limpus, C.J., Parmenter, C.J., Baker, V., Fleay, A., 1983. '*The flatback turtle, Chelonia depressa, in Queensland: post-nesting migration and feeding ground distribution'*. Australian Wildlife Research, 10:557-561.

Lindquist, D.C., Shaw, R.F., Hernandez Jr, F.J., 2005. '*Distribution patterns of larval and juvenile fishes at offshore petroleum platforms in the north-central Gulf of Mexico'*. Estuarine, Coastal and Shelf Science. 62(4):655-665.

Lowry, H., Lill, A., Wong, B.B., 2012. '*How noisy does a noisy miner have to be? Amplitude adjustments of alarm calls in an avian urban 'adapter*'. PLoS One, 7: e29960.

Luczkovich, J.J., Daniel, H.J., Hutchinson, M., Jenkins, T., Johnson, S.E., Pullinger, R.C., Sprague, M.W., 2000. '*Sounds Of Sex And Death In The Sea: Bottlenose Dolphin Whistles Suppress Mating Choruses Of Silver Perch'*. Bioacoustics, 10:323-334.

Lugli, M., Yan, H.Y., Fine, M.L., 2003. '*Acoustic Communication In Two Freshwater Gobies: The Relationship Between Ambient Noise, Hearing Thresholds And Sound Spectrum'*. J. Comp. Phys. A., 189:309-320.

Lukoschek, V., Beger, M., Ceccarelli, D., Richards, Z., Pratchett, M., 2013. '*Enigmatic declines of Australia's sea snakes from a biodiversity hotspot*'. Biological Conservation, 166:191-202.

Lusseau, D., Bain, D.E., Williams, R., Smith, J.C., 2009. '*Vessel traffic disrupts the foraging behaviour of southern resident killer whales Orcinus orca'*. Endangered Species Research, 6: 211 – 221.

Lutz, P.L and Musick, J.A., 1996. '*The Biology of Sea Turtles'*. United States of America: CRC Press.

MacDiarmid, A., Beaumont, J., Bostock, H., Bowden, D., Clark, M., Hadfield, M., Heath, P., Lamarche, G., Nodder, S., Orpin, A., Stevens, C., Thompson, D., Torres, L., Wysoczanski, R., 2012. '*Expert Risk Assessment of Activities in the New Zealand Exclusive Economic Zone and Extended Continental Shelf*', prepared for the Ministry for the Environment, NIWA Client Report No: WLG2011-39, 139pp.

Macduff-Duncan, C., Davies, G., 1995. '*Managing seismic exploration in a nearshore environmentally sensitive areas*'. Society of Petroleum Engineers, DOI:10.2118/30431-MS.

MacGillivray, A. and Z. Li., 2018. *Vessel Noise Measurements from the ECHO Slowdown Trial*: Final Report. Document 01518, Version 3.0. Technical Report by JASCO Applied Sciences for Vancouver Fraser Port Authority ECHO Program. ECHO Haro Strait slowdown trial summary by portvancouver - Flipsnack

Machernis, A.F., Powell, J.R., Engleby, L., Spradlin, T.R. 2018. '*An updated literature review examining the impacts of tourism on marine mammals over the last fifteen years (2000-2015) to inform research and management programs'*. U.S. Dept. of Commerce 66:7. DOI: https://doi.org/10.7289/V5/TM-NMFS-SER-7.

Madsen, P.T., Møhl, B., Nielsen, B.K., Wahlberg, M., 2002. '*Male sperm whale behaviour during exposures to distant seismic survey pulses*'. Aquatic Mammals, 28(3): 231 – 240.

Maitland, R.N., Lawler, I.R., Sheppard, J.K., 2005. '*Assessing the risk of boat strike on dugongs Dugong Dugon at Burrum Heads, Queensland, Australia*'. Pacific Conservation Biology 12: 321-326.

Malme, C.I., Wursig, B., Bird, J.E., Tyack, P., 1988. '*Observations of feeding gray whale responses to controlled industrial noise exposure'*. In Sackinger, W.M., Jeffroes. M.O. (Eds), '*Port and ocean engineering under arctic conditions – symposium on noise and marine mammals'*.

Mann, D., Hill-Cook, M., Manire, C., Greenhow, D., Montie, E., et al. 2010. '*Hearing Loss in Stranded Odontocete Dolphins and Whales'*. PLoS ONE 5(11): e13824. doi:10.1371/journal.pone.0013824.

Marchant, S. and Higgins, P.J. (eds.), 1993. '*Handbook of Australian, New Zealand and Antarctic Birds*'. Volume 2 - Raptors to Lapwings. Melbourne, Victoria: Oxford University Press.

Marchant, S. and Higgins, P.J., 1990. '*Handbook of Australian, New Zealand and Antarctic birds'*. Volume 1, Part A: Ratites to Petrelexs. Oxford University Press, Melbourne.

Marchesan, M., Spotto, M., Verginella, L., Ferrero, E.A., 2006. '*Behavioural Effects of Artificial Light on Fish Species of Commercial Interest*'. Fisheries Research, vol. 73, pp. 171-185.

Marsh, H., O'Shea, T.J., Reynolds, J.R., 2011. '*The ecology and conservation of sirenia; dugongs and manatees*'. Cambridge University Press, London.

Marsh, H., Penrose, H., Eros, C., Hugues, J., 2002. '*Dugong Status Report and Action Plans for Countries and Territories. Early Warning Assessment Reports*'. United Nations Environment Programme, Nairobi.

Marsh, L.M., 1993. *Cnidaria, other than reef-building corals of Ashmore Reef and Cartier Island*. **In:** Marine and Faunal surveys of Ashmore Reef and Cartier Island North-western Australia. *Edited* by Berry, P.F. Western Australian Museum, Perth, Western Australia. pp. 21 -23.

Marsh, L.M., Vail, L.L., Hoggett, A.K., Rowe., 1993. *Echinoderms of Ashmore Reef and Cartier Island*. **In:** Marine and Faunal Surveys of Ashmore Reef and Cartier Island North-western Australia. *Edited* by Berry, P.F. Western Australian Museum, Perth, Western Australia. pp. 53 – 65.

Marshall, A., Bennett, M.B., Kodja, G., Hinojosa-Alvarez, S., Galvan-Magana, F., Harding, M., Stevens, G., Kashiwagi, T., 2018a. '*Mobula birostris (amended version of 2011 assessment). The IUCN Red List of Threatened Species 2018'*:

Marshall, A., Kashiwagi, T., Bennett, M.B., Deakos, M., Stevens, G., McGregor, F., Clark, T., Ishihara, H., Sato, K., 2018b. '*Mobula alfredi (amended version of 2011 assessment). The IUCN Red List of Threatened Species 2018*': e.T195459A126665723. http://dx.doi.org/10.2305/IUCN.UK.2011-2.RLTS.T195459A126665723.en. Downloaded June 2019.

Mate, B.R., Stafford, K.M., Ljungblad, D.K., 1994. '*A change in sperm whale (Physeter macrocephalus) distribution correlated to seismic surveys in the Gulf of Mexico'*. Conference paper in The Journal of the Acoustical Society of America, 96(5): 3268 – 3269.

McCauley, R. D., Jenner, C., Jenner, M. N., Murdoch, J., McCabe, K., 1998. '*The response of humpback whales to offshore seismic survey noise: Preliminary results of observations about a working seismic vessel and experimental exposures'*. APPEA Journal 2000: 692-708.

McCauley, R., Fewtrell, J., Popper, A., 2003a. '*High intensity anthropogenic sound damages fish ears'*. Journal of the acoustical society of America, 113:1-5.

McCauley, R., Gavrilov, A., Jolliffe, C., Ward, R., Gill, P., 2018. '*Pygmy blue and Antarctic blue whale presence, distribution and population parameters in southern Australia based on passive acoustics*'. Deep Sea Research Part II: Topical Studies in Oceanography.

McCauley, R.D., 1994. '*The environmental implications of offshore oil and gas development in Australia seismic surveys'*. In: *Environmental Implications of Offshore Oil and Gas Development in Australia - The Findings of an Independent Scientific Review*, J.M. Swan, J.M. Neff and P.C. Young, (eds.), pp. 123-207. Australian Petroleum Exploration Association, Sydney.

McCauley, R.D., 2009. '*Sea Noise Logger Deployment Scott Reef, 2006-2008 – Whales, Fish and Seismic Surveys*'. Report prepared for Woodside Energy, CMST R2009-15. 88 pp.

McCauley, R.D., 2011. '*Woodside Kimberley Sea Noise Logger Program, September 2006 to June 2009: Whales, fish and man-made noise*'. For Woodside Energy. Project CMST 861. Report R2010–50_3 (unpublished).

McCauley, R.D., 2014. '*Joseph Bonaparte Gulf Sea Noise Logger Program, Sep-2010 to Sep-2013, Ambient Noise, Great Whales and Fish*'. Report prepared for RPS MetOcean, CMST R2013-52, 75 pp.

McCauley, R.D., Day, R.D., Swadling, K.M., Fitzgibbon, Q.P., Watson, R.A., Semmens, J.M., 2017. '*Widely used marine seismic survey air gun operations negatively impact zooplankton*'. Nature Ecology & Evolution, 1:1-8. http://dx.doi.org/10.1038/s41559-017-0195.

McCauley, R.D., Fewtrell, J., Duncan, A., Jenner, C., Jenner, M., Penrose, J. D, Prince, R., Adhitya, A., Murdoch, J., McCabe, K., 2003b. '*Marine Seismic Surveys: Analysis and Propagation of Air-gun Signals in Environmental implications of offshore oil and gas development in Australia: further research*'. APPEA Ltd.

McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M-N., Penrose, J.D., Prince, R.I.T., Adhitya, A., Murdoch, J., McCabe, K., 2000a. '*Marine Seismic Surveys: Analysis and propagation of air-gun signals; and effects of air-gun exposure on humpback whales, sea turtles, fishes and squid*'. Prepared for Australian Petroleum Production Exploration Association, Project CMST 163, Report R99-15.

McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M-N., Penrose, J.D., Prince, R.I.T., Adhitya, A., Murdoch, J., McCabe, K., 2000. '*Marine Seismic Surveys – A Study of Environmental Implications*'. APPEA Journal. 40.

McCauley, R.D., Jenner, C., 2010. '*Migratory patterns and estimated population size of pygmy blue whales (Balaenoptera musculus brevicauda) traversing the Western Australian coast based on passive acoustics*'. Paper SC/62/SH26 presented to the IWC Scientific Committee (unpublished).

McCosker, J.E., 1975. '*Feeding behaviour of Indo-Australian Hydrophiidae*'. **In:** Dunson, W. A., ed. The Biology of Sea Snakes. Page(s) 217-232. Baltimore: University Park Press.

McCrea-Strub, A., Kleisner, K., Sumaila, U.R., Swartz, W., Watson, R., Zeller, D., Pauly, D., 2011. '*Potential impact of the Deepwater Horizon oil spill on commercial fisheries in the Gulf of Mexico*'. Fisheries, 36(7):332-336.

McDonald, M.A., 2006. '*An acoustic survey of baleen whales off Great Barrier Island*'. New Zealand Journal of Marine and Freshwater Research, 40:519-529.

McDonald, M.A., Calambokidis, J., Teranishi, A.M., Hildebrand, J.A., 2001. 'The *acoustic calls of blue whales off California with gender data*'. The Journal of the Acoustical Society of America, 109:1728-1735.

McDonald, M.A., Hildebrand, J.A., Webb, S.C., 1995. '*Blue and fin whales observed on a seafloor array in the Northeast Pacific*'. Journal of the Acoustical Society of America, 98(2): 712 – 721.

McGregor, P.K., Horn, A.G., Leonard, M.L., Thomsen, F., 2013. '*Chapter 14 - Anthropogenic noise and conservation*'. In Brumm, H. (Ed) '*Animal Communication and Noise*', DOI:10.1007/978-3-642-41494-7_14.

McKenna, M.F., Calambokidis, J., Oleson, E.M., Laist, D.W., Goldbogen, J.A., 2015. '*Simultaneous tracking of blue whales and large ships demonstrates limited behavioural responses for avoiding collision*'. Endangered Species Research, 27:219-232.

McKenna, M.F., Ross, D., Wiggins, S.M., Hildebrand, A.J. 2012. '*Underwater radiated noise from modern commercial ships*'. Journal of the Acoustical Society of America 131(1): 92-103.

McPherson, C., Kowarski, K., Delarue, J., Whitt, C., MacDonnell, J., Martin, B., 2016. '*Passive Acoustic Monitoring of Ambient Noise and Marine Mammals—Barossa Field*'. JASCO Document 0997, Version 1.0. Technical report by JASCO Applied Sciences for Jacobs

McPherson, C., Quijano, J., Weirathmueller, M., Hiltz, K., Lucke, K., 2019. '*Browse to North-West Shelf Project Noise Modelling Study, Assessing Marine Fauna Sound Exposures*'. Document 01824, Version 2.2. Technical report prepared by JASCO Applied Sciences for Jacobs.

Meekan, M.G., Speed, C.W., McCauley, R.D., Fisher, R., Birt, M.J., Currey-Randall, L.M., Semmens, J.M., Newman, S.J., Cure, K., Stowar, M., Vaughan, B. and Parsons, M.J.G., 2021. '*A large-scale experiment finds no evidence that a seismic survey impacts a demersal fish fauna*'. Proceedings of the National Academy of Sciences of the United States of America (PNAS), July 27, 2021 118 (30) e2100869118; https://doi.org/10.1073/pnas.2100869118.

Meekan, M.G., Bradshaw, C.J.A., Press, M., McLean, C., Richards, A., Quasnichka, S., Taylor, J.G., 2006. '*Population size and structure of whale sharks Rhincodon typus at Ningaloo Reef, Western Australia*'. Marine Ecology Progress Series, 319:275-85.

Meekan, M.G., Wilson, S.G., Halford, A., Retzel, A., 2001. '*A comparison of catches of fishes and invertebrates by two light trap designs, in tropical NW Australia*'. Marine Biology, 139:373-381.

Meekan, M.G., Speed, C.W., McCauley, R.D., Parsons, M.J.G., 2021. A large-scale experiment finds no evidence that a seismic survey impacts a demersal fish fauna. A large-scale experiment finds no evidence that a seismic survey impacts a demersal fish fauna | PNAS

Milicich, M.J., 1992. '*Light traps: a novel technique for monitoring larval supply and replenishment of coral reef fish populations'*. Ph.D. thesis, Griffith University, Brisbane.

Miller, B.S., Collins, K., Barlow, J., Calderan, S., Leaper, R., McDonald, M., Ensor, P., Olson, P., Olavarria, C., Double, M.C., 2014. '*Blue whale songs recorded around South Island, New Zealand 1964-2013*'. Journal of the Acoustical Society of America, 135:1616-1623.

Miller, I., Cripps, E., 2013. *'Three dimensional marine seismic survey has no measurable effect on species richness or abundance of a coral reef associated fish community'.* Marine Pollution Bulletin, 77:63-70.

Miller, P.J.O., Johnson, M.P., Madsen, P.T., Biassoni, N., Quero, M., tyack, P.L., 2009. '*Using at-sea experiments to study the effects of airguns on the foraging behaviour of sperm whales in the Gulf of Mexico'*. Deep Sea Research Part I: Oceanographic Research Papers, 56(7): 1168 – 1181.

Milton, D.A., 2005. '*Birds of Ashmore Reef National Nature Reserve: an assessment of its importance for seabirds and waders*'. The Beagle: Records of the Museums and Art Galleries of the Northern Territory. 1:133-141.

Minton, S.A., Heatwole, H., 1975. '*Sea Snakes from Reefs of the Sahul Shelf*'. **In**: Dunson, W.A. (Ed.), The Biology of Sea Snakes. University Park Press, Baltimore, pp. 141–144.

Miyashita, T., Kato, H., Kasuya, T., 1995. '*Worldwide map of cetacean distribution based on Japanese sighting dat*a'. Volume 1. National Research Institute of Far Seas Fisheries, Shizuoka, Japan. 140p.

Mizroch, S.A., Rice, D.W., Breiwick, J.M., 1984. '*The Sei whale Balaenoptera borealis*'. Marine Fisheries Review, 46(4):25-29.

MMOA, 2019. '*Position Statement 5: Passive Acoustic Monitoring (PAM) Operator Qualifications*.' Available at: https://www.mmo-association.org/mmoa-activities/position-statements?id=113.

MMPATF, 2022. Western Australian Humpback Whale Migration Route IMMA. https://www.marinemammalhabitat.org/portfolio-item/western-australian-humpback-whale-migration-route/.

Moein, S.E., Musick, J.A., Keinath, J.A., Barnard, D.E., Lenhardt, M., George, R., 1994. '*Evaluation of seismic sources for repelling sea turtles from hopper dredges*'. Report from Virginia Institute of Marine Science, Gloucester Point, VA, for U.S. Army Corps of Engineers, Vicksburg, MS.

Möller, L.M. and Beheregaray, L.B., 2001. '*Coastal bottlenose dolphins from southeastern Australia are Tursiops aduncus according to sequences of the mitochondrial DNA control region*'. Marine Mammal Science, 17(2):249-263.

Mollet, H.F. and Cailliet, G.M., 1996. '*Using Allometry to Predict Body Mass from Linear Measurements of the White Shark*'. In: Klimley, A.P & D.G Aimley, eds. Great White Sharks The Biology of Carcharodon carcharias. Page(s) 81-89. United States of America: Academic Press.

Mooney, T.A., Samson, J.E., Schlunk, A.D., Zacarias, S., 2016. '*Loudness-dependent behavioural responses and habituation to sound by the longfin squid (Doryteuthis pealeii)*'. Journal of Comparative Physiology A, 202(7):489-501.

Morgan, G.J., and Berry, P.F., 1993. *Decapod crustacea of Ashmore Reef and Cartier Island*. **In***:* Marine and Faunal Surveys of Ashmore Reef and Cartier Island North-western Australia. *Edited by* Berry, P.F., Western Australian Museum, Perth, Western Australia. pp. 47-65.

Moulton, V.D., Miller, G.W., 2005. '*Marine mammal monitoring of a seismic survey on the Scotian Slope, 2003'*. Pages 29 – 40, in Lee, K., Bain, H., Hurley, G.V. (Eds), 2005. Acoustic monitoring and marine mammal surveys in The Gully and Outer Scotian Shelf before and during active seismic programs. Environmental Studies Research Funds Report No. 151, 154pp.

Musick, J.A. and Limpus, C.J., 1997. '*Habitat utilization and migration in juvenile sea turtles*'. **In:** Lutz, P., & J. A. Musick, eds. The Biology of Sea Turtles. Page(s) 137-163. Boca Raton, Florida: CRC Press Inc.

Myrberg Jr, A.A., 2001. '*The acoustical biology of elasmobranchs*'. Environmental Biology of Fishes, 60:31-45.

Möller, L. M., Attard, C. R. M., Bilgmann, K., Andrews-Goff, V., Jonsen, I., Paton, D., Double, M. C., 2020. '*Movements and behaviour of blue whales satellite tagged in an Australian upwelling system*'. Scientific Reports, 10:21165.

Nachtigall, P. E., Supin, A. Y., Pawloski, J. and Au, W. W. L. 2004. '*Temporary threshold shift after noise exposure in the bottlenose dolphin (Tursiops truncatus) measured using evoked auditory potentials*'. Mar. Mamm. Sci. 20, 673-687.

NAILSMA, 2008. Bardi-Jawi Rangers Make New Find. *NAILSMA Dugong and Marine Turtle Project Newsletter 22 July 2008*. Available from: http://www.nailsma.org.au/projects/22_july_2008.html.

National Science Foundation, 2011. '*Final programmatic environmental impact statement/overseas environmental impact statement for Marine Seismic Research*'. Funded by the National Science Foundation or conducted by the US Geological Survey. Available online from: nsf-usgs-final-eis-oeis_3june2011.pdf

Neff, J.M., Burns, W.A., 1996. '*Estimation of polycyclic aromatic hydrocarbon concentrations in the water column based on tissue residues in mussels and salmon: An equilibrium partitioning approach*'. Environ. Toxicol. Chem., 15:2240-2253.

Nelms, S.E., Piniak, W.E.D., Weir, C.R., Godley, B.J., 2016. '*Seismic surveys and marine turtles: An underestimated global threat?*' Biological Conservation, 193:49-65. https://doi.org/10.1016/j.biocon.2015.10.020.

NERA, 2018. '*Consequence Analysis of an Accidental Release of Diesel*'. Environment Plan Reference Case.

NERP MBH National Environmental Research Program Marine Biodiversity Hub, 2014. '*Exploring the Oceanic Shoals Commonwealth Marine Reserve*'. NERP MBH, Hobart.

Newman, S. J., Smith, K. A., Skepper, C. L., Stephenson, P. 'Northern Demersal Scalefish Managed Fishery'. Ecologically Sustainable Development (ESD) Report Series No. 6. Department of Primary Industries and Regional Development, Western Australia.

Newman, S., Wakefield, C., Skepper, C., Boddington, D., Steele, A., 2021a. North Coast Demersal Resource Status Report 2020. In: '*Status Reports of the Fisheries and Aquatic Resources of Western Australia 2019/20*': The State of the Fisheries (eds). D.J. Gaughan and K. Santoro. Department of Primary Industries and Regional Development, Western Australia. pp. 156-165.

Newman, S.J., Wise, B.S., Santoro, K.G., Gaughan, D.J. (eds). 2021. '*Status reports of the Fisheries and Aquatic Resources of Western Australia 2020/21: The State of the Fisheries*'. Department of Primary Industries and Regional Development, Western Australia.

Newman, S.J., Wise, B.S., Santoro, K.G., Gaughan, D.J. (eds)., 2021. '*Status Reports of the Fisheries and Aquatic Resources of Western Australia 2020/21: The State of the Fisheries*'. Department of Primary Industries and Regional Development, Western Australia. 311 pages.

Nichol, S.L., Howard, F.J.F., Kool, J., Stowar, M., Bouchet, P., Radke, L., Siwabessy, J., Przeslawski, R., Picard, K., Alvarez de Glasby, B., Colquhoun, J., Letessier, T., Heyward, A., 2013. '*Oceanic Shoals Commonwealth Marine Reserve (Timor Sea) Biodiversity Survey*': GA0339/SOL5650 – Post Survey Report. Record 2013/38. Geoscience Australia: Canberra.

Nicol, D.J., 1987. '*A Review and Update of the Tasmanian Cetacean Stranding Record to the end of February 1986*'. University of Tasmania Environmental Studies Working Paper, 21:96 pp.

NMFS (National Marine Fisheries Service US.), 2018. '*2018 Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts*'. US Department of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-59. 167 pp.

NNTT, 2022. '*Search Register of Indigenous Land Use Agreements*'. http://www.nntt.gov.au/searchRegApps/NativeTitleRegisters/Pages/Search-Register-of-Indigenous-Land-Use-Agreements.aspx accessed March 2022.

NOAA (National Oceanic and Atmospheric Administration), 2012. '*Small Diesel Spills (500 – 5,000 gallons)*'. Office of Response and Restoration.

NOAA, 2013. '*Draft guidance for assessing the effects of anthropogenic sound on marine mammals: Acoustic threshold levels for onset of permanent and temporary threshold shifts*'. Page 20.

NOAA, 2018. '*Fin whale*'. https://www.fisheries.noaa.gov/species/fin-whale. Accessed March 2022.

NOAA, 2019. '*ESA Section 7 Consultation Tools for Marine Mammals on the West Coast*' (webpage), 27 Sep 2019. https://www.fisheries.noaa.gov/west-coast/endangered-species-conservation/esa-section-consultation-tools-marine-mammals-west. Accessed March 2022.

NOAA, 2022. '*How oil harms animals and plants in marine environments*'. https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/how-oil-harms-animals-and-plants-marine-environments.html. Accessed May 2022.

NOPSEMA, 2020. '*Environment plan content requirement*'. Guidance Note, N-04750-GN1344 A339814. September 2020, 41p.

NOPSEMA, 2020a. '*Environment plan assessment policy*'. Policy N-04750-PL1347, A662608. May 2020, 16p.

NOPSEMA, 2020b. '*Environment plan decision making*'. Guideline N-04750-GL1721, A524696. June 2021, 33p.

NOPSEMA, 2020c. '*Acoustic impact evaluation and management*'. Information Paper N-04750-IP1765, A625748. June 2020, 39p.

NOPSEMA, 2020d. '*Petroleum activities and Australian marine* parks'. Guidance Note: N-04750-GN 1785, A620236. June 2020, 15p.

NOPSEMA, 2019. *Bulletin #1 Oil Spill Modelling*, April 2019. Available at https://www.nopsema.gov.au/assets/Bulletins/A652993.pdf, accessed March 2022.

Nowacek, D.P., Thorne, L.H., Johnston, D.W., Tyack, P.L., 2007. '*Responses of cetaceans to anthropogenic noise*'. Mammal Rev., 37(2):81-115.

O'Brien, G., Glenn, K., Lawrence, G., Williams, A.K., Webster, M., Burns, S., Cowley, R., 2002. '*Influence of hydrocarbon migration and seepage on benthic communities in the Timor Sea, Australia*'. APPEA Journal. March 2002, 225-240p.

O'Hara, P.D., Morandin, L.A., 2010. '*Effects of sheens associated with offshore oil and gas development on the feather microstructure of pelagic seabirds*'. Marine Pollution Bulletin, 60(5): 672 – 678.

O'Shea, T.J., Poche, L.B. 2006. '*Aspects of underwater sound communication in Florida manatees (Trichechus manatus latirostris)*'. Journal of Mammology 87(6): 1061-1071.

O2 Marine, 2018. '*Cash Maple Field Development: Marine Environmental Baseline Survey*'. Report number R1702055, Prepared for ERM Australia.

OGP, I., 2011. '*An overview of marine seismic operations*' (Report No. 448) (I. A. o. G. Contractors, Trans.). **In**: I. A. o. O. a. G. Producers (Ed.), (pp. 50). London.

Oleson, E., Barlow, J., Gordon, J., Rankin, S., Hildebrand, J., 2003. '*Low frequency calls of Bryde's whales*'. Marine Mammal Science, 19(2):407-419.

Palmer, C., Baird, R.W., Webster, D.L., Edwards, A.C., Patterson, R., Withers, A., Withers, E., Groom, R., Woinarski, J.C.Z., 2017. '*A preliminary study of the movement patterns of false killer whales (Pseudorca crassidens) in the coastal and pelagic waters of the Northern Territory, Australia*'. Marine and Freshwater Research http://dx.doi.org/10.1071/MF16296.

Parks, S., Clark, C., Tyack, P., 2007. '*Short- and long-term changes in right whale calling behaviour: the potential effects of noise on acoustic communication*'. Journal of the Acoustical Society of America, 122(6): 3725 – 3731.

Parks, S., Johnson, M., Nowacek, D., Tyack, P., 2011. '*Individual right whales call louder in increased environmental noise*'. Biology letters, 7: 33 – 35.

Parra, G.J. and Cagnazzi, D., 2016. '*Conservation Status of the Australian Humpback Dolphin (Sousa sahulensis) Using the IUCN Red List Criteria*'. Advances in Marine Biology, 73:157-192.

Parra, G.J. and Corkeron, P.J, 2001. '*Feasibility of using photo-identification techniques to study the Irrawaddy dolphin, Orcaella brevirostris*'. Aquatic Mammals, 27:45-49.

Parra, G.J., 2005. '*Behavioural ecology of Irrawaddy, Orcaella brevirostris (Owen in Gray, 1866), and Indo-Pacific humpback dolphins, Sousa chinensis (Osbeck, 1765), in northeast Queensland, Australia: a comparative study*'. Ph.D. Thesis. Townsville: James Cook University.

Parra, G.J., 2006. '*Resource partitioning in sympatric delphinids: Space use and habitat preferences of Australian snubfin and Indo-Pacific humpback dolphins*'. Journal of Animal Ecology, 75:862-874.

Parra, G.J., Preen, A.R., Corkeron, P.J., Azuma, C., Marsh, H., 2002. '*Distribution of Irrawaddy dolphins, Orcaella brevirostris, in Australian waters*'. Raffles Bulletin of Zoology, 10:141-154.

Parry, G.D., Gason, A., 2006. '*The effect of seismic surveys on catch rates of rock lobsters in western Victoria, Australia*'. Fisheries Research, 79:272-284.

Parry, G.D., Heislers, S., Werner, G.F., Asplin, M.D., Gason, A., 2002. '*Assessment of Environmental Effects of Seismic Testing on Scallop Fisheries in Bass Strait*'. Marine and Freshwater Resources Institute Report No. 50. Marine and Freshwater Resources Institute, Queenscliff, Victoria.

Payne, J.F., Andrews, C., Fancey, L., White, D., Christian, J., 2008. '*Potential Effects of Seismic Energy on Fish and Shellfish: An Update since 2003*'. Report Number 2008/060. Canadian Science Advisory Secretariat. 22 p.

Payne, J.F., Coady, J., White, D., 2009. '*Potential Effects of Seismic Air Gun Discharges on Monkfish Eggs (Lophius americanus) and Larvae*'. National Energy Board, Canada.

Pearson, W., Skalski, J., Malme, C., 1992. '*Effects of sounds from geophysical survey device on behaviour of captive rockfish (Sebastes spp.*)'. Canadian Journal of Fisheries and Aquatic Sciences, 49:1343-1356.

Peel, D., Smith, J.N., Childerhouse, S., 2018. '*Vessel Strike of Whales in Australia: The Challenges of Analysis of Historical Incident Data*'. Front. Mar. Sci. 5:69 doi: 10.3389/fmars.2018.00069.

Peña, H., Handegard N.O., Ona E., 2013. '*Feeding Herring Schools Do Not React To Seismic Airgun Surveys*'. ICES Journal of Marine Science. doi: 10.1093/icesjms/fst079.

Pendoley, K., 1997. '*Sea turtles and management of marine seismic programs in Western Australia*'.

Pendoley, K.L., 2005. '*Sea turtles and the environmental management of industrial activities in north-west Western Australia*'. Ph.D. Thesis, Murdoch University: Perth.

Perić, T., 2016. '*Wastewater Pollution from Cruise Ships in Coastal Sea Area of the Republic of Croatia*'. Scientific Journal of Maritime Research, 30:160-164.

Peteiro, L.G., Babarro, J.M.F., Labarta, U., Fernandex-Reiriz, M.J., 2006. '*Growth of Mytilus galloprovincialis after the Prestige oil spill*'. ICES Journal of Marine Science, 63(6):1005-1013.

Picciulin, M., Sebastianutto, L., Codarin A., Calcagno, G., Ferrero, E.A., 2012. '*Brown Meagre Vocalization Rate Increases During Repetitive Boat Noise Exposures: A Possible Case Of Vocal Compensation*'. Journal of the Acoustical Society of America, 132:3118–3124.

Pichegru, L., Nyengera, R., McInnes, A.M., Pistorius, P., 2017. '*Avoidance of seismic survey activities by penguins*'. Scientific Reports, 7:16305, doi:10.1038/s41598-017-16569-x.

Pidcock, S., Burton, C., Lunney, M., 2003. '*The potential sensitivity of marine mammals to mining and exploration in the Great Australian Bight Marine Park Marine Mammal Protection Zone – An independent review and risk assessment report to Environment Australia*'. 114p.

Pillans, R.D., Stevens, J.D., Kyne, P.M., Salini, J., 2009. '*Observations on the distribution, biology, short-term mvoements and habitat requirements of river sharks Glyphis spp. in northern Australia*'. Endangered Species Research, 10:321-332.

Pirotta, E., Booth, C., Cade, D., Calambokidis, J., Costa, D., Fahlbusch, J., Friedlaender, A., Goldbogen, J., Harwood, J., Hazen, E., New, L., Southall, B. 2021. '*Context-dependent variability in the predicted daily energetic costs of disturbance for blue whales*'. Conservation Physiology: doi:10.1093/conphys/coaa13.

Plotkin, P., Wicksten, M.K., Amos, A., 1993. '*Feeding ecology of the loggerhead turtle Caretta caretta in the Northwestern Gulf of Mexico*'. Marine Biology (Berlin), 115(1):1-5. 10.1007/BF00349379.

Pomilla, C., Rosenbaum, H.C., 2005. '*Against the current: an inter-oceanic whale migration event*'. Biology Letters, 1:476-479.

Poot, H., Ens, B.J., de Vries, H., Donners, M.A.H., Wernand, M.R., Marquenie, J.M., 2008. '*Green Light for Nocturnally Migrating Birds*'. Ecology and Society, 13(2).

Popov, V., Supin, A., Rozhnov, V., Nechaev, D., Sysuyeve, E., Klishin, V., Pletenko, M., Tarakanov, M., 2013. '*Hearing threshold shifts and recovery after noise exposure in Beluga whales, Delphinapterus leucas*'. The Journal of Experimental Biology 216: 1587-1596.

Popper A.N., 2003. '*Effects of Anthropogenic Sounds on Fishes*'. Fisheries, 28(10):24-31.

Popper, A., Hastings, M., 2009. '*The effects of anthropogenic sources of sound on fishes*'. Journal of Fish Biology, 75:455-489.

Popper, A., Hawkins, A., Fay, R., Mann, D., Bartol, S., Carlson, T., Coombs, S., Ellison, W., Gentry, R., Halvorsen, M., Lokkeborg, S., Rogers, P., Southall, S., Zeddies, D., Tavlga, W., 2014. '*Sound exposure guidelines for fishes and sea turtles'*. A technical report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. Acoustical Society of America and Springer Press. 88 pp.

Prince, R.I., 1993. '*Western Australian marine turtle conservation project: an outline of scope and an invitation to participate*'. Marine Turtle Newsletter. 60: Aug-14.

Prince, R.I., 1994a. '*The Flatback Turtle Natator depressus in Western Australia: new information from the Western Australian Marine Turtle Project'*. **In:** James, R., ed. Proceedings of the Australian Marine Turtle Conservation Workshop, Gold Coast 14-17 November 1990. Page(s) 146-153. Qld Dept Env. & Heritage. Canberra, ANCA.

Prince, R.I., 1994b*. 'Status of the Western Australian marine turtle populations: the Western Australian Marine Turtle Project 1986-1990'*. **In:** Russell, J., ed. Proceedings of the Australian Marine Turtle Conservation Workshop, Gold Coast 14-17 November 1990. Page(s) 1-14. Queensland Department of Environment and Heritage. Canberra, ANCA.

Prince, R.I., 1998. '*Marine turtle conservation: the links between populations in Western Australia and the norther Australian region - people and turtles*'. **In:** Kennett, R., A. Webb, G. Duff, M. Guinea and G. Hill, eds. Marine turtle conservation and management in northern Australia. Proceedings of a workshop held at the Northern Territory University 3-4 June 1997. Page(s) 93-100. Centre for Indigenous Natural and Cultrual Resource Management and Centre for Tropical Wetlands Management, Northern Territory University.

Przeslawski, R., Brooke, B., Carroll, A.G., Fellows, M., 2018. '*An integrated approach to assessing marine seismic impact: Lessons learnt from the Gippsland Marine Environmental Monitoring project*'. Ocean and Coastal Management, 160:117-123.

Przeslawski, R., Daniell, J., Anderson, T., Barrie, J.V., Heap, A., Hughes, M., Li, J., Potter, A., Radke, R., Siwabessy, J., Tran, M., Whiteway, T., Nichol, S., 2011. '*Seabed Habitats and Hazards of the Joseph Bonaparte Gulf and Timor Sea, Northern Australia*'. Geoscience Australia, Record 2011/40.

Przeslawski, R., Hurt, L., Forrest, A., Carroll, A., 2016. '*Potential short-term impacts of marine seismic surveys on scallops in the Gippsland Basin*'. FRDC Report 2014/041. Geoscience Australia, Canberra. 60 pp.

Przeslawski, Z., Huang, J., Anderson, A.G., Carroll, M., Edmunds, L., Hurt, S., Williams., 2018a. '*Multiple field-based methods to assess the potential impacts of seismic surveys on scallops'*. Mar. Pollut. Bull., 129:750-761

Radford, A., Kerridge, E., Simpson, S., 2014. '*Acoustic Communication In A Noisy World: Can Fish Compete With Anthropogenic Noise?'.* Behavioural Ecology, 25(5):1022-1030.

Radford, A.N., Lèbre, L., Lecaillon, G., Nedelec, S.L., Simpson, S.D., 2016. *'Repeated exposure reduces the response to impulsive noise in European seabass*'. Glob. Chang. Biol., 22:3349-3360.

Reid, T.A., Hindell, M.A., Eades, D.W., Newman, M., 2002. '*Seabird Atlas of Australian Waters*'. Birds Australia Monograph 4. Birds Australia, Melbourne.

Reynolds, S.D., Norman, B.M., Beger, M., Franklin, C.E., Dwyer, R.G., 2017. '*Movement, distribution and marine reserves use by an endangered migratory giant*'. Biodiversity Research, 23:1268-1279.

Rich, C., Longcore, T., 2006. '*Ecological Consequences of Artificial Night Lighting'* C. Rich & T. Longcore (Eds.).

Richard, Z., Bowling, T., Beger, M., Hobbs, J.P., Chong-Seng, K., and Pratchett, M., 2009. '*Ashmore Reef National Nature Reserve and Cartier Island Marine Reserve: Marine Survey 2009'*. James Cook University, Townsville, Queensland.

Richardson, A.J., Matear, R.J, Lenton, A., 2017. '*Potential impacts on zooplankton of seismic surveys*'. CSIRO, Australia. 34 pp.

Richardson, W.J., Greene, C.R. Jr., Malme, C.I., Thompson, D.H., 1995. '*Marine Mammals and Noise*'. Academic Press, San Diego.

Rigby, C.L., Barreto, R., Carlson, J., Fernando, D., Fordham, S., Francis, M.P., Jabado, R.W., Liu, K.M., Marshall, A., Pacoureau, N., Romanov, E., Sherley, R.B., Winker, H., 2019. *Isurus paucus. 'The IUCN Red List of Threatened Species 2019*': e.T60225A3095898. http://dx.doi.org/10.2305/IUCN.UK.2019-1.RLTS.T60225A3095898.en.

Risch, D., Corkeron, P.J., Ellison, W.T., van Parijs, S.M., 2012. '*Changes in humpback whale song occurrence in response to an acoustic source 200 km away*'. PLoS One, 7(1): doi:10.1371/journal.pone.0029741.

Robbins, J., Dalla Rosa, L., Allen, J.M., Mattila, D.K., Secchi, E.R., Friedlaender, A.S., Stevick, P.T., Nowacek, D.P., Steel, D., 2011. '*Return movement of a humpback whale between the Antarctic Peninsula and American Samoa: a seasonal migration record*'. Endangered Species, 13:117-121.

Roberts, L., Cheesman, S., Breithaupt, T., Elliott, M., 2015. '*Sensitivity of the mussel Mytilus edulis to substrate-borne vibration in relation to anthropogenically-generated noise*'. Marine Ecology Progress Series, 538. 10.3354/meps11468.

Robins, C.M., Goodspeed, A.M., Poiner, I., Harch, B.D., 2002. '*Monitoring the catch of turtles in the Northern Prawn Fishery*'. Fisheries Research and Development Corporation. Department of Agriculture, Fisheries & Forestry: Canberra.

Robins, J.B., 1995. '*Estimated catch and mortality of sea turtles from the East Coast Otter Trawl Fishery of Queensland, Australia*'. Biological Conservation, 74:157-167.

Robins, J.B., 2002. '*A scientific basis for a comprehensive approach to managing sea turtle by-catch: The Queensland East Coast as a case study*'. Ph.D. Thesis. James Cook University.

Rolland, R.M., Parks, S.E., Hunt, K.E., Castellote, M., Corkeron, P.J., Nowacek, D.P., Wasser, S.K., Kraus, S.D., 2012. '*Evidence that ship noise increases stress in right whales*'. Proc. R. Soc. B., 279: 2363 – 2368.

Romano, T.A., Keogh, M.J., Kelly, C., Feng, P., Berk, L., Schlundy, C.E., Carder, D.A., Finneran, J.J., 2004. '*Anthropogenic sound and marine mammal health: measures of the nervous and immune systems before and after intense sound exposure*'. Can. J. Fish. Aquat. Sci., 61: 1124 – 1134.

Ross, A., Stalvies, C., Talukder, A., Trefry, C., Mainson, M., Cooper, L., Yuen, M., Palmer, J. 2017. '*Interpretive geochemical data report on samples obtained during ARP2 Trip 6184, May 2015*'. A report prepared by CSIRO, Perth, Western Australia.

Ross, D., 1976. '*Mechanics of underwater noise*'. New York, Pergamon Press, 375pp.

Ross, G.J.B., 2006. '*Review of the Conservation Status of Australia's Smaller Whales and Dolphins*'. Page(s) 124. Report to the Australian Department of the Environment and Heritage, Canberra. Available from: http://www.environment.gov.au/resource/review-conservation-status-australias-smaller-whales-and-dolphins.

Rowe, S., 2007. '*A review of methodologies for mitigating incidental catch of protected marine mammals*'. DOC Research and Development Series 283. Department of Conservation, Wellington.

RPS MetOcean, 2008. '*Detailed Metocean Conditions for the Browse Development*'. Report produced for Woodside Energy Limited. **In:** Woodside Browse LNG Development Draft Upstream Environmental Impact Statement 2011.

RPS, 2011. '*Bonaparte LNG Preliminary Metocean Study*'. Report prepared for GDF SUEZ Bonaparte LNG, Perth, Western Australia.

Russel , B., Larson, H., Hutchins, J., and Allen, G.R., 2005. '*Reef Fishes of the Sahul Shelf*'. **In**: Understanding the Cultural and Natural Heritage Values and Management Challenges of the Ashmore Region, Proceedings from a Symposium.

Ryan, K.L., Hall, N.G., Lai, E.K., Smallwood, C.B., Tate, A., Taylor, S.M., Wise, B.S., 2019. '*Statewide survey of boat-based recreational fishing in Western Australia 2017/2018*'. Fisheries Research Report No. 297, Department of Primary Industries and Regional Development, Western Australia. 195 pp.

Saetre, R., Ona, E., 1996. '*Seismic investigations and damages on fish eggs and larvae; an evaluation of possible effects on stock level*'. Fisken og Havet: 1-17, 1-8.

Salgado Kent, C., Jenner, K.C., Jenner, M., Bouchet, P., Rexstad, E. 2012. '*Southern Hemisphere Breeding Stock 'D' Humpback Whale Population Estimates from North-West Cape, Western Australia*'. Journal of Cetacean Research and Management, 12:29-38.

Salini, J.P., Ovenden, J.R., Street, R., Pendrey, R., Haryanti, Ngurah, 2006. '*Genetic population structure of red snappers (Lutjanus malabaricus Bloch & Schneider, 1801 and Lutjanus erythropterus Bloch, 1790) in central and eastern Indonesia and northern Australia*'. Journal of Fish Biology, 68(B):217-234.

Salmon, M., Wyneken, J., Fritz, E., Lucas, M., 1992. '*Seafinding by hatchling sea turtles: role of brightness, silhouette and beach slope as orientation cues*'. Behaviour Journal, 122:56-77.

Samson, J.E., Mooney, T.A., Gussekloo, S.W.S., Hanlon, R.T., 2014. '*Graded behavioural responses and habituation to sound in the common cuttlefish Sepia officinalis*'. J. Exp. Biol., 217:4347-4355.

Santos, 2021. '*Petrel Sub-Basin South-West 3D Marine Seismic Survey Environmental Plan*'. Report prepared by ERM for Santos.

Santulli, A., Modica, A., Messina, C., Ceffa, L., Curatolo, A., Rivas, G., Fabi, G., D'Amelio, V., 1999. '*Biochemical responses of European sea bass (Dicentrarchus labrax L.) to the stress induced by offshore experimental seismic prospecting*'. Marine Pollution Bulletin, 38:1105-1114.

Sara, G., Dean, J.M., D'Amato, D., Busciano, G., Oliveri, A., Genovese, S., Ferro, S., Buffa, G., Lo Martire, M., Mazzola, S., 2007. '*Effect of boat noise on the behaviour of bluefin tuna (Thunnus thynnys) in the Mediterranean Sea'*. Marine Ecology Progress Series, 331:243-253.

Sarnocinska, J., Teilmann, J., Dalgaard Balle, J., van Beest, F., Delefosse, M., Tougaard, J. 2020. '*Harbor Porpoise (Phocoena phocoena) Reaction to a 3D Seismic Airgun Survey in the North Sea*'. Frontiers of Marine Science. 6:824. doi: 10.3389/fmars.2019.00824.

Scholik, A., Yan, H., 2002. '*Effects of boat engine noise on the auditory sensitivity of the fathead minnow, Pimphales promelas*'. Environmental biology of fishes, 63:203-209.

Schwacke, L.H., Smith, C.R., Townsend, F.I., Wells, R.S., Hart, L.B., Balmer, B.C., Collier, T.K., De Guise, S., Fry, M.M., Guillette, L.J., Lamb, S.V., Lane, S.M., McFee, W.E., Place, N.J., Tumlin, M.C., Ylitalo, G.M., Zolman, E.S., Rowles, T.K., 2013. '*Health of common bottlenose dolphins (Tursiops truncatus) in Barataria Bay, Louisiana, following the Deepwater Horizon oil spill*'. Environmental Science & Technology, 48: 93 – 103.

Semeniuk, V., Chalmer, P.N., Le Provost, I., 1982. '*The marine environments of the Dampier Archipelago'*. Journal of the Royal Society of Western Australia, 65:97-114

Senigaglia, V., Christiansen, F., Bejder, L., Gendron, D., Lundquist, D., Noren, D.P., Schaffar, A., Smith, J.C., Williams, R., Martinez, E., Stockin, K., Lusseau, D. 2016. '*Meta-analyses of whale-watching impact studies: comparisons of cetacean responses to disturbance'*. Marine Ecology Progress Series 542:251–263. DOI: https://doi.org/10.3354/meps11497.

Sheppard, J., Preen, A.R., Marsh, H., Lawler, I.R., Whiting, S., Jones, R.E., 2006. '*Movement heterogeneity of dugongs, Dugong dugon (Muller) over large spatial scales*'. Journal of Experimental Marine Biology and Ecology, 334:64-83.

Simmonds, M., Dolman, S., and Weilgart, L 2004. '*Oceans of Noise 2004*.' A Whale and Dolphin Conservation Science Report.

Simpson, S.L., Batley, G.B., Chariton, A.A., 2013. '*Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines'*. CSIRO Land and Water Science Report 08/07. CSIRO Land and Water.

Širović, A., Hildebrand, J.A., Wiggins, S.M., 2007. '*Blue and fin whale call source levels and propagation range in the Southern Ocea*n'. Journal of the Acoustical Society of America, 122(2):1208-1215.

Skaret, G., Axelsen, B.E., Mottestad, L., Ferno, A., Johannessen, A., 2005. '*The behaviour of spawning herring in relation to a survey vessel'*. ICES Journal of Marine Science, 62:1061-1064.

Skewes, T.D., Dennis, D.M., Jacobs, D.R., Gordon, S.R., Taranto, T.J., Haywood, M., Pitcher, C.R., Smith, G.P., Milton, D., Pointer, I.R., 1999a. '*Survey and Stock Size Estimates of the Shallow Reef (0-15 M Deep) and Shoal Are (15-50 M Deep) Marine Resources and Habitat Mapping Within the Timor Seas MoU74 Box Volume 1: Stock Estimates and Stock Status'*. CSIRO Marine Research.

Skewes, T.D., Gordon, S.R., McLeod, I.R., Taranto, T.J., Dennis, D.M., Jacobs, D.R., Pitcher, C.R.., Haywood, M., Smith, G.P., Poiner, I.R., Milton, D., Griffin, D., Hunter, C., 1999b. '*Survey and Stock Size Estimates of the Shallow Reef (0-15 M Deep)* *and Shoal Area (15-50 M Deep) Marine Resources and Habitat Mapping Within the Timor Sea MoU74 Box Volume 2: Habitat Mapping and Coral Dieback'*. CSIRO Marine Research.

Sleeman, J.C., Meekan, M.G., Fitzpatrick, B.J., Steinberg, C.R., Ancel, R., Bradshaw, C.J.A., 2010. '*Oceanographic and atmospheric phenomena influence the abundance of whale sharks at Ningaloo Reef, Western Australia*'. Journal of Experimental Marine Biology and Ecology, 383:77-81.

Slotte, A., Hansen, K., Dalen, J., Ona, E., 2004. '*Acoustic Mapping Of Pelagic Fish Distribution And Abundance In Relation To A Seismic Shooting Area Off The Norwegian West Coast*'. Fisheries Research, 67(2):143-150.

Smith, J.N., Grantham, H.S., Gales, N., Double, M.C., Noad, M.J., Paton, D., 2012. '*Identification of humpback whale breeding and calving habitat in the Great Barrier Reef*'. Marine Ecology Progress Series, 447:259-272.

Smith, M.A., 1926. '*Monograph of the sea-snakes (Hydrophiidae)*'. Taylor and Francis, London.

Smith, N., 1970. '*The problem of oil pollution of the sea*'. Advances in Marine Biology, 8: 215 – 306.

Smyth, D., 2007. '*Sea Countries of the North-west, Literature Review on Indigenous Connection to and Uses of the Northwest Marine Region*'. Department of the Environment and Water Resources, Canberra.

Sprogis, K., Videsen, S., Madsen, P. 2020. '*Vessel noise levels drive behavioural responses of humpback whales with implications for whale-watching*'. eLife 2020;9:e56760. DOI: https://doi.org/10.7554/eLife.56760.

Solan, M., Hauton, C., Godbold, J. A., Wood, C. L., Leighton, T. G., White, P., 2016. '*Anthropogenic sources of underwater sound can modify how sediment-dwelling invertebrates mediate ecosystem properties*'. Scientific reports, 6, 20540.

Solé, M., Lenoir, M., Durfort, M., López-Bejar, M., Lombarte, A., Van der Schaar, M., André, M., 2013. '*Does exposure to noise from human activities compromise sensory information from cephalopod statocysts?*'. Deep Sea Research Part II: Topical Studies in Oceanography, 95:160-181.

Solé, M., Lenoir, M., Durfort, M., López-Bejar, M., Lombarte, A., André, M., 2013a. '*Ultrastructural damage of Loligo vulgaris and Illex coindetii statocysts after low frequency sound exposure*'. PLoS One, 8(10), e78825.

Somaweera, R., Udyawer, V., Guinea, M.L., Ceccarelli, D.M., Clarke, R.H., Glover, M., Hourston, M., Keesing, J., Rasmussen, A.R., Sanders, K., Shine, R., Thomson, D.P., Webber, B.L., 2021. '*Pinpointing Drivers of Extirpation in Sea Snakes: A Synthesis of Evidence From Ashmore Reef*'. Front. Mar. Sci. 8:658756. doi: 10.3389/fmars.2021.658756.

Southall, B.L., 2005. '*Shipping noise and marine mammals: a forum for science, management, and technology*'. Final report of the 2004 NOAA symposium "shipping noise and marine mammals", 40p.

Southall, B.L., Bowles, A., Ellison, W., Finneran, J., Gentry, R., Greene, C., Kastak, D., Ketten, D., Miller, J., Nachtigall, P., Thomas, J., Tyack, P., 2007. '*Marine mammal noise exposure criteria: Initial scientific recommendations*'. Aquatic Mammals, 33.

Southall, B.L., Finneran, J.J., Reichmuth, C.J., Nachtigall, P.E., Ketten, D.R., Bowles, A.E., Ellison, W.T., Nowacek, D.P., Tyack, P.L., 2019. '*Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects*'. Aquatic Mammals 45(2):125-232. https://doi.org/10.1578/AM.45.2.2019.125.

Southall, B.L., Hatch, L., 2008. '*Impacts of Anthropogenic Underwater Sound in the Marine Environment, Module 5: Shipping*' OSCPAR Convention for the protection of the marine environment of the north-east Atlantic, Draft preliminary comprehensive overview of the impacts of anthropogenic underwater sound in the marine environment.

Spear, L.B., 2001. '*Seabird migration*'. Encyclopaedia of Ocean Sciences, pp 236-246.

Spotila, J.R, 2004. '*Sea turtles: a complete guide to their biology, behaviour, and conservation*'. Baltimore, Maryland: The Johns Hopkins University Press and Oakwood Arts.

Spotila, J.R., Dunham, A.E., Leslie, A.J., Steyermark, A.C., Plotkin, P.T., Paladino, F.V., 1996. '*Worldwide population decline of Dermochelys coriacea: are leatherback turtles going extinct?*'. Chelonian Conservation Biology, 2:209-222.

Spring, C.S.,1982. '*Status of marine turtle populations in Papua New Guinea*'. **In:** Bjorndal, K. A., ed. Biology and Conservation of Sea Turtles. Page(s) 281-289. Washington D. C., Smithsonian Institute Press.

Steiner, S., Bisig, C., Petri-Fink, A., Rothen-Rutishauser, B., 2016. '*Diesel Exhaust: Current Knowledge of Adverse Effects and Underlying Cellular Mechanisms*'. Arch. Toxicol., 90:1541-1553.

Stevens, J., 2005. '*Tope or school shark Galeorhinus galeus (Linneaus, 1758)*'. In: Fowler, S.L., R.D. Cavanagh, M. Camhi, G.H. Burgess, G.M. Cailliet, S.V. Fordham, C.A. Simpfendorfer & J.A. Musick, eds. Sharks, Rays and Chimaeras: The Status of the Chondrichthyan Fishes. Gland: IUCN.

Stimpert, A.K., DeRuiter, S.L., Southall, B.L., Moretti, D.J., Falcone, E.A., Goldbogen, J.A., Friedlaender, A., Schorr, G.S., Calambokidis, J., 2014. '*Acoustic and foraging behaviour of a Baird's beaked whale, Berardius bairdii, exposed to simulated sonar*'. Scientific Reports 4: 7031. DOI: 10.1038/srep07031.

Stone, C.J., 2003. '*The effects if seismic activity on marine mammals in UK waters, 1998-2000*'. Rep. No. 323. Joint Nature Conservation Committee, Aberdeen.

Stone, C.J., Tasker, M.L., 2006. '*The effects of seismic airguns on cetaceans in UK waters*'. J. Cetacean. Res. Manage., 8(3):255-263.

Streftaris, N., Zenetos, A., Papathanassiou, E., 2005. '*Globalisation in marine ecosystems: the story of non-indigenous marine species across European seas*'. Oceanogr. Marine Biol.' 43:419–453.

Sutton, A.L., Jenner, K.C.S., Jenner, M.-N.M., 2019. '*Habitat associations of cetaceans and seabirds in the tropical eastern Indian Ocean. Deep Sea Research Part II*'. Topical Studies in Oceanography, 166:171-186.

Sverdrup, A., Kjellsby, P.G., Kruger, P.G., Floys, R., Knudsen, F.R., Enger, P.S., Serck-Hanssen, G., Helle, K.B., 1994. '*Effects of Experimental Seismic Shock on Vasoactivity of Arteries, Integrity of the Vascular Endothelium and on Primary Stress Hormones of the Atlantic Salmon*'. Fish Biology, 45:973-995.

Swan, G., 2005. '*Occasional count no. 7, Ashmore Reef, 21 to 30 January 2002*'. Stilt 47.

Tang, K.W., Gladyshev, M.I., Dubovskaya, O.P., Kirillin, G. and Grossart, H-P. 2014. '*Zooplankton carcasses and non-predatory mortality in freshwater and inland sea environments.*' Journal of Plankton Research 36: 597–612.

Taylor, R., R. Chatto, Woinarski, J., 2006. '*Olive Ridley Pacific Ridley Lepidochelys olivacea*'. Threatened Species of the Northern Territory. Department of Natural Resources, Environment and the Arts, Northern Territory Government. https://nt.gov.au/environment/animals/threatened-animals.

Te Ara, 2018. '*Octopus in New Zealand*'. https://teara.govt.nz/en/octopus-and-squid/page-4.

Telfer, T., Sincock, J., Bryd, G., Reed, J., 1987. '*Attraction of Hawaiian Seabirds to lights: Conservation efforts and effect of moon phase*'. Wildlife Society Bulletin, 15:406-413.

Thiele, L., 1983. '*Underwater noise from the propellers of a triple screw container ship*'. Rep. 82.54 from Ødegaard & Danneskiold-Samsoe K/S for Greenl. Fisheries Investig., Copenhagen, Denmark.

Thode, A., Blackwell, S., Conrad, A., Kim, K., Marques, T., Thomas, L., Oedekoven, C., Harris, D., Broker, K. 2020. '*Roaring and repetition: how bowhead whales adjust their call density and source level (Lombard effect) in the presence of natural and seismic airgun survey noise*'. The Journal of the Acoustical Society of America 147, 2061; doi: 10.1121/10.0000935.

Thomas, J., Kastelein, R., Supin, A., 1992. '*Marine mammal sensory systems*'. Plenum Press, New York.

Thompson, P.M., Brookes, K.L., Graham, I.M., Barton, T.R., Needham, K., Bradbury, G., Merchant, N.D., 2013. '*Short-term disturbance by a commercial two-dimensional seismic survey does not lead to long-term displacement of harbour porpoises*'. Proceedings of the Royal Society B, 280:20132001.

Thums, M., Ferreira, L., Jenner, C., Jenner, M., Harris, D., Davenport, A., Andrews-Goff, V., Double, M., Möller, L., Attard, CRM., Bilgmann, K., Thomson, P., McCauley, R., 2021. '*Pygmy blue whale movement, distribution and important areas in the Eastern Indian Ocean*'. Global Ecology and Conservation, doi:https://doi.org/10.1016/j.gecco.2022.e02054.

Thums, M., Jenner, C., Waples, K., Salgado Kent, C., Meekan, M., 2018. '*Humpback whale use of the Kimberley; understanding and monitoring spatial distribution*'. Report of Project 1.2.1 prepared for the Kimberley Marine Research Program, Western Australian Marine Science Institution, Perth, Western Australia, 78pp.

Tonks, M., Griffiths, S., Heales, D.S., Brewer, D., Dell, Q., 2008. '*Species composition and temporal variation of prawn trawl bycatch in the Joseph Bonaparte Gulf, north-western Australia*'. Fisheries Research. 89. 276-293. 10.1016/j.fishres.2007.09.007.

Troisi, G., Borjesson, L., Bexton, S., Robinson, I., 2007. '*Biomarkers of polycyclic aromatic hydrocarbon (PAH)-associated haemolytic anemia in oiled wildlife*'. Environmental Research, 105(3): 324 – 329.

Tucker, A.D., Fitzsimmons, N.N., Limpus, C.J., 1995. '*Conservation implications of internesting habitat use by loggerhead turtles Caretta caretta in Woongarra Marine Park, Queensland, Australia*'. Pacific Conservation Biology, 2:157-166.

Udyawer, V., Barnes, P., Bonnet, X., Brischoux, F., Crowe-Riddell, J.M., D'Anastasi, B., Fry, B.G., Gillett, A., Goiran, C., Guinea, M.L., Heatwole, H., Heupel, M.R., Hourston, M., Kangas, M., Kendrick, A., Koefoed, I., Lillywhite, H.B., Lobo, A.S., Lukoschek, V., McAuley, R., Nitschke, C., Rasmussen, A.R., Sanders, K.L., Sheehy, C., Shine, R., Somaweera, R., Sweet, S.S., Voris, H.K., 2018. '*Future Directions in the Research and Management of Marine Snakes*'. Front. Mar. Sci. 5:399. doi: 10.3389/fmars.2018.00399.

United Nations, 2018. '*United Nations – Indigenous Peoples. United Nations Declaration on the Rights of Indigenous Peoples*'. https://www.un.org/development/desa/indigenouspeoples/declaration-on-the-rights-of-indigenous-peoples.html.

Vabø, R., Olsen, K., Huse, I., 2002. '*The effect of vessel avoidance of wintering Norwegian spring spawning herring*'. Fisheries research, 58(1):59-77.

Vancouver Fraser Port Authority, 2018. '*ECHO Program: Voluntary Vessel Slowdown Trial Summary Findings*'. June 2018 Report. https://www.flipsnack.com/portvancouver/echo-haro-strait-slowdown-trial-summary/full-view.html.

van Ginkel, C., Becker, D., Gowans, S., Simard, P., 2017. '*Whistling in a noisy ocean: bottlenose dolphins adjust whistle frequencies in response to real-time ambient noise levels*'. Bioacoustics 2017. https://doi.org/10.1080/09524622.2017.1359670.

Van Waerebeek, K., Baker, A.N., Félix, F., Gedamke, J., I-iguez, M., Sanino, G.P., 2007. '*Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere, an initial assessment*'. Lat. Am. J. Aquat. Mammals 6:43–69. doi: 10.5597/lajam00109.doee

Vanderlaan, A.S.M., Taggart, C.T., 2007. '*Vessel collisions with whales: The probability of lethal injury based on vessel speed*'. Marine Mammal Science 23(1): 144-156.

Verfuss, U.K., Gillespie, D., Gordon, J., Marques, T.A., Miller, B., Plunkett, R., Theriault, J.A., Tollit, D.J., Zitterbart, D.P., Hubert, P., Thomas, L., 2018. '*Comparing methods suitable for monitoring marine mammals in low visibility conditions during seismic surveys*'. Marine Pollution Bulletin, 126: 1 -18.

Vernon, J., 1993. '*Hermatypic corals of Ashmore Reef and Cartier Island'.* **In**: Marine and Faunal Surveys of Ashmore Reef and Cartier Island North-western Australia. *Edited by* Berry, P.F., Western Australian Museum, Perth, Western Australia. pp. 13-20.

WA DEC (Western Australian Department of Environment and Conservation), 2009. '*Marine turtles in Western Australia: Loggerhead Turtle*'. Available from: http://www.naturebase.net/content/view/2462/1401.

WA EPA, 2010. '*Environmental Assessment Guideline for Protecting Marine Turtles from Light Impacts*'.

Wada, S., Oishi, M., Yamada, T.K., 2003. '*A newly discovered species of living baleen whale*'. Nature 426 (6964): 278-281. http://dx.doi.org/10.1038/nature02103.

Wagner, T.L., Cooper, C.D., Gross, J.A., Coffin, A.B., 2015. '*The effect of seismic waterguns on the inner ears of round goby*'. Journal of Great Lakes Research, 41(4):1191-1196.

Walker, T.A. and Parmenter, C.J., 1990. '*Absence of a pelagic phase in the life cycle of the flatback turtle, Natator depressa (Garman)*'. Journal of Biogeography, 17:275-278.

Walsh, B. and Whitehead, P.J., 1993. '*Problem crocodiles, Crocodylus porosus, at Nhulunbuy, Northern Territory: an assessment of relocation as a management strategy*'. Wildlife Research.

Wang, J.Y., 2018. '*Bottlenose dolphin, Tursiops aduncus, Indo-Pacific bottlenose dolphin*'. **In**: 'Encyclopaedia of Marine Mammals (Third Edition', Wursig, B., Thewissen, J.G.M., Kovas, K.M., 2018, p. 125-130.

Ward, T.M., 1996. '*Sea snake bycatch of prawn trawlers on the northern Australian continental shelf*'. Marine and Freshwater Research 47, 631–635. doi:10.1071/MF9960631.

Wardle, C., Carter, T., Urquhart, G., Johnstone, A., Ziolkowski, A., Hampson, G., Mackie, D., 2001. *'Effects of seismic air guns on marine fish*'. Continental Shelf Research, 21:1005-1027.

Wassenberg, T.J., Salini, J.P., Heatwole, H., Kerr, J.D., 1994. '*Incidental capture of sea snakes (Hydrophiidae) by prawn trawlers in the Gulf of Carpentaria, Australia'*. Australian Journal of Marine and Freshwater Research 45, 429–443. doi:10.1071/MF9940429.

Webb, G. and Manolis, S.C.,1989. '*Crocodiles of Australia'*. Reed Books Pty Ltd, Sydney.

Webb, G.J.W. and Messel, H., 1978. '*Movement and dispersal patterns of Crocodylus porosus in some rivers of Arnhem Land, northern Australia'*. Australian Wildlife Research, 5:263-283.

Webb, G.J.W., Whitehead, P.J., Manolis, S.C., 1987. '*Crocodile management in the Northern Territory of Australia*'. **In:** Webb, G. J. W., S. C. Manolis & P. J. Whitehead, eds. Wildlife Management: Crocodiles and Alligators. Page(s) 107-124. Sydney, Surrey Beatty & Sons.

Weilgart, L.S., 2007. '*A brief review of known effects of noise on marine mammals'*. International Journal of Comparative Psychology, 20: 159 – 186.

Weilgart, L.S., 2013. '*A review of the impacts of seismic airgun surveys on marine life'*. Submitted to the CBD Expert Workshop on Underwater Noise and its Impacts on Marine and Coastal Biodiversity, 25 -27 February 2014, London, UK. Available at http://www.cbd.int/doc/?meeting=MCBEM-2014-01.

Weinberg, C., Westphal, H., Kwoll, E., and Hebbeln, D., 2009. '*An isolated carbonate knoll in the Timor Sea (Sahul Shelf, NW Australia): facies zonation and sediment composition'*. Facies, 56(2):179-193.

Weir, C., Dolman, S.J., 2007. '*Comparative review of the regional marine mammal mitigation guidelines implemented during industrial seismic surveys, and guidance towards a worldwide standard'*. Journal of International Wildlife Law and Policy, 10: 1 – 27.

Weir, C.R., 2007. '*Observation of marine turtles in relation to seismic airgun sound off Angola'*. Marine Turtle Newsletter, 116:17-20.

Weir, C.R., 2008. '*Overt responses of humpback whales (Megaptera novaeangliae), sperm whales (Physeter macrocephalus), and Atlantic spotted dolphins (Stenella frontalis) to seismic exploration off Angola'*. Aquatic Mammals, 34(1): 71 – 83.

Wells, F.E., 1993. '*Molluscs of Ashmore Reef and Cartier Island'*. **In:** Marine and Faunal Surveys of Ashmore Reef and Cartier Island North-western Australia. *Edited by* Berry, P.F. Western Australian Museum, Perth, Western Australia. pp. 25-45.

Whiting, S.D. and Guinea, M., 2005. '*Dugongs of Ashmore Reef and the Sahul Banks: a review of current knowledge and a distribution of sightings*'. **In:** Understanding the Cultural and Natural Heritage Values and Management Challenges of the Ashmore Region, Proceedings of a Symposium organised by the Australian Marine Sciences Association and the Museum and Art Gallery of the Northern Territory, Darwin, 4-6 April 2001. *Edited by* B. Russel, H. Larson, C.J. Glasby, R.C. Wilan, and J. Martin. Museum and Art Galleries of the Northern Territory & Australia Marine Sciences Association, Darwin, Northern Territory. pp. 83-105.

Whiting, S.D., 2000. '*The ecology of immature Green and Hawksbill Turtles foraging two reef systems in north-western Australia'*. Page(s) 370. Ph.D. Thesis. Darwin, Northern Territory University.

Whiting, S.D., Guinea, M., Pike, G.D., 2000. '*Sea turtles nesting in the Australian Territory of Ashmore and Cartier Islands, Eastern Indian Ocean'*. Pilcher, N. & G. Ismail, eds. Sea Turtles of the Indo-Pacific: Research Management & Conservation. Page(s) 86-93. ASEAN Academic Press, London.

Whiting, S.D., Long, J., Hadden, K., Lauder, A., 2005. '*Identifying the links between nesting and foraging grounds for the Olive Ridley (Lepidochelys olivacea) sea turtles in northern Australia*'. Report to the Department of the Environment and Water Resources.

Wilewska-Bien, M., Granhag, L., Andersson, K., 2016. '*The Nutrient Load From Food Waste Generated Onboard Ships in the Baltic Sea*'. Marine Pollution Bulletin, 105:359-366.

Willan, R., 2005. '*The molluscan fauna from the emergent reefs of the northmost Sahul Shelf, Timor Sea – Ashore, Cartier and Hibernia Reefs; biodiversity and zoogeography'*. **In:** Understanding the Cultural and Natural Heritage Values and

Management Challenges of the Ashmore Region. Proceedings of a Symposium organised by the Australian Marine Sciences Association and the Museum and Art Gallery of the Northern Territory, Darwin, 4-6 April 2001. Edited by B. Russel, H. Larson, C.J. Glasby, R.C. Wilan, and J. Martin. Museum and Art Galleries of the Northern Territory & Australia Marine Sciences Association, Darwin, Northern Territory. pp. 207-210.

Williams, R., Wright, A., Ashe, E., Blight, L., Bruintjes, R., Canessa, R. et al. 2015. '*Impacts of anthropogenic noise on marine life: publication patterns, new discoveries, and future directions in research and management*'. Ocean and Coastal Management 115: 17-24.

Wilson, S.G., Carlton, J.H. and Meekan, M.G., 2003. '*Spatial and temporal patterns in the distribution and abundance of microzooplankton on the southern Northwest Shelf, Western Australia*'. Journal of Estuarine Coastal and Shelf Science, 56:897-908.

Wilson, S.G., Polovina, J.J., Stewart, B.S., Meekan, M.G., 2006. '*Movements of Whale Sharks (Rhincodon typus) tagged at Ningaloo Reef, Western Australia*'. Marine Biology, 148:1157-1166.

Winsor, M., Irvine, L., Mate, B. 2017. '*Analysis of the spatial distribution of satellite tagged sperm whales (Physeter macrocephalus) in close proximity to seismic surveys in the Gulf of Mexico*'. Aquatic Mammals 43(4): 439 – 446. DOI 10.1578/AM.43.4.2017.439.

Wise, C.F., Wise, J.T.F., Wise, S.S., Thompson, W.D., Wise, J.P., 2014. '*Chemical dispersants used in the Gulf of Mexico oil crisis are cytotoxic and genotoxic to sperm whale skin cells*'. Aquatic Toxicology, 152: 335 – 340.

Woinarski, J., Brennan, K., Hempel, C., Armstrong, M., Milne, D., Chatto, R., 2003. '*Biodiversity conservation on the Tiwi Islands, Northern Territory: Part 2. Fauna*'. Northern Territory Government, Darwin.

Woinarski, J., Burbidge, A., Harrison, P., 2014. '*The Action Plan for Australian Mammals 2012*'. CSIRO Publishing, Victoria, Australia.

Woodside, 2007. '*Impacts of seismic airgun noise on fish behaviour: a coral reef case study*'.

Woodside, 2021. Galactic Hybrid 2D MSS - Environment Plan, Exploration.

Wright, A.J., Soto, N.A., Baldwin, A.L., Bateson, M., Beale, C.M., Clark, C., Deak, T., Edwards, E.F., Fernndez, A., Godinho, A., Hatch, L.T., Kakuschke, A., Lusseau, D., Martineau, D., Romero, M.L., Weilgart, L.S., Wintle, B.A., Notarbartolo-di Sciara, G., Martin, V. 2007. '*Do marine mammals experience stress related to anthropogenic noise?*' International Journal of Comparative Psychology 20 (2): 274–316.

Wright, A.J., Consentino, M., 2015. '*JNCC guidelines for minimising the risk of injury and disturbance to marine mammals from seismic surveys: we can do better*'. Marine Pollution Bulletin, 100(1), http://dx.doi.org/10.1016/j.marpolbul.2015.08.045

Wunambal Gaambera Aboriginal Corporation, 2016. '*Uunguu Indigeneous Protected Area: Wundaagu (Saltwater) Country, Draft Management Plan 2016 – 2020*'.

Wursig, B., Spencer, L., Jefferson, T., Mullin, K., 1998. '*Behaviour of cetaceans in the northern Gulf of Mexico relative to survey ships and aircraft*'. Aquatic Mammals 24(1): 41-50.

Wysocki, L. E., Davidson III, J. W., Smith, M. E., Frankel, A. S., Ellison, W. T., Mazik, P. M., Bebak, J., 2007. '*Effects of aquaculture production noise on hearing, growth, and disease resistance of rainbow trout Oncorhynchus mykiss*'. Aquaculture, 272(1-4):687-697.

Yang, W., Chen, C., Chuah, Y., Zhuang, C., Chen, I., Mooney, T., Stott, J., Blanchard, M., Jen, I., Chou, L. 2021. '*Anthropogenic Sound Exposure-Induced Stress in Captive Dolphins and Implications for Cetacean Health*'. Frontiers of Marine Science. 8:606736. doi: 10.3389/fmars.2021.606736.

Zangerl, R., Hendrickson, L.P., Hendrickson, J.R., 1988. '*A redistribution of the Australian flatback sea turtle Natator depressus*'. Bishop Museum Bulletins in Zoology. 1: Jan-69.

Zug, G.R., Chaloupka, M., Balazs, G.H., 2006. '*Age and growth in olive ridley seaturtles (Lepidochelys olivacea) from the North-central Pacific: a skeltochronological analysis*'. Marine Ecology, 27:263-270.

APPENDIX A

Underwater Acoustic Modelling Report

Bonaparte Basin Marine Seismic Survey

Acoustic Modelling for Assessing Marine Fauna Sound Exposures

JASCO Applied Sciences (Australia) Pty Ltd

17 May 2022

Submitted to:

Dan Govier
SLR
Contract 740.30017.00000

Authors:

Steven C. Connell
Karlee E. Zammit
Michelle J. Weirathmueller
Matthew W. Koessler
Alina M. Muellenmeister
Craig R. McPherson

P001657-001
Document 02724
Version 2.0

Suggested citation:

Connell, S.C., K.E. Zammit, M.J. Weirathmueller, M.W. Koessler, A. M. Muellenmeister, and C.R McPherson. 2022. Bonaparte Basin Marine Seismic Survey: Acoustic Modelling for Assessing Marine Fauna Sound Exposures. Document 02724, Version 2.0. Technical report by JASCO Applied Sciences for SLR.

Contents

Figures

Tables

Executive Summary

JASCO Applied Sciences (JASCO) performed a numerical estimation study of underwater sound levels associated with the planned Schlumberger Bonaparte Basin Marine Seismic Survey (MSS) to assist in understanding the potential acoustic impacts on key regional receptors including marine mammals, fish, turtles, benthic invertebrates, sponges, coral, and plankton. The modelling considered a single seismic source in triple configuration with a total volume of 3000 in^3, towed at a depth of 8 m behind a single vessel, with an impulse interval (inter-pulse interval) of 16.67 m and a crossline array separation of 40 m.

JASCO's 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 signatures to estimate sound levels over a large area around the sources. Single-impulse sound fields were predicted at 21 sites within the Operational Area, with water depths ranging from 95 to 221 m. Accumulated sound exposure fields were predicted for four static acoustic scenarios and five animal movement modelling scenarios, to address different line acquisition plans, for likely survey operations over 24 hours. The seismic source will be continuously operating, including on turns.

The modelling methodology considered source directivity and range-dependent environmental properties likely to be encountered within the survey area. Estimated underwater acoustic levels are presented as sound pressure levels (SPL, L_p), zero-to-peak pressure levels (PK, L_{pk}), peak-to-peak pressure levels (PK-PK; $L_{pk\text{-pk}}$), and either single-impulse (i.e., per-pulse) or accumulated sound exposure levels (SEL, L_E) as appropriate for different noise effect criteria. A conservative sound speed profile that would be most supportive of sound propagation conditions for the period of the survey was defined and applied to all modelling.

SEL_{24h} is a cumulative metric that reflects the dosimetric effect of noise levels within 24 hours, based on the assumption that a receiver (e.g., an animal) is consistently exposed to such noise levels at a fixed position. More realistically, marine animals would not stay in the same location for 24 hours (especially in the absence of location-specific habitat) but rather a shorter period, depending on the animal's behaviour and the source's proximity and movements. Therefore, a reported radius for the SEL_{24h} criteria does not mean that marine fauna travelling within this radius of the source will be impaired, but rather that an animal could be exposed to the sound level associated with impairment (either Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS)) if it remained at that location for 24 hours.

A more realistic representation of the potential exposures for migrating pygmy blue whales in the migration BIA was undertaken using animal movement modelling ('animat modelling'). Simulations with animats restricted to the BIA provide an understanding of how animats will be exposed given the location and environment-specific context in which they are most likely to occur. Scenarios in which the pygmy blue whales are seeded in an unrestricted manner allow for the calculation of exposure range across the entire survey area. These ranges may then be interpreted to determine buffer zones around the BIA for different survey options and scenarios. The unrestricted seeding approach is informative in cases where there is very little overlap between the BIA and the planned acquisition area, as is the case for the majority of this survey.

While acoustic modelling inherently assumes static animals, the JASCO Animal Simulation Model Including Noise Exposure (JASMINE) combines modelled sound fields with realistic animal movements to predict how animals might be impacted through sound exposure. JASMINE provides a framework for understanding and predicting sound exposure for species of interest and for calculating ranges to relevant regulatory thresholds. The distribution of distances to the source of simulated animals ('animats') predicted to be exposed to sound levels above relevant thresholds was used to calculate the 95th percentile exposure range ($ER_{95\%}$), and the probability of animats being exposed above threshold within the $ER_{95\%}$ (P_{exp}).

A total of four acquisition scenarios were considered using both acoustic and animal movement modelling. A fifth scenario was included for animal movement modelling only, in this scenario the considered survey lines were further from the BIA, and it was considered with the aim of determining potential buffer zones around the BIA through the use of unrestricted animat seeding. All animat simulations were run in two configurations: one with animats restricted to the BIA, and another with unrestricted animat seeding.

The acoustic 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 considering all the representative single-impulse sites and all accumulated SEL scenarios for both acoustic modelling results and pygmy blue whale animat $ER_{95\%}$ results and probabilities.

Marine mammals – Acoustic results

- The maximum distance where the NOAA (2019b) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) for impulsive noise could be exceeded varied between 8.79 and 14.3 km for the 3000 in^3 seismic source, depending on modelled site – in particular related to the site depth and proximity to the shelf edge and shoals.
- The results for marine mammal injury considered the criteria from Southall et al. (2019a). These criteria contain two metrics (PK and SEL_{24h}), both required for the assessment of marine mammal PTS and TTS. The longest distance associated with either metric is required to be applied for assessment; Table 1 summarises the maximum distances, along with the relevant metric.
- The distance to PTS and TTS was always furthest in the broadside direction, distances are shown in Table 1.

Table 1. Summary of maximum (R_{max}) horizontal distances (in km) from all modelled sites and scenarios to behavioural response thresholds and temporary threshold shift (TTS) and permanent threshold shift (PTS) for marine mammals showing the relevant metric. Maximum extents are in the broadside direction of the 3000 in^3 seismic source.

Hearing group	Maximum modelled distance to effect threshold (R_{max})		
	Behavioural response[1]	Impairment: TTS[2]	Impairment: PTS[2]
LF cetaceans	14.3	47.5 (SEL_{24h})	6.84 (SEL_{24h})
HF cetaceans		0.08 (SEL_{24h})	–
VHF cetaceans		0.92 (PK)	0.48 (PK)
Sirenians		0.08 (SEL_{24h})	–

Noise exposure criteria: [1] NOAA (2019b) and [2] Southall et al. (2019b).
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Pygmy blue whales – Animat results

- The exposure ranges predicted using animat modelling are significantly more realistic, due to the incorporation of species-specific realistic movements, rather than conservative approach of calculating ranges using the maximum-over-depth sound fields and receivers which are stationary for 24 hours. This is because the exposure ranges account for animats sampling the sound field vertically and horizontally based on species-specific diving and movement parameters.
- Only two scenarios with pygmy blue whale BIA restricted animat seeding resulted in exposures. Of these, the maximum $ER_{95\%}$ to the marine mammal behavioural response threshold (NOAA 2019b) was 11.47 km, with a probability of exposure of 86%. The maximum $ER_{95\%}$ to TTS and PTS

thresholds (Southall et al. 2019b) were 14.0 km and 0.06 km, respectively, with probabilities of exposure of 63% and 93%.

- Exposure ranges ($ER_{95\%}$) for single exposure metrics, such as the SPL behavioural response criteria, are typically comparable to the predicted acoustic ranges. Exposure ranges are generally slightly lower than the R_{max} acoustic ranges and in this case are fairly aligned with the $R_{95\%}$ acoustic ranges.
    - For the scenarios run with unrestricted animat seeding, the $ER_{95\%}$ distances to the behavioural response were slightly shorter than for the restricted case, with a maximum of 9.74 km and a probability of exposure of 93%.
- Exposure ranges from animal movement modelling for PTS and TTS criteria are typically shorter than those predicted using acoustic propagation modelling because of the shorter dwell time of the moving animats. In all scenarios, for both BIA-restricted and unrestricted cases, PTS and TTS exposure ranges were substantially shorter than acoustic ranges to threshold.
    - Overall, the scenarios run with unrestricted animats had slightly longer TTS and PTS $ER_{95\%}$ than their BIA restricted counterparts, with a maximum of range for TTS 17.11 km and a probability of exposure of 75%.

Sea turtles

- The PK sea 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} metrics was 80 m for PTS onset and 6.11 km for TTS onset for the 3000 in^3 seismic source (Finneran et al. 2017). As is the case with marine mammals, a reported radius for SEL_{24h} criteria does not mean that sea 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 criterion for behavioural response of turtles to 166 dB re 1 µPa (SPL) (NSF 2011) 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 horizontal distances (in km) to turtle behavioural response criteria, temporary threshold shift (TTS), and permanent threshold shift (PTS).

Hearing group	Maximum modelled distance to effect threshold (R_{max})			
	Behavioural response[1]	Behavioural disturbance[2]	Impairment: TTS[3]	Impairment: PTS[3]
Sea Turtles	7.68	2.44	6.11	0.08

Noise exposure criteria: [1] NSF (2011), [2] McCauley et al. (2000a), and [3] Finneran et al. (2017)

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. Seafloor sound levels were assessed at five different depths within the Active Source Zone (75, 100, 125, 150, and 200 m).

Table 3. Summary of maximum fish, fish eggs, and larvae injury and temporary threshold shift (TTS) onset distances for single impulse and 24 hour sound exposure level (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	Recoverable injury	PK	0.08	PK	0.08
	TTS	SEL_{24h}	10.5	SEL_{24h}	9.31
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing	Recoverable injury	PK	0.20	PK	0.25
	TTS	SEL_{24h}	10.5	SEL_{24h}	9.31
Fish eggs, and larvae	Injury	PK	0.20	PK	0.25

Benthic invertebrates, Sponges, Coral, and Plankton

To assist with assessing the potential effects on these receptors, the following results were determined:

- Crustaceans: The sound level of 202 dB re 1 µPa PK-PK from Payne et al. (2008) which is representative of no effects, was considered for seafloor sound levels; the sound level was reached at ranges between 307 and 426 m for the 3000 in^3 source.
- 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). This particle acceleration was reached at a range of 10.5 m for depth 75 m and was not reached at any of the other considered depths.
- 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 not reached.

1. Introduction

JASCO Applied Sciences (JASCO) performed a numerical estimation study of underwater sound levels associated with the planned Schlumberger Bonaparte Basin Marine Seismic Survey (MSS) to assist in understanding the potential acoustic effect on receptors including marine mammals, fish, sea turtles, benthic invertebrates, plankton, sponges, and corals.

This study considered a 3000 in^3 seismic source array. JASCO's specialised Airgun Array Source Model (AASM) was used to predict acoustic signatures and spectra (see Section 4.2). AASM accounts for individual airgun volumes, airgun bubble interactions, and array geometry to yield accurate source predictions.

Complementary underwater acoustic propagation models were used in conjunction with the array signature and spectra to estimate sound levels considering site specific environmental influences. Single-impulse sound fields were predicted at 21 unique geographic locations within the Operational Area and four representative scenarios for accumulated SEL modelling were considered. The acquisition plan for the survey is proposed to be Continuous Line Acquisition, which involves acquiring during turns, and thus the source is continuously active - there is not a run out at the end of each line, followed by a quiet period and ramp up prior to the next acquisition line. Five representative animal movement modelling scenarios were considered for survey acquisition over 24 h (Section 2), with the scenarios designed to provide information which could be used to inform buffer zones around the pygmy blue whale migration Biologically Important Area (BIA).

The modelling methodology considered source directivity and range-dependent environmental properties. Estimated underwater acoustic levels are presented as sound pressure levels (SPL, L_p), zero-to-peak pressure levels (PK, L_{pk}), peak-to-peak pressure levels (PK-PK; $L_{pk\text{-pk}}$), and either single-impulse (i.e., per-pulse) or accumulated sound exposure levels (SEL, L_E) as appropriate for different noise effect criteria.

The planned seismic acquisition area is adjacent to the pygmy blue whale migration BIA with a small overlapping area. Therefore, the acoustic modelling results were also used in conjunction with animal movement modelling ('animat modelling') simulations to predict the distance at which migrating pygmy blue whales (*Balaenoptera musculus brevicauda*) are expected to be exposed above threshold criteria for PTS, TTS, and behavioural response. 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 SPL and SEL_{24h} for comparison against the relevant thresholds.

Section 3 explains the metrics used to represent underwater acoustic fields and the effect 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 4 also describes the methodology used in the animal movement and exposure modelling simulations. Section 5 presents the results, which are then discussed and summarised in Section 6.

2. Modelling Scenarios

A total of five nominal acquisition scenarios were considered using both acoustic propagation modelling and animal movement modelling, with one additional scenario considered using animal movement modelling only. Acoustic source and propagation modelling was done at 21 individual single-impulse sites, with some sites being modelled at several tow azimuths to account for acquisition on turns. The locations of the modelled sites are provided in Table 4. The modelling considered a 3000 in^3 seismic source towed in a triple array configuration at a speed of ~4.5 knots. An impulse interval (inter-pulse interval) of 16.66 m and a crossline array separation of 40 m were assumed. The acoustic propagation modelling utilised a March sound speed profile as this this month will likely results favourable propagation conditions within potential acquisition time periods for the proposed survey.

The single impulse sites and the accumulated SEL scenarios were determined based on proposed survey line plans with lines orientated either at 26/206° or 159/339°. The locations were selected based on their proximity to shoals and were inclusive of depths that support the greatest sound propagation into deep waters towards the pygmy blue whale (PBW) migratory Biologically Important Area (BIA). The single impulse sites and accumulated SEL scenarios are representative of the range of water depths and the potential sound propagation characteristics within the Operational Area. Seafloor sound levels were assessed at five different representative depths within the Operational Area (75, 100, 125, 150, and 200 m).

A total of four acquisition scenarios were considered using both acoustic and animal movement modelling. A fifth scenario was included for animal movement modelling only, in this scenario the considered survey lines were further from the BIA, and it was considered with the aim of determining potential buffer zones around the BIA through the use of unrestricted animat seeding. All animat simulations were run in two configurations: one with animats restricted to the BIA, and another with unrestricted animat seeding.

All five scenarios considered continuous 24 h acquisition, including on turns. A speed of 4.5 kts and an inter-pulse interval of 16.66 m results in a total of approximately 12,000 impulses per scenario.

Table 4. Location details for the single impulse modelled sites.

Scenario	Site	Tow Azimuth (°)	Latitude (°S)	Longitude (°E)	MGA[1] Zone 51		Water depth (m)
					X (m)	Y (m)	
1	1	26	11° 02' 22.39"	125° 35' 14.24"	782697	8778424	221
	2	26	11° 06' 09.47"	125° 33' 02.29"	778630	8771478	211
	3	26	11° 12' 34.88"	125° 29' 54.01"	772813	8759678	115
	4	26	11° 20' 32.88"	125° 26' 0.19"	765595	8745044	103
	5	26	11° 44' 31.93"	125° 15' 07.03"	745435	8700971	114
	6	26	12° 05' 17.80"	125° 12' 48.97"	740947	8662710	108
	7	26	11° 17' 49.22"	125° 34' 47.81"	781646	8749937	104
2	8	26	11° 47' 30.06"	124° 57' 49.59"	713976	8695732	198
	9	26	11° 51' 28.63"	124° 55' 51.92"	710363	8688425	133
	10	26	12° 04' 07.95"	124° 49' 36.86"	698856	8665167	119
	11	26	12° 01' 55.17"	124° 58' 11.57"	714453	8669140	114
	12	26	11° 50' 33.44"	125° 03' 47.82"	724781	8690018	117
	13	71	11° 45' 41.09"	124° 59' 15.40"	716598	8699062	208
	14	116	11° 46' 07.88"	125° 02' 44.19"	722915	8698194	155
	15	26	12° 14' 20.82"	124° 47' 47.25"	695416	8646355	117
3	16	159	12° 16' 24.06"	125° 10' 56.47"	737379	8642258	95
	17	159	11° 54' 47.92"	125° 02' 38.27"	722618	8682212	118
	18	159	Reprocessing Site 12 with new tow azimuth				
	19	114	Reprocessing Site 14 with new tow azimuth				
	20	69	Reprocessing Site 8 with new tow azimuth				
	21	24	Reprocessing Site 9 with new tow azimuth				
	22	159	12° 01' 9.48"	125° 14' 40.57"	744386	8670315	101
4	23	296	11° 06' 17.02"	125° 40' 51.69"	792881	8771120	108
	24	26	11° 16' 25.43"	125° 59' 21.17"	826386	8752088	95
	25	296	11° 08' 15.83"	125° 52' 10.46"	813459	8767274	101
	26	251	Reprocessing Site 1 with new tow azimuth				
	27	161	Reprocessing Site 2 with new tow azimuth				
5	Scenario only for animal movement modelling using Sites 5, 7, and 25						

[1] Map Grid of Australia (MGA)

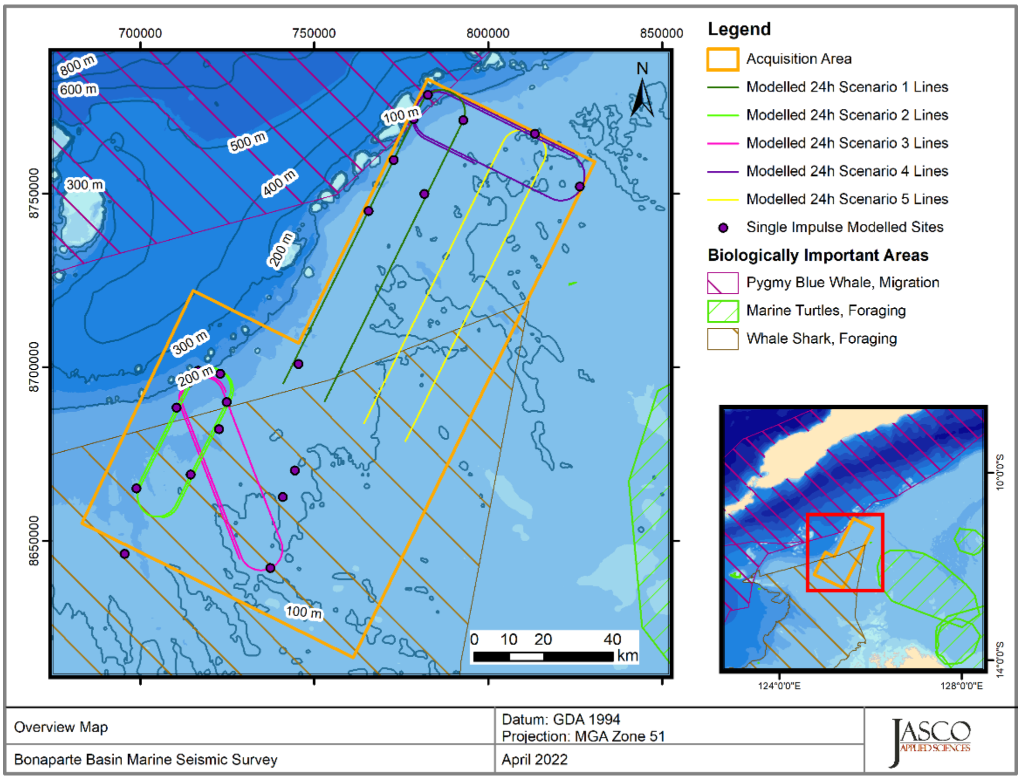


Figure 1. Overview of the modelled sites, acquisition lines, and features for the Bonaparte Basin Marine Seismic Survey (MSS).

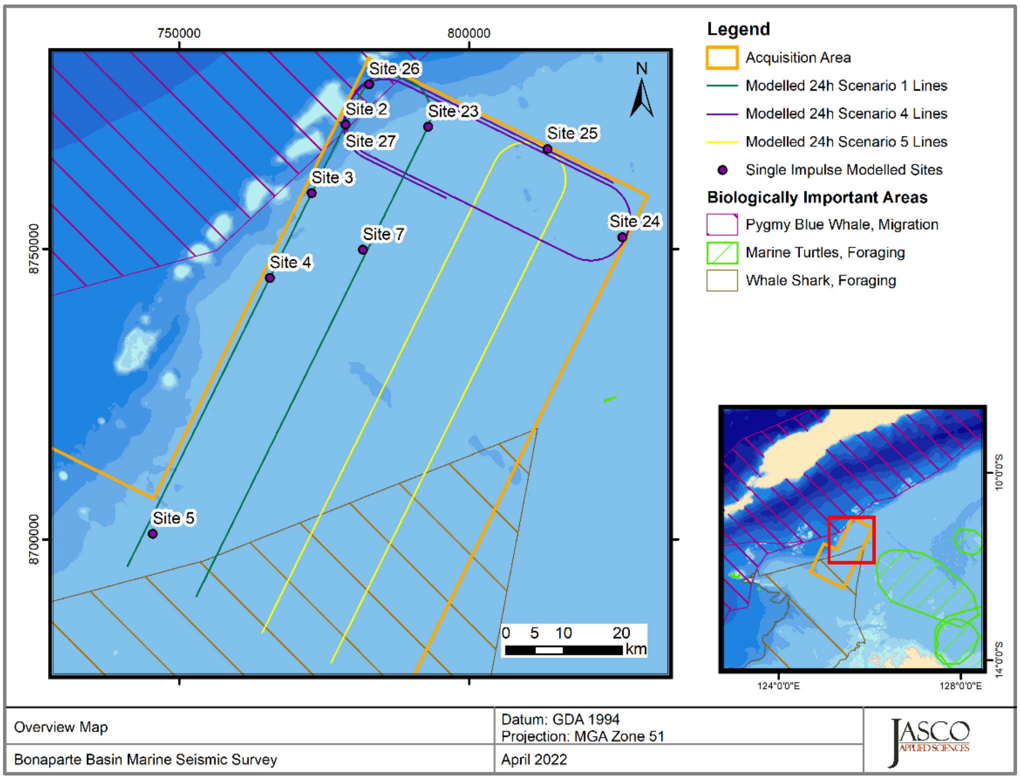


Figure 2. Scenarios 1, 4, and 5: Overview of the modelled sites, acquisition lines, and features for the Bonaparte Basin Marine Seismic Survey (MSS).

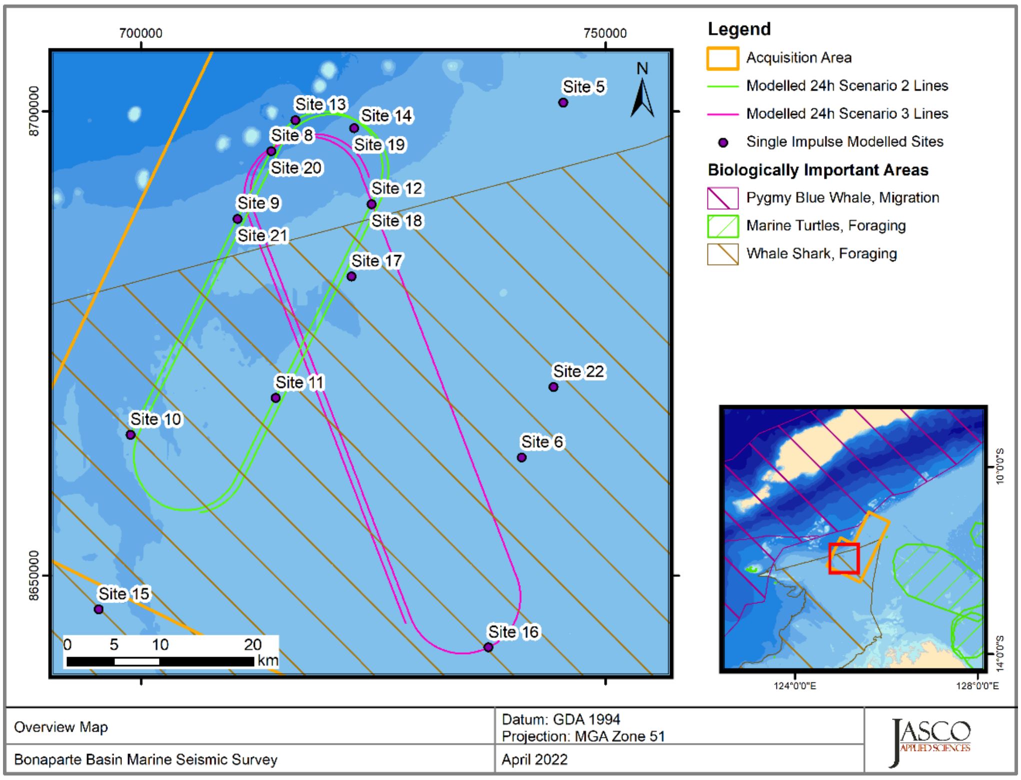


Figure 3. Scenarios 2 and 3: Overview of the modelled sites, acquisition lines, and features for the Bonaparte Basin Marine Seismic Survey (MSS).

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), United States National Marine Fisheries Service (NMFS 2018) and Southall et al. (2019b). The number of studies that have investigated the level of behavioural disturbance to marine fauna by anthropogenic sound has also increased substantially.

The following noise criteria and sound levels for this study were chosen 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 3.1–3.4 and Appendix A):

1. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24\text{h}}$) from (Southall et al. 2019b) for the onset of Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS) in marine mammals.
2. Marine mammal behavioural threshold based on the current US National Oceanic and Atmospheric Administration (NOAA 2019b) criterion for marine mammals of 160 dB re 1 µPa (SPL; L_p) for impulsive sound sources.
3. Sound exposure guidelines for fish, fish eggs and larvae (including plankton) (Popper et al. 2014).
4. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24\text{h}}$) from Finneran et al. (2017) for the onset of permanent threshold shift (PTS) and temporary threshold shift (TTS) in turtles.
5. Sea 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; L_p) (McCauley et al. 2000b, 2000a).
6. Peak-peak pressure levels (PK-PKS; $L_{pk\text{-pk}}$) and particle acceleration (ms^{-2}) at the seafloor to help assess effects of noise on crustaceans through comparing to results in Day et al. (2016a), Day et al. (2019), Day et al. (2016b), Day et al. (2017) and Payne et al. (2008).
7. A sound level of 226 dB re 1 µPa (PK; L_{pk}) reported for comparing to Heyward et al. (2018) for sponges and corals.

Additionally, to assess the size of the low-power zone required under the Australian Environment Protection and Biodiversity Conservation (EPBC) Act Policy Statement 2.1, Department of the Environment, Water, Heritage and the Arts (DEWHA 2008), the distance to an unweighted per-pulse SEL of 160 dB re 1 µPa^2·s (L_E) is reported.

The following subsections (Sections 3.1–3.4, along with Appendix A.3 and A.4), expand on the thresholds, guidelines and sound levels for marine mammals, fish, fish eggs, fish larvae, sea turtles, and benthic invertebrates.

3.1. Marine Mammals

There are two categories of auditory threshold shifts or hearing loss: permanent threshold shift (PTS), a physical injury to an animal's hearing organs; and Temporary Threshold Shift (TTS), a temporary reduction in an animal's hearing sensitivity as the result of receptor hair cells in the cochlea becoming fatigued.

To help assess the potential for the possible injury and hearing sensitivity changes in marine mammals, this report applies the criteria recommended by Southall et al. (2019b), considering both PTS and TTS. These criteria, along with the applied behavioural criteria (NOAA 2019b), are summarised in Table 5, with descriptions included in Appendix A.3.1 (auditory impairment) and Appendix A.3.2 (behavioural response), with frequency weighting explained in Appendix A.4. Of particular note, whilst the newly published Southall et al. (2021) provides recommendations and discusses the nuances of assessing behavioural response, the authors do not recommend new numerical thresholds for onset of behavioural responses for marine mammals.

Table 5. Unweighted sound pressure level (SPL), 24-hour sound exposure level (SEL_{24h}), and peak pressure (PK) thresholds for acoustic effects on marine mammals.

Hearing group	NOAA (2019b)	Southall et al. (2019b)			
	Behaviour	PTS onset thresholds[1] (received level)		TTS onset thresholds* (received level)	
	SPL (L_p; dB re 1 µPa)	Weighted SEL (L_E; dB re 1 µPa² s)	PK (L_{pk}; dB re 1 µPa)	Weighted SEL (L_E; dB re 1 µPa² s)	PK (L_{pk}; dB re 1 µPa)
Low-frequency cetaceans	160	183	219	168	213
High-frequency cetaceans		185	230	170	224
Very-high-frequency cetaceans		155	202	140	196
Sirenians		190	226	175	220

[1]Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS and TTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
L_p-denotes sound pressure level period and has a reference value of 1 µPa.
L_{pk}, flat–peak sound pressure is flat weighted or unweighted and has a reference value of 1 µPa.
L_E - denotes cumulative sound exposure over a 24-hour period and has a reference value of 1 µPa²s.
Subscripts indicate the designated marine mammal auditory weighting.

3.2. Fish, 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. However, as these depend upon activity-based subjective ranges, these effects are not addressed in this report and are included in Table 6 for completeness only. 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).

The SEL metric integrates noise intensity over some period of exposure. Because the period of integration for regulatory assessments is not well defined for sounds that do not have a clear start or end time, or for very long-lasting exposures, it is required to define a time. Popper et al. (2014) recommend applying a standard period, where this is either defined as a justified fixed period or the duration of the activity; however, Popper et al. (2014) also included caveats about how long the fish will be exposed because they can move (or remain in location) and so can the source. Popper et al. (2014) summarises that in all TTS studies considered, fish that showed TTS recovered to normal hearing levels within 18–24 hours. Due to this, a period of accumulation of 24 hours has been applied in this study for SEL, which is similar to that applied for marine mammals in NMFS (2016, 2018).

Additional information is provided in Appendix A.3.

Table 6. Criteria for seismic noise exposure for fish, adapted from Popper et al. (2014).

Type of animal	Mortality and Potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	>219 dB SEL_{24h} or >213 dB PK	>216 dB SEL_{24h} or >213 dB PK	>>186 dB SEL_{24h}	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	210 dB SEL_{24h} or >207 dB PK	203 dB SEL_{24h} or >207 dB PK	>>186 dB SEL_{24h}	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	207 dB SEL_{24h} or >207 dB PK	203 dB SEL_{24h} or >207 dB PK	186 dB SEL_{24h}	(N) Low (I) Low (F) Moderate	(N) High (I) High (F) Moderate
Fish eggs and fish larvae (relevant to plankton)	>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 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).

3.3. Sea 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. Popper et al. (2014) suggested thresholds for onset of mortal injury (including PTS) and mortality for sea turtles and, in absence of taxon-specific information, adopted the levels for fish that do not hear well (suggesting that this likely would be conservative for sea turtles).

Finneran et al. (2017) presented revised thresholds for sea turtle injury and hearing impairment (TTS and PTS). Their rationale is that sea turtles have best sensitivity at low frequencies and are known to have poor auditory sensitivity (Bartol and Ketten 2006, Dow Piniak et al. 2012). Accordingly, TTS and PTS thresholds for turtles are likely more similar to those of fishes than to marine mammals (Popper et al. 2014).

McCauley et al. (2000b) observed the behavioural response of caged sea turtles—green (*Chelonia mydas*) and loggerhead (*Caretta caretta*)—to an approaching seismic airgun. For received levels above 166 dB re 1 µPa (SPL), the sea 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 response by NMFS and applied in the Arctic Programmatic Environment Impact Statement (PEIS) (NSF 2011). In addition the 175 dB re 1 µPa level from McCauley et al. (2000b) is recommended as a criterion for behavioural disturbance. The Recovery Plan for Marine Turtles in Australia (Department of the Environment and Energy et al. 2017) acknowledges the 166 dB re 1 µPa SPL reported by McCauley et al. (2000b) as the level that may result in a behavioural response to marine turtles. These thresholds are shown in Table 7.

Table 7. Acoustic effects of impulsive noise on sea turtles: Unweighted sound pressure level (SPL), 24 hour sound exposure level (SEL_{24h}), and peak pressure (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)
Behavioural response	NSF (2011)	166	NA	
Behavioural disturbance	McCauley et al. (2000a)	175		
PTS onset thresholds[1] (received level)	Finneran et al. (2017)	NA	204	232
TTS onset thresholds[1] (received level)			189	226

[1] Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS and TTS 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 is flat weighted or unweighted and has a reference value of 1 µPa.
L_E denotes cumulative sound exposure over a 24 h period and has a reference value of 1 µPa²s.

3.4. Invertebrates

3.4.1. 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 and seismic source size are related to the particle motion levels at the seafloor, with larger arrays and shallower water being related to higher particle motion levels, more likely relevant to effects on crustaceans and bivalves.

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

The pressure and acceleration examples provided in Day et al. (2016a)(Figures 11 and 12) indicate that the acceleration and pressure signals occurred simultaneously, which was interpreted as an indication that the waterborne sounds were responsible for the accelerations measured by the geophones. For clarity, it is important to distinguish that the acceleration from waterborne sound energy is *not* ground roll, which Day et al. (2016a) correctly define as the sound that propagates along the interface at a speed lower than the shear wave speed of the sediment. However, the report subsequently uses ground roll for all further discussions of particle acceleration. While Day et al. (2016a) discuss that they chose the simplest measure of ground roll, it should have been referring to as ‘the acceleration from waterborne sound energy’, or ‘waterborne acceleration’ for short.

For crustaceans, a PK-PK sound level of 202 dB re 1 µPa (Payne et al. 2008) is considered to be associated with no effect, and therefore applied in the assessment. Additionally for context related to different levels of potential impairment, the PK-PK sound levels determined for crustaceans in Day et al. (2016b), 209–212 dB re 1 µPa and 213 dB re 1 µPa from Day et al. (2019), are also included.

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.

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. (2016a). The maximum particle acceleration assessed for scallops was 37.57 ms^{-2}.

3.4.2. Plankton

To assess effects on plankton, there are only a few studies to base threshold criteria on. Popper et al. (2014) cites many of the references and studies on potential impacts of noise emissions on fish eggs and larvae prior to 2014. Results presented in Day et al. (2016b) for embryonic lobsters and Fields et al. (2019) for copepods align with those presented in Popper et al. (2014), which is that mortality and sub-lethal injury are limited to within tens of metres of seismic sources. Additionally, the Popper et al.

(2014) criteria (Table 6), are extrapolated from simulated pile driving signals which have a more rapid rise time and greater potential for trauma than pulses from a seismic source.

Other research, such as McCauley et al. (2017), has indicated the potential for effects at longer range and at levels of 178 dB PK-PK, however, Fields et al. (2019) noted that it was difficult to reconcile the high mortality reported by McCauley et al. (2017) with the low mortalities reported in the greater previous body of earlier research and their experiment. They recommended further research into whether it is the sound pulse itself (i.e., the energy, peak pressures, or particle acceleration), the (turbulent) fluid flow occurring more slowly (i.e., not related to the sound pulse), or other effects such as the bubble cloud that which might cause higher mortality near the seismic source.

4. Methods

4.1. Parameter Overview

The specifications of the seismic sources and the environmental parameters used in the propagation models are described in detail in Appendix D. A single sound speed profile for March was considered in this modelling study; this was identified as the seasonal period that would provide the farthest propagation (Appendix D.3.2).

Seabed sediments in the operational area were mostly characterised as sandy silt where the modelled sites are in depths of 95–221 m. The seabed was modelled as increasingly consolidated sandy silt.

4.2. Acoustic Source Model

The pressure signature of the individual airguns and the composite decidecade-band point-source equivalent directional levels (i.e., source levels) of the 3000 in^3 seismic source were modelled with JASCO's Airgun Array Source Model (AASM). Although AASM accounts for notional pressure signatures of each seismic source with respect to the effects of surface-reflected signals on bubble oscillations and inter-bubble interactions, the surface-reflected signal (known as surface ghost) is not included in the far-field source signatures. The acoustic propagation models account for those surface reflections, which are a property of the propagating medium rather than the source.

AASM considers:

- Array layout.
- Volume, tow depth, and firing pressure of each airgun.
- Interactions between different airguns in the array.

All seismic sources considered were modelled over AASM's full frequency range, up to 25 kHz. Appendix B.1 details this model.

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, 5 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 4 transects at the seafloor along the endfire and broadside directions of the seismic source at 5 water depths, 75, 100, 125, 150, and 200 m for PK and PK-PK and 3 water depths for particle motion, 75, 100, 150 m.

4.4. 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 2600 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 1.25 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 along 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 begins at 20 m and increases with range from the source.

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 5 and 50 cm above the seafloor to assist in the assessment on invertebrates and fish respectively.

4.5. 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 3.1–3.2), 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.

The planned Bonaparte Basin MSS has been proposed to incorporate continuous line acquisition where the seismic source will be operational during line turns. It would be similarly impractical to model acquisition during turns where the tow azimuth for the seismic source is constantly changing. To approximate the sound field around a turn, modelled sites were reprocessed with 5 tow azimuths at angles of 0, 45, 90, 135, and 180° relative to the main survey line. As the modelled vessel traversed a curved track, the azimuth was calculated and at each point along the turn the closest azimuth of these 5 tow directions was used.

Although estimating the accumulated 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 unweighted (fish) and frequency-weighted SEL_{24h} results were rendered as contour maps, including contours that focus on the relevant criteria-based thresholds. Only contours at ranges larger than the nearfield of the seismic source were rendered.

4.6. Animal Movement and Exposure Modelling

4.6.1. Methodology

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was used to predict the exposure of animats to sound arising from the seismic activity. JASMINE integrates the predicted sound field with biologically meaningful movement rules for each marine mammal species (pygmy blue whales for the current analysis) that results in an exposure history for each animat in the model. In JASMINE, the sound received by the animats is determined by the proposed seismic operations. As illustrated in Figure 4, animats are programmed to behave like the marine animals that may be present in an area. The parameters used for forecasting realistic behaviours (e.g., diving and foraging depth, swim speed, surface times) are determined and interpreted from marine mammal studies (e.g., tagging studies) where available, or reasonably extrapolated from related or comparable species. For cumulative metrics, an individual animat's sound exposure levels are summed over a 24 h duration to determine its total received energy, and then compared to the relevant threshold criteria. For single-exposure metrics, the maximum exposure is evaluated against threshold criteria for each 24 h period. For additional information on JASMINE, see Appendix D.4.

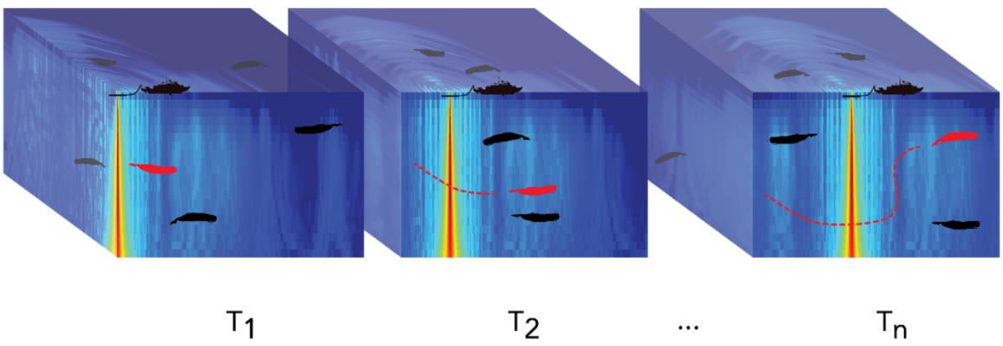


Figure 4. Depiction of animats in a moving sound field. Example animat (red) shown moving with each time step (T_n). The acoustic exposure of each animat is determined by where it is in the sound field, and its exposure history is accumulated as the simulation steps through time.

The exposure criteria for impulsive sounds (described in Section 3) were used to determine the number of animats that exceeded thresholds. To generate statistically reliable probability density functions, model simulations were run with animat sampling densities of 4 animats/km^2. The modelling results are not related to real-world density estimates for pygmy blue whales within the BIA, as the number of animals potentially exposed is not calculated. To evaluate PTS, TTS and behavioural response, exposure results were obtained using detailed behavioural information for migrating pygmy blue whales (described in Section 4.6.3). The simulation was run for a representative period of 24 h, with the spatial distribution of the animats restricted to the BIA.

The seismic source was modelled as a vessel towing an airgun array at a speed of ~4.5 knots, with an impulse interval of 16.66 m. The simulated source tracks followed a racetrack configuration with acquisition occurring on turns. At the time and location of each seismic pulse, the modelled source location with the closest distance was selected for exposure modelling. The track lines along with the acoustic modelling locations are shown in Figure 1.

Figure 5 shows an example animat track (generated for information purposes only and not related to the results presented in this report) with associated received levels from a stationary point source. The top panel displays the animat track relative to the point source, and the bottom panel displays the accumulation of SEL_{24h} for TTS and PTS criteria. At approximately 50 seconds, the animat is exposed so that the TTS threshold is exceeded, and at approximately 700 seconds the animat is exposed so that the PTS threshold is exceeded.

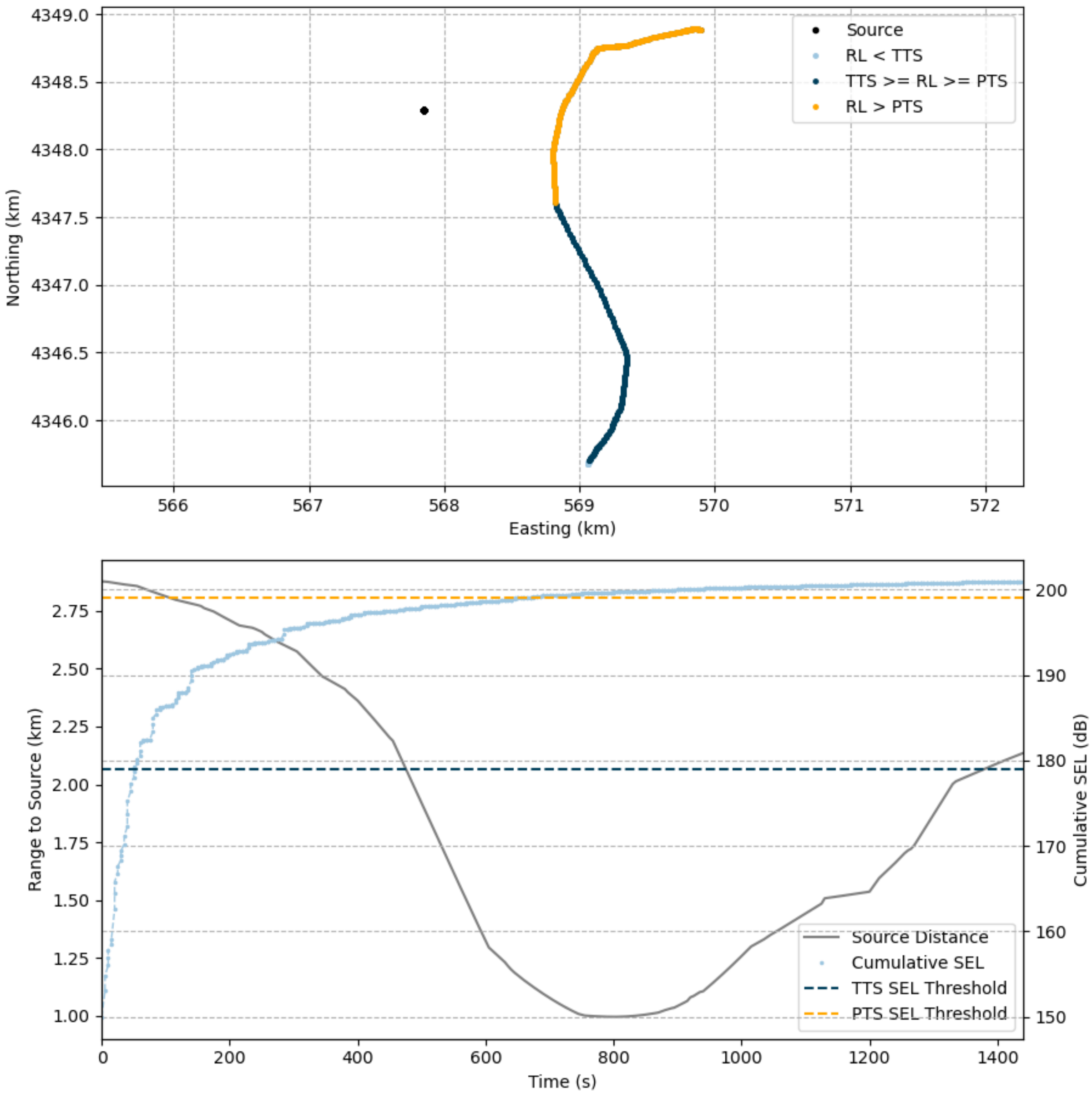


Figure 5. Animat track from an example simulation showing northward movement over a duration of 1400 seconds. The upper panel shows a plan view of both a stationary point source and a foraging animat. Animat steps are coloured to indicate whether the accumulated sound energy at that point has exceeded either TTS or PTS threshold criteria. The lower panel shows horizontal distance in kilometres to the source (grey line; left y-axis) and cumulative 24-h SEL ($L_{E,24h}$, dB re 1 µPa²·s; right y-axis) as a function of time. Note that this example does not use data from the current study.

4.6.2. Exposure–based Radial Distance Estimation

The results from the animal movement and exposure modelling provided a way to estimate radial distances to effect thresholds. The distance to the closest point of approach (CPA) for each of the animats was recorded. The $ER_{95\%}$ (95% Exposure Range) is the horizontal distance that includes 95% of the animat CPAs that exceeded a given effect threshold (see Section 3.1). Within the $ER_{95\%}$, there is generally some proportion of animats that do not exceed threshold criteria. This occurs for several reasons, including the spatial and temporal characteristics of the sound field and the way in which animats sample the sound field over time, both vertically and horizontally. The sound field varies as a function of range, depth, and azimuth based on a variety of factors such as bathymetry, sound speed profile, and geoacoustic parameters. The way the animats sample the sound field depends upon species-typical swimming and diving characteristics (e.g., swim speed, dive depth, surface intervals, and reversals). Furthermore, even within a particular species definition, these characteristics vary with behavioral state (e.g., feeding, migrating). As this results in some animats not exceeding threshold criteria even within the $ER_{95\%}$, the probability that an animat within that distance was exposed above threshold within the $ER_{95\%}$ was also computed (P_{exp}) to provide additional context.

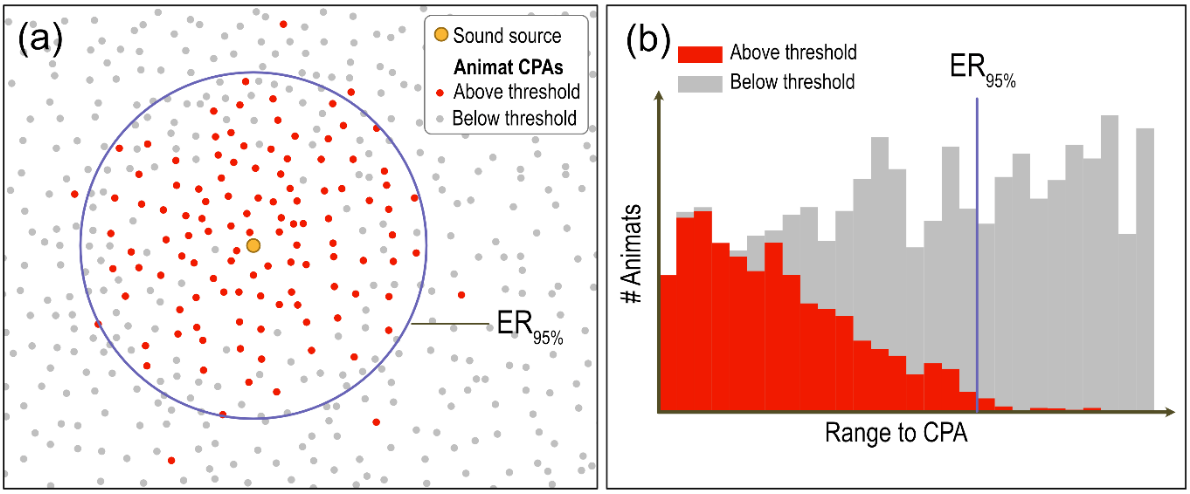


Figure 6. Example distribution of animat closest points of approach (CPAs). Panel (a) shows the horizontal distribution of animats near a sound source. Panel (b) shows the distribution of distances to animat CPAs. The 95% exposure range ($ER_{95\%}$) is indicated in both panels.

4.6.3. Pygmy Blue Whale Behaviour Profile

The Bonaparte Basin MSS is adjacent to and overlaps with the migration BIA for pygmy blue whales, along with the therefore migratory behaviour was the only behavioural profile considered. The north-bound migrations were modelled to account for variability in movement and diving behaviour during the month of March, which was selected for sound propagation modelling. The north-bound migration was used as a nominal migratory direction as there is insufficient publicly available data to differentiate between parameters for different migratory directions.

Detailed information on pygmy blue whales was derived from a range of sources that used multi-sensor tags to record fine-scale dive and movement behaviour (Owen et al. 2016, Möller et al. 2020). Where information was unavailable for pygmy blue whales, parameters were derived from blue whale (*B. musculus*) tagging data (Goldbogen et al. 2011).

Multi-sensor tags typically record the depth of an animal along with various movement parameters such as swim speed and their body's orientation. Owen et al. (2016) equipped a sub-adult pygmy blue whale with a multi-sensor tag off Western Australia. They identified dives for their tagged animal as migratory, feeding, or exploratory (i.e., no lunges recorded which would indicate feeding). Pygmy blue whales in the simulation area are presumed to be migrating, and so feeding was not included in the model. Exploratory dives were considered to be part of migratory behaviour, and so the two dive types were modelled together such that the animats were migrating 96% of the time and engaged in exploratory dives 4% of the time (Owen et al. 2016). Using data from Owen et al. (2016), the approximate length of a bout of exploratory dives could be determined, as well as the average (± SD) depth of this dive type. The analysis of the dive data showed that the depth of migratory dives was highly consistent over time and unrelated to local bathymetry. The mean depth of migratory dives was 14 ± 4 m while the mean maximum depth of exploratory dives was 107 ± 81 m (23–320 m range).

The behaviour of migrating pygmy blue whales was modelled to reflect animats transiting through the modelling area on a 50° track. This represents the animals migrating along the west coast of Australia, to and from Indonesia (Double et al. 2014, DoE (AU) 2015-2025). The speed of travel for migratory behaviour (1.17 ± 0.60 m/s) and exploratory dives (0.88 ± 0.14 m/s) were calculated from data presented in Möller et al. (2020).

5. Results

5.1. Acoustic Source Levels and Directivity

AASM (Section 4.2) was used to predict the horizontal and vertical overpressure signatures and corresponding power spectrum levels for the seismic sources, with results provided in Appendix B.3 along with the horizontal directivity plots for the selected 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 for the modelled array signature (3000 in^3 source). 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-2 in Appendix B.3 shows the broadside, endfire, and vertical overpressure signature and corresponding power spectrum levels for the source. The signature consists of a strong primary peak, related to the initial release of high-pressure air, followed by a series of pulses associated with bubble oscillations. Most energy was produced at frequencies below 500 Hz. Frequency-dependent peaks and nulls in the spectrum result from interference among airguns in the source and correspond with the volumes and relative locations of the airguns to each other.

Table 8. Far-field source level specifications for 3000 in^3 source, for an 8 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	250.1	225.3	185.4
Endfire	245.0	223.0	186.4
Vertical	256.3	228.8	195.1
Vertical (surface affected source level)	256.3	231.0	198.3

5.2. Per-pulse Sound Fields

This section presents the per-pulse sound fields in terms of maximum-over-depth SPL, SEL, PK, and seafloor PK and PK-PK. The different metrics are presented for the following reasons:

- SPL sound fields were used to determine the distances to marine mammal and turtle behavioural thresholds (see Sections 3.1 and 3.3).
- Per-pulse SEL sound fields are used as inputs into the 24 h SEL scenario and to provide context for the range to 160 dB re 1 µPa^2·s, relevant for the EPBC Act Policy Statement 2.1 (DEWHA 2008).
- PK metrics within the water column are relevant to thresholds and guidelines for marine mammals, sea turtles, fish, fish eggs and larvae (as well as plankton; Sections 3.1–3.3).
- PK metrics at the seafloor are relevant to guidelines for fish, fish eggs and larvae (Section 3.3) and the sound level for no effect on corals and sponges.

- PK-PK metrics at the seafloor are relevant to sound levels used in the assessment of effect on benthic invertebrates (Section 3.4.1).

The maximum and 95% distances to per-pulse SEL and SPL metrics are presented in Tables 9 through 16. The SPL sound fields, and distances to relevant isopleths can be visualised on the contour maps presented in Figures 7–33. The SPL sound fields are also presented as vertical slices for selected sites along the endfire and broadside directions out to 50 km, with the airgun array in the centre (Figures 34–39).

Maximum distances to maximum-over-depth water column PK thresholds were calculated for six modelled single impulse sites, Sites 1, 7, 8, 11, 14, and 22, and presented in Table 17. Seafloor sound levels were assessed at five different representative depths within the Operational Area (75, 100, 125, 150, and 200 m), and Tables 18–19 present the PK and PK-PK results.

5.2.1. Tabulated Results

5.2.1.1. Entire Water Column

Table 9. *Scenario 1, 3000 in^3 source*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the seismic source to modelled maximum-over-depth and maximum-over-azimuth unweighted per-pulse sound exposure level (SEL) isopleths from the modelled single impulse sites, with water depth indicated.

Per-pulse SEL (L_E; dB re 1 µPa²·s)	Site 1 (221 m)		Site 2 (211 m)		Site 3 (115 m)		Site 4 (103 m)		Site 5 (114 m)		Site 6 (108 m)		Site 7 (103 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
180	0.19	0.16	0.18	0.16	0.33	0.28	0.33	0.29	0.32	0.27	0.33	0.28	0.33	0.29
170	0.96	0.83	0.99	0.83	1.47	1.20	1.54	1.28	1.49	1.20	1.52	1.22	1.56	1.31
160[1]	4.90	4.05	4.27	3.43	5.35	4.51	5.57	4.65	5.68	4.62	5.77	4.66	5.81	4.60
150	17.1	13.5	9.89	8.08	16.6	12.9	14.4	11.7	14.3	11.7	13.9	11.5	14.1	11.6
140	56.9	44.8	20.0	16.0	57.4	51.0	38.1	26.0	34.3	24.6	30.5	24.5	30.8	23.7
130	>100	/	68.3	46.7	>100	/	99.0	70.0	78.9	59.6	62.4	48.6	69.1	53.1

[1] Low power zone assessment criteria DEWHA (2008).
A slash indicates that $R_{95\%}$ radius to threshold is not reported when the R_{max} is greater than the maximum modelling extent.

Table 10. *Scenario 2, 3000 in³ source*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the seismic source to modelled maximum-over-depth and maximum-over-azimuth unweighted per-pulse sound exposure level (SEL) isopleths from the modelled single impulse sites, with water depth indicated.

Per-pulse SEL (L_E; dB re 1 µPa²·s)	Site 8 (198 m)		Site 9 (113 m)		Site 10 (119 m)		Site 11 (114 m)		Site 12 (117 m)		Site 13 (208 m)		Site 14 (155 m)		Site 15 (117 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
180	0.20	0.17	0.30	0.25	0.32	0.27	0.32	0.27	0.32	0.27	0.19	0.16	0.25	0.21	0.32	0.27
170	1.19	0.94	1.33	1.06	1.37	1.19	1.49	1.20	1.43	1.19	1.22	0.89	1.17	1.00	1.41	1.19
160[1]	4.99	3.91	5.68	4.72	5.50	4.66	5.73	4.66	5.68	4.62	5.17	4.42	5.35	4.38	5.59	4.62
150	12.5	10.3	16.7	12.1	14.5	11.7	14.2	11.8	14.7	11.7	16.4	13.4	14.5	11.6	14.8	12.1
140	33.6	26.4	45.4	33.9	34.0	27.3	33.6	26.1	36.7	26.4	51.6	44.4	38.5	31.1	29.9	24.5
130	82.4	60.2	77.3	60.3	63.9	51.7	64.5	51.8	80.9	60.1	95.1	83.3	87.1	76.0	64.2	50.2

[1] Low power zone assessment criteria DEWHA (2008).
A slash indicates that $R_{95\%}$ radius to threshold is not reported when the R_{max} is greater than the maximum modelling extent.

Table 11. *Scenario 3, 3000 in³ source*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the seismic source to modelled maximum-over-depth and maximum-over-azimuth unweighted per-pulse sound exposure level (SEL) isopleths from the modelled single impulse sites, with water depth indicated.

Per-pulse SEL (L_E; dB re 1 µPa²·s)	Site 16 (95 m)		Site 17 (118 m)		Site 18 (117 m)		Site 19 (155 m)		Site 20 (198 m)		Site 21 (133 m)		Site 22 (101 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
180	0.33	0.29	0.32	0.27	0.32	0.27	0.25	0.21	0.20	0.17	0.30	0.25	0.34	0.29
170	1.58	1.36	1.37	1.19	1.47	1.18	1.15	1.00	1.22	0.95	1.25	1.05	1.55	1.29
160[1]	5.37	4.61	5.48	4.66	5.38	4.63	5.31	4.39	5.80	4.33	5.73	4.77	5.72	4.74
150	14.0	11.5	14.6	11.7	13.9	11.7	14.7	11.7	17.4	13.9	15.9	12.0	15.0	12.2
140	33.4	27.3	33.8	26.5	32.6	27.0	40.5	31.9	54.8	46.8	44.0	32.4	30.9	26.0
130	90.0	63.8	71.3	55.2	72.8	56.7	87.9	77.5	>100	/	76.0	59.8	71.1	56.2

[1] Low power zone assessment criteria DEWHA (2008).
A slash indicates that $R_{95\%}$ radius to threshold is not reported when the R_{max} is greater than the maximum modelling extent.

Table 12. *Scenario 4, 3000 in³ source*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the seismic source to modelled maximum-over-depth and maximum-over-azimuth unweighted per-pulse sound exposure level (SEL) isopleths from the modelled single impulse sites, with water depth indicated.

Per-pulse SEL (L_E; dB re 1 µPa²·s)	Site 23 (114 m)		Site 24 (108 m)		Site 25 (104 m)		Site 26 (95 m)		Site 27 (101 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
180	0.33	0.28	0.34	0.29	0.34	0.29	0.19	0.16	0.18	0.16
170	1.42	1.18	1.65	1.28	1.52	1.31	0.97	0.83	1.08	0.84
160[1]	5.50	4.55	5.49	4.72	5.58	4.58	5.18	4.10	4.81	4.03
150	19.8	12.3	14.6	12.0	14.7	12.1	16.0	12.1	12.9	10.3
140	30.2	24.7	33.3	27.0	35.5	28.0	50.4	40.9	27.6	23.1
130	66.2	50.8	70.1	56.6	71.6	53.6	>100	/	93.4	70.9

[1] Low power zone assessment criteria DEWHA (2008).
A slash indicates that $R_{95\%}$ radius to threshold is not reported when the R_{max} is greater than the maximum modelling extent.

Table 13. *Scenario 1, 3000 in³ source*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the seismic source to modelled maximum-over-depth and maximum-over-azimuth per-pulse sound pressure level (SPL) isopleths from the modelled single impulse sites, with water depth indicated.

SPL (L_p; dB re 1 µPa)	Site 1 (221 m)		Site 2 (211 m)		Site 3 (115 m)		Site 4 (103 m)		Site 5 (114 m)		Site 6 (108 m)		Site 7 (103 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
190	0.16	0.14	0.16	0.14	0.27	0.22	0.28	0.23	0.27	0.22	0.27	0.23	0.28	0.23
180	0.86	0.71	0.90	0.75	1.20	0.96	1.27	1.08	1.23	1.01	1.25	1.05	1.25	1.07
175[1]	2.00	1.59	1.88	1.45	2.37	1.88	2.52	1.97	2.43	1.94	2.51	1.97	2.48	1.99
170	3.28	2.76	3.05	2.47	4.11	3.41	4.11	3.46	3.99	3.38	4.11	3.46	3.98	3.43
166[2]	6.15	5.16	4.87	3.82	6.07	4.84	6.07	5.06	6.19	5.14	6.24	5.13	6.18	5.16
160[3]	12.4	10.6	8.79	7.02	11.5	8.71	11.9	8.92	10.6	8.71	10.7	8.77	10.6	8.75
150	38.5	32.6	15.7	13.9	45.6	38.9	26.9	19.8	26.5	19.8	23.8	19.5	25.0	19.4
140	>100	/	51.4	31.0	>100	/	84.0	56.9	75.4	50.5	54.5	43.2	55.4	44.0

[1] Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000b).
[2] Threshold for turtle behavioural response to impulsive noise (NSF 2011).
[3] Marine mammal behavioural threshold for impulsive sound sources (NOAA 2019b).
A slash indicates that $R_{95\%}$ radius to threshold is not reported when the R_{max} is greater than the maximum modelling extent.

Table 14. *Scenario 2, 3000 in³ source*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the seismic source to modelled maximum-over-depth and maximum-over-azimuth per-pulse sound pressure level (SPL) isopleths from the modelled single impulse sites, with water depth indicated.

SPL (L_p; dB re 1 µPa)	Site 8 (198 m)		Site 9 (113 m)		Site 10 (119 m)		Site 11 (114 m)		Site 12 (117 m)		Site 13 (208 m)		Site 14 (155 m)		Site 15 (117 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
190	0.16	0.14	0.22	0.20	0.25	0.22	0.27	0.22	0.26	0.22	0.15	0.14	0.20	0.17	0.26	0.22
180	0.85	0.71	1.02	0.90	1.21	0.97	1.24	1.01	1.22	1.00	0.85	0.75	1.05	0.90	1.24	0.98
175[1]	2.00	1.69	2.08	1.84	2.18	1.93	2.37	1.87	2.44	1.91	1.82	1.55	2.16	1.80	2.39	1.88
170	4.38	3.47	3.90	3.22	3.97	3.26	3.96	3.31	4.03	3.29	3.64	2.85	3.59	3.02	3.94	3.27
166[2]	6.82	5.40	5.92	5.07	5.85	4.88	6.01	5.02	6.02	4.91	5.41	4.73	5.41	4.45	5.89	4.91
160[3]	11.5	9.41	11.5	9.14	10.4	8.68	10.4	8.66	10.4	8.45	11.6	9.18	11.9	10.0	11.3	8.86
150	22.3	18.5	36.0	24.2	26.2	21.2	26.8	20.7	27.3	19.4	38.6	32.4	26.4	21.3	23.3	19.4
140	73.1	56.0	69.9	55.9	57.3	45.4	59.3	45.5	71.6	55.1	83.8	72.9	72.1	61.4	55.8	43.2

[1] Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000b).
[2] Threshold for turtle behavioural response to impulsive noise (NSF 2011).
[3] Marine mammal behavioural threshold for impulsive sound sources (NOAA 2019b).
A slash indicates that $R_{95\%}$ radius to threshold is not reported when the R_{max} is greater than the maximum modelling extent.

Table 15. *Scenario 3, 3000 in³ source*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the seismic source to modelled maximum-over-depth and maximum-over-azimuth per-pulse sound pressure level (SPL) isopleths from the modelled single impulse sites, with water depth indicated.

SPL (L_p; dB re 1 µPa)	Site 16 (95 m)		Site 17 (118 m)		Site 18 (117 m)		Site 19 (155 m)		Site 20 (198 m)		Site 21 (133 m)		Site 22 (101 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
190	0.29	0.25	0.26	0.22	0.26	0.22	0.20	0.17	0.16	0.14	0.23	0.20	0.29	0.24
180	1.30	1.09	1.24	0.98	1.22	0.99	1.05	0.91	0.84	0.70	1.01	0.90	1.27	1.09
175[1]	2.50	2.04	2.19	1.95	2.14	1.90	2.17	1.81	2.14	1.71	2.07	1.84	2.49	1.99
170	4.07	3.53	4.11	3.40	3.98	3.28	3.65	3.04	4.81	3.82	3.87	3.22	4.34	3.39
166[2]	6.32	5.19	6.34	5.22	6.05	5.00	5.37	4.47	7.68	6.18	5.95	5.05	6.27	5.19
160[3]	10.9	9.07	10.7	9.00	10.4	8.73	11.8	10.1	14.3	11.3	11.4	9.11	11.5	9.44
150	27.4	22.6	28.1	22.0	25.3	20.7	27.5	21.6	47.9	40.8	34.2	23.1	26.4	21.7
140	77.0	54.1	62.3	48.4	59.9	47.6	73.6	62.8	91.6	74.7	68.2	55.4	61.0	49.0

[1] Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000b).
[2] Threshold for turtle behavioural response to impulsive noise (NSF 2011).
[3] Marine mammal behavioural threshold for impulsive sound sources (NOAA 2019b).
A slash indicates that $R_{95\%}$ radius to threshold is not reported when the R_{max} is greater than the maximum modelling extent.

Table 16. *Scenario 4, 3000 in³ source*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the seismic source to modelled maximum-over-depth and maximum-over-azimuth per-pulse sound pressure level (SPL) isopleths from the modelled single impulse sites, with water depth indicated.

SPL (L_p; dB re 1 µPa)	Site 23 (114 m)		Site 24 (108 m)		Site 25 (104 m)		Site 26 (95 m)		Site 27 (101 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
190	0.27	0.23	0.29	0.25	0.29	0.24	0.15	0.14	0.15	0.14
180	1.23	1.04	1.31	1.09	1.24	1.06	0.87	0.71	0.83	0.69
175[1]	2.26	1.97	2.25	2.02	2.44	2.05	1.93	1.51	1.93	1.59
170	4.14	3.35	4.17	3.51	3.98	3.38	3.23	2.63	3.35	2.74
166[2]	5.90	4.92	6.27	5.12	6.07	5.00	5.82	4.71	5.96	4.71
160[3]	11.2	8.77	10.5	8.90	11.0	8.73	11.8	8.98	10.9	8.61
150	26.0	20.7	26.6	21.4	26.4	21.3	37.2	30.8	19.8	16.4
140	56.3	43.1	59.3	49.2	61.1	47.0	>100	/	73.4	52.5

1 Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000b).
2 Threshold for turtle behavioural response to impulsive noise (NSF 2011).
3 Marine mammal behavioural threshold for impulsive sound sources (NOAA 2019b).
A slash indicates that $R_{95\%}$ radius to threshold is not reported when the R_{max} is greater than the maximum modelling extent.

Table 17. *3000 in³ source*: Maximum (R_{max}) horizontal distances (in km) from the seismic source to modelled maximum-over-depth peak pressure level (PK) thresholds based on Southall et al. (2019b) for marine mammals, and Popper et al. (2014) for fish and Finneran et al. (2017) for sea turtles, Sites 1, 7, 8, 11, 14, and 22), with water depth indicated.

Hearing group	PK threshold (L_{pk}; dB re 1 µPa)	Distance R_{max} (km)					
		Site 1 (221 m)	Site 7 (104 m)	Site 8 (198 m)	Site 11 (114 m)	Site 14 (155 m)	Site 22 (101 m)
Low-frequency cetaceans (PTS)	219	–	–	–	–	–	–
Low-frequency cetaceans (TTS)	213	0.08	0.08	0.08	0.08	0.08	0.08
High-frequency cetaceans (PTS)	230	–	–	–	–	–	–
High-frequency cetaceans (TTS)	224	–	–	–	–	–	–
Very-high-frequency cetaceans (PTS)	202	0.29	0.48	0.42	0.41	0.34	0.45
Very-high-frequency cetaceans (TTS)	196	0.92	0.82	0.85	0.79	0.87	0.81
Sea Turtles (PTS)	232	–	–	–	–	–	–
Sea Turtles (TTS)	226	–	–	–	–	–	–
Sirenians (PTS)	226	–	–	–	–	–	–
Sirenians (TTS)	220	–	–	–	–	–	–
Fish: No swim bladder (also applied to sharks)	213	0.08	0.08	0.08	0.08	0.08	0.08
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae	207	0.17	0.19	0.17	0.15	0.16	0.20

A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).

5.2.1.2. Seafloor

Ranges presented at the seafloor (50 and 5 cm above the interface) provided in Tables 18 and 19 are different to those for the maximum-over-depth modelling results presented in Table 17. This is because the model used for the water column results, calculated using FWRAM do not represent the maximum sound levels at the seafloor close to the array. This is because FWRAM is based on a wide-angle parabolic equation (PE) algorithm which is valid to only approximately 70° down angle from the horizontal, and while it provides accurate predictions in the horizontal direction, it cannot predict sound levels directly under the array. The VSTACK model is used to determine the levels at the seafloor directly under the array, and due to seafloor interactions, these can be greater than those elsewhere in the water column.

Table 18. *3000 in³ source*: Maximum (R_{max}) horizontal distances (in m) from the seismic source to modelled seafloor (receiver located 50 cm above seafloor) peak pressure level thresholds (PK) at five water depths within the Operational Area.

Hearing group/animal type	PK threshold (L_{pk}; dB re 1 µPa)	Distance R_{max} (m)				
		75 m	100 m	125 m	150 m	200 m
Sound levels for sponges and corals[1]	226	*	*	*	*	*
Fish: No swim bladder (also applied to sharks)	213	76	65	56	50	44
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae	207	252	200	172	159	148

[1] Heyward et al. (2018)
An asterisk indicates that the sound level was not reached.

Table 19. *3000 in³ source*: Maximum (R_{max}) horizontal distances (in m) from the seismic source to modelled seafloor (receiver located 5 cm above seafloor) peak-peak pressure levels (PK-PK) at five water depths within the Operational Area. Results included in relation to benthic invertebrates.

PK-PK ($L_{pk\text{-}pk}$; dB re 1 µPa)	Distance R_{max} (m)				
	75 m	100 m	125 m	150 m	200 m
213[1,2,3]	241	259	214	185	132
212[2,3]	252	280	300	230	170
210[1,2]	267	302	320	336	220
209[1,2]	292	315	351	368	281
202[4]	307	340	365	394	426

[1] Day et al. (2019), lobster
[2] Day et al. (2016a), lobster and scallops
[3] Day et al. (2017), scallops.
[4] Payne et al. (2008), lobster

5.2.2. Sound Field Maps and Graphs

5.2.2.1. Sound Level Contour Maps

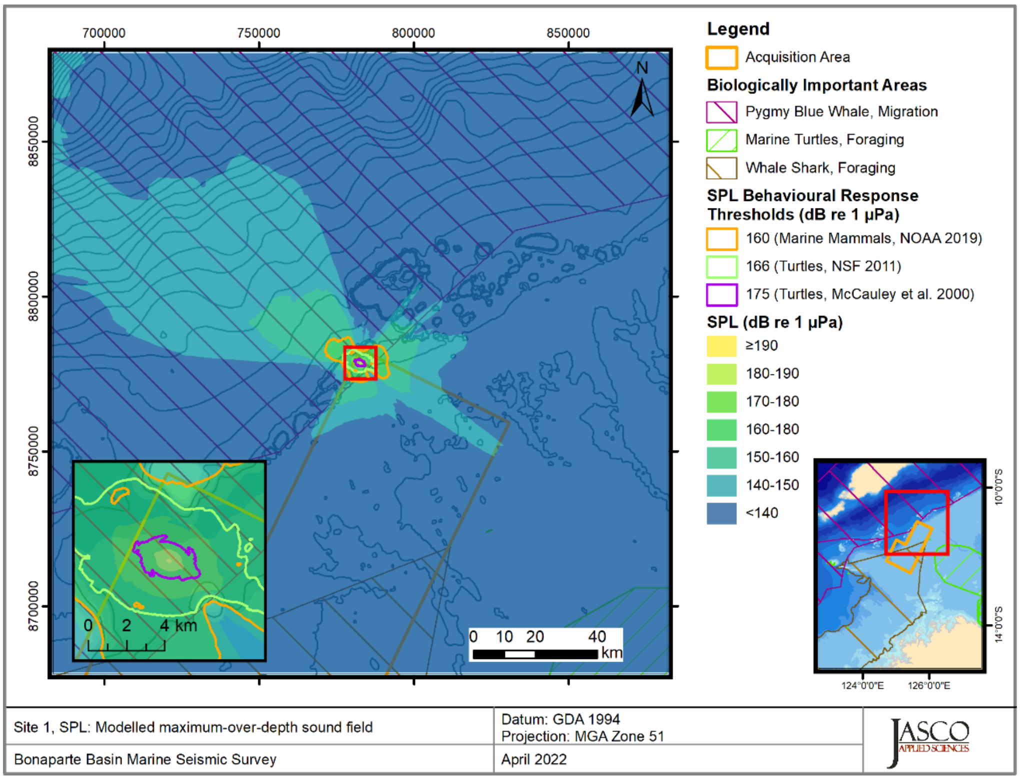


Figure 7. *Site 1, SPL, 3000 in³ source, tow azimuth 26°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

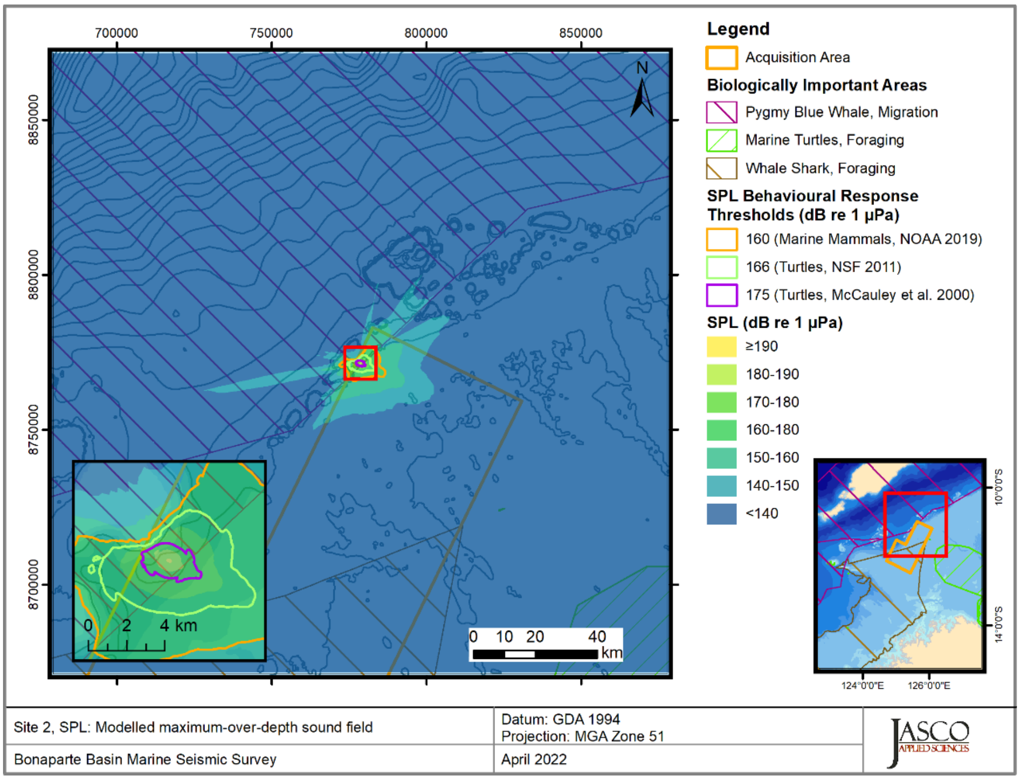


Figure 8. *Site 2, SPL, 3000 in³ source, tow azimuth 26°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

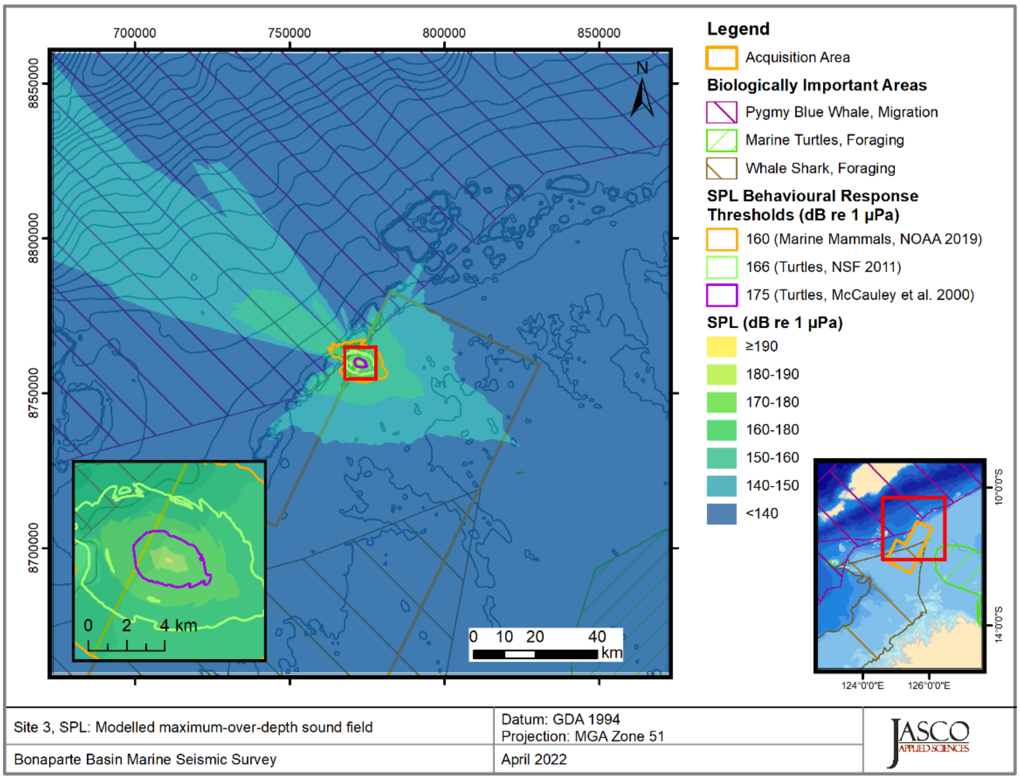


Figure 9. *Site 3, SPL, 3000 in³ source, tow azimuth 26°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

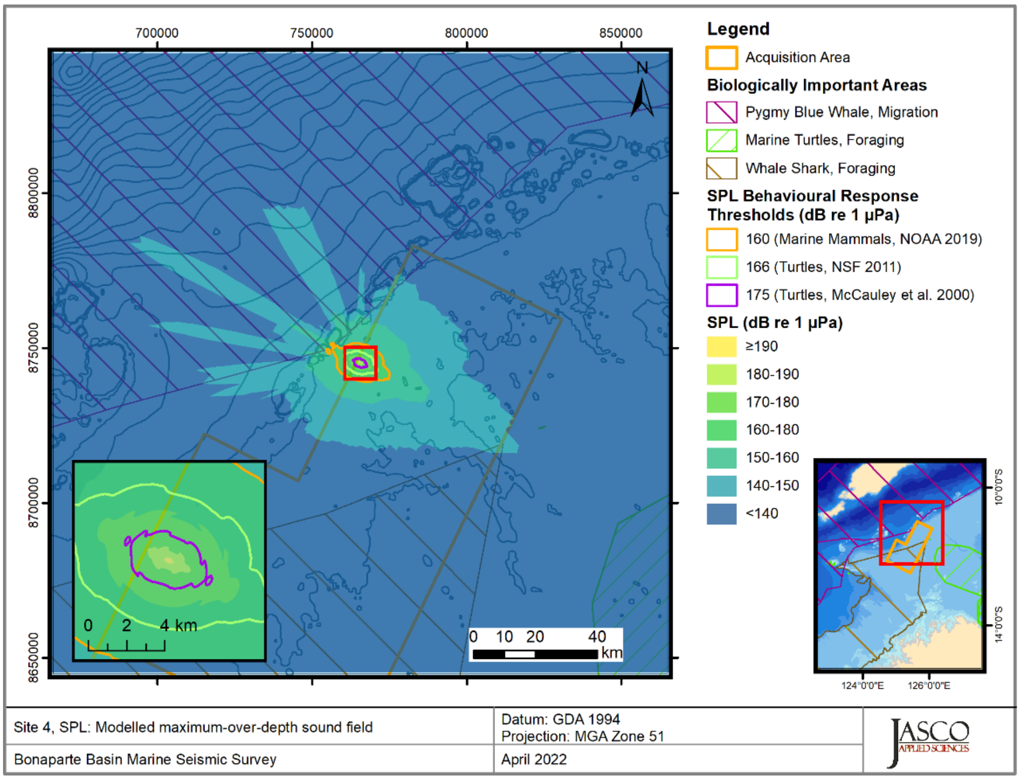


Figure 10. *Site 4, SPL, 3000 in³ source, tow azimuth 26°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

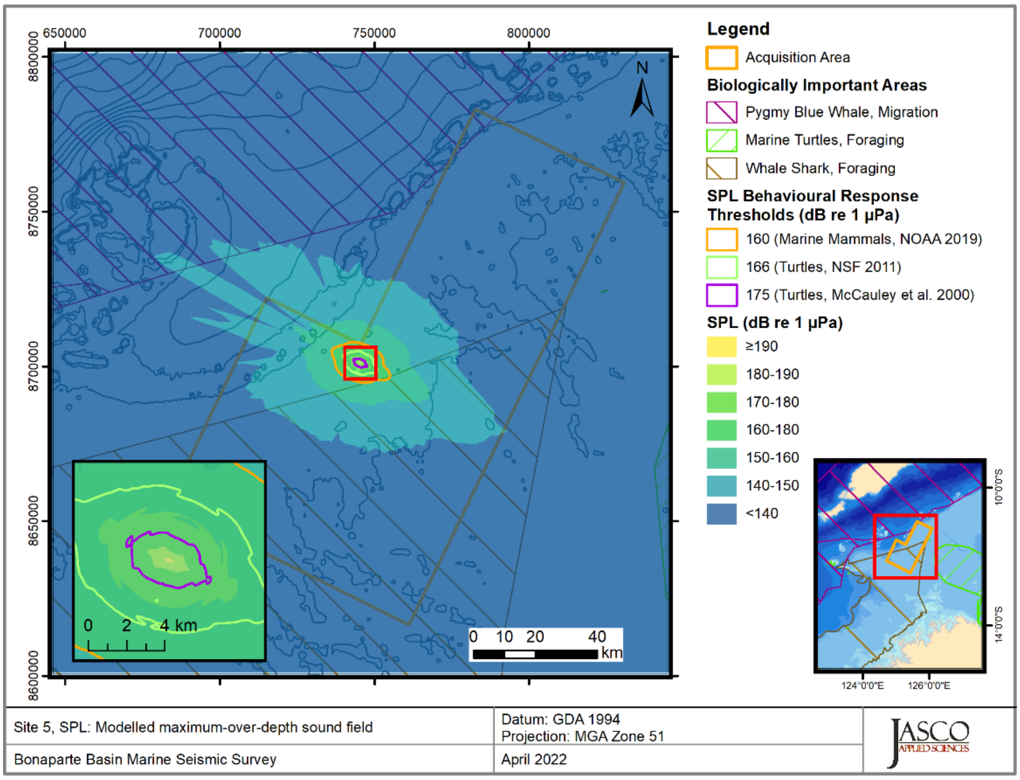


Figure 11. *Site 5, SPL, 3000 in³ source, tow azimuth 26°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

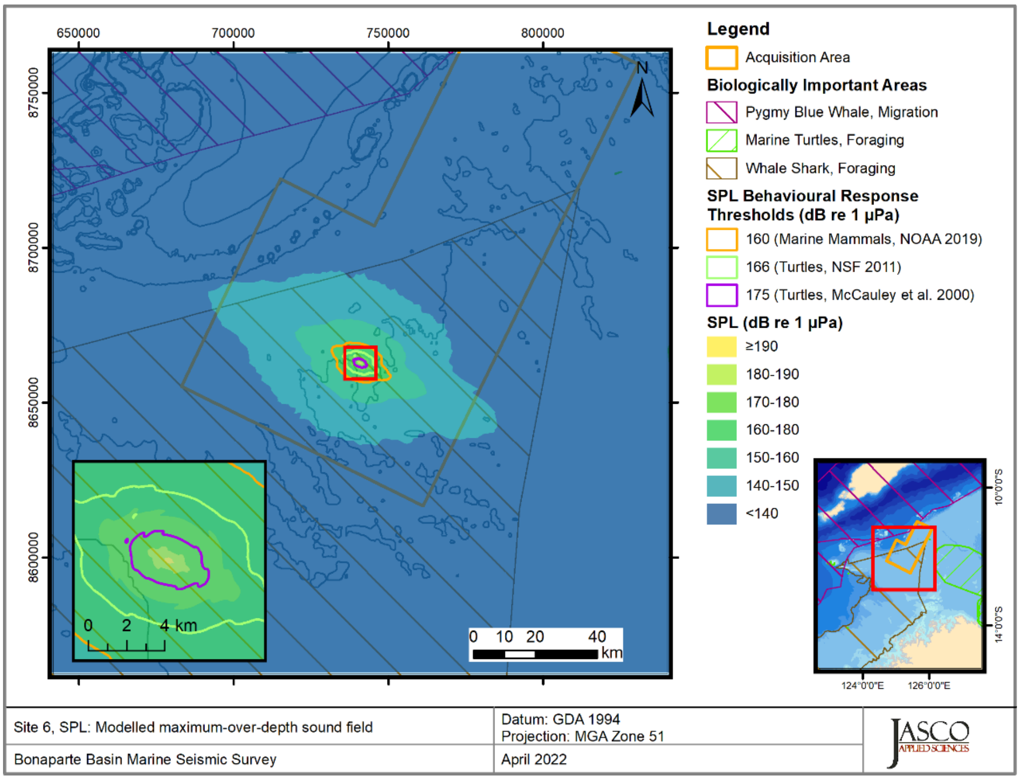


Figure 12. *Site 6, SPL, 3000 in³ source, tow azimuth 26*°: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

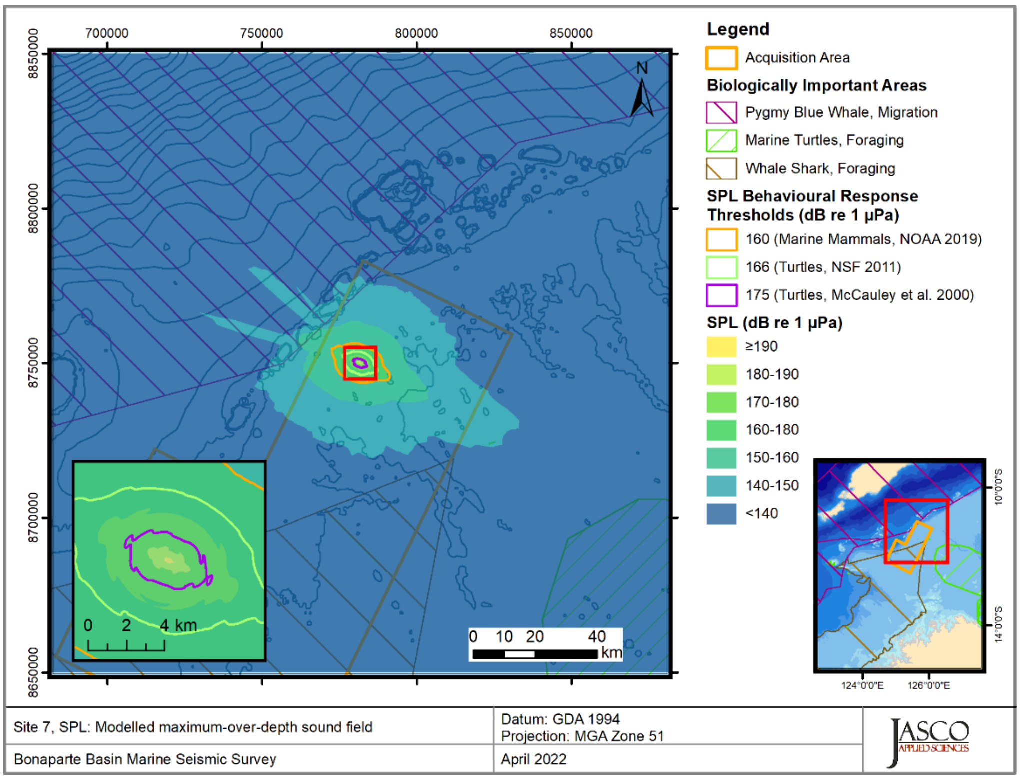


Figure 13. *Site 7, SPL, 3000 in³ source, tow azimuth 26*°: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

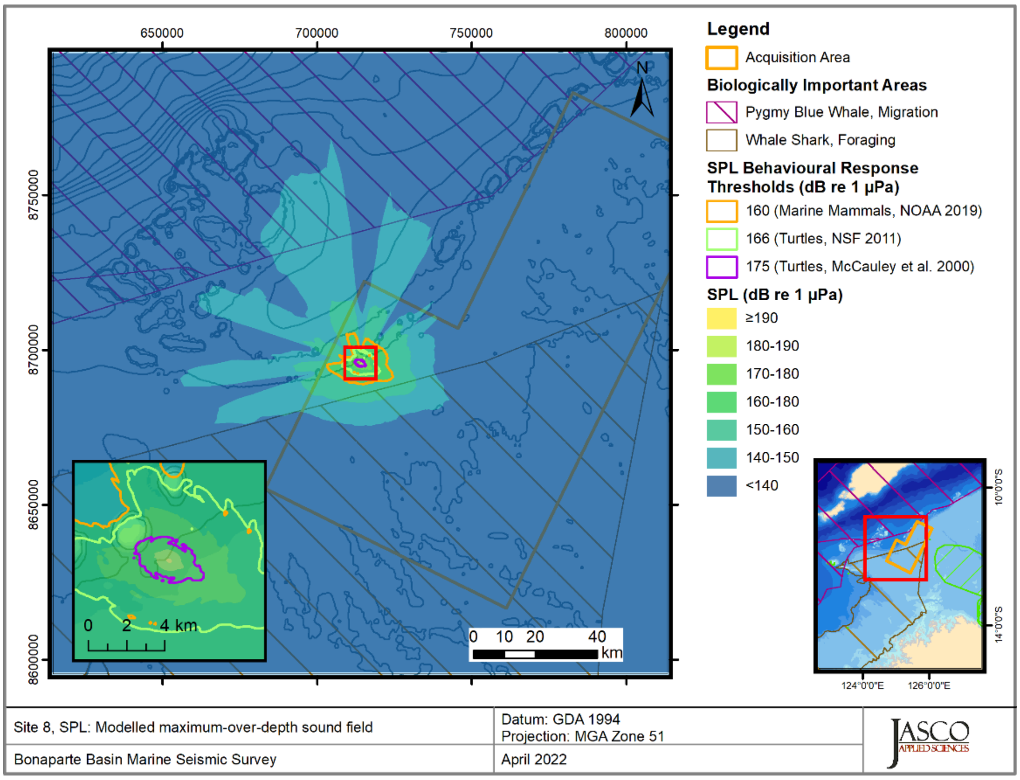


Figure 14. *Site 8, SPL, 3000 in³ source, tow azimuth 26°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

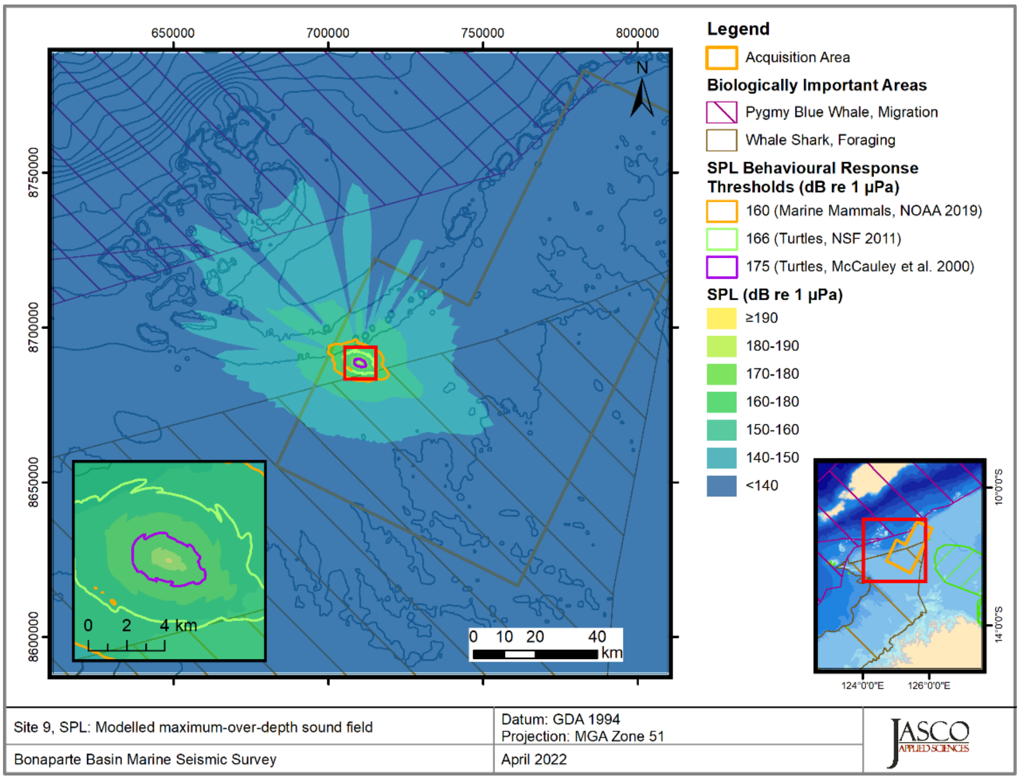


Figure 15. *Site 9, SPL, 3000 in³ source, tow azimuth 26°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

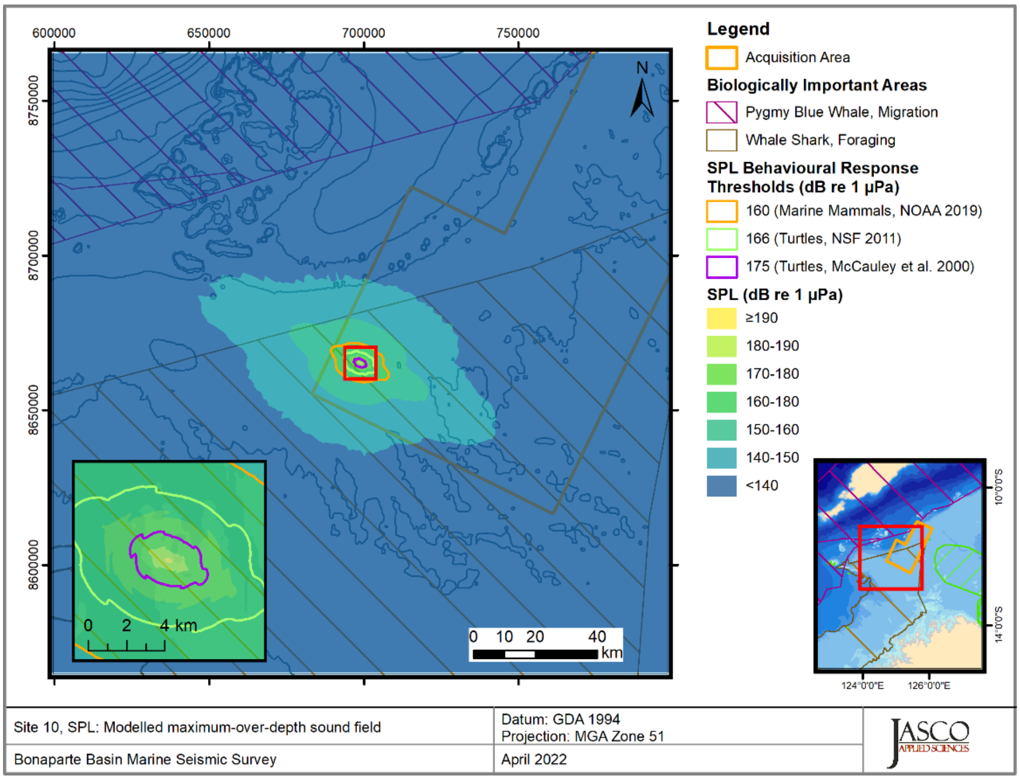


Figure 16. *Site 10, SPL, 3000 in³ source, tow azimuth 26°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

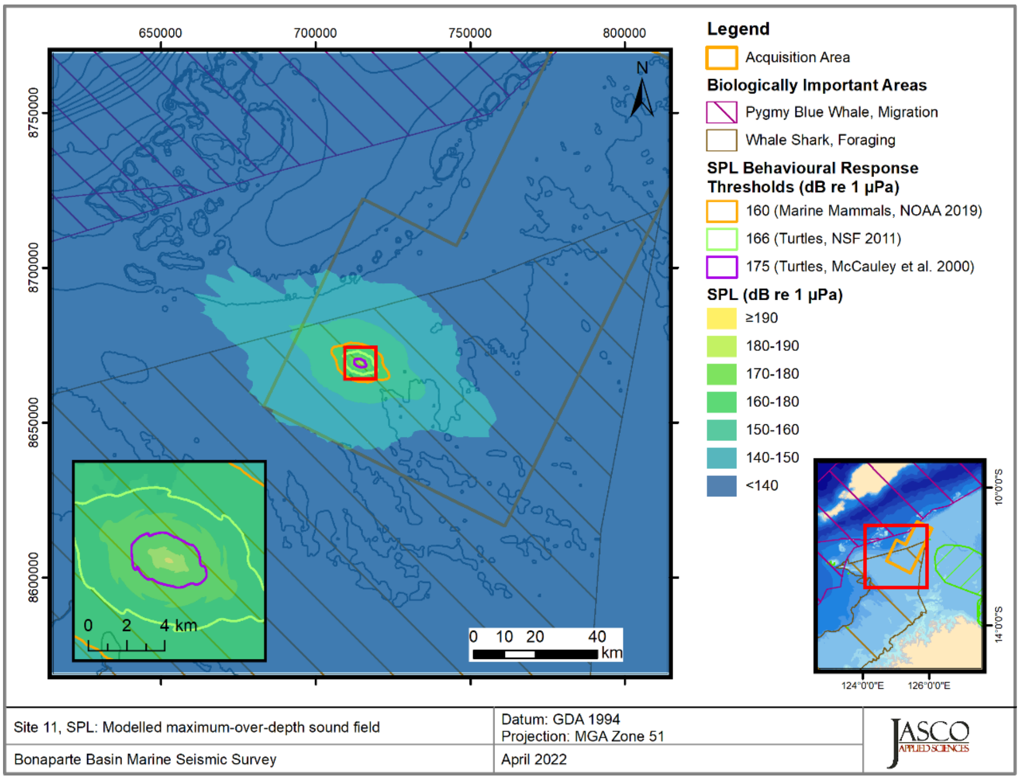


Figure 17. *Site 11, SPL, 3000 in³ source, tow azimuth 26°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

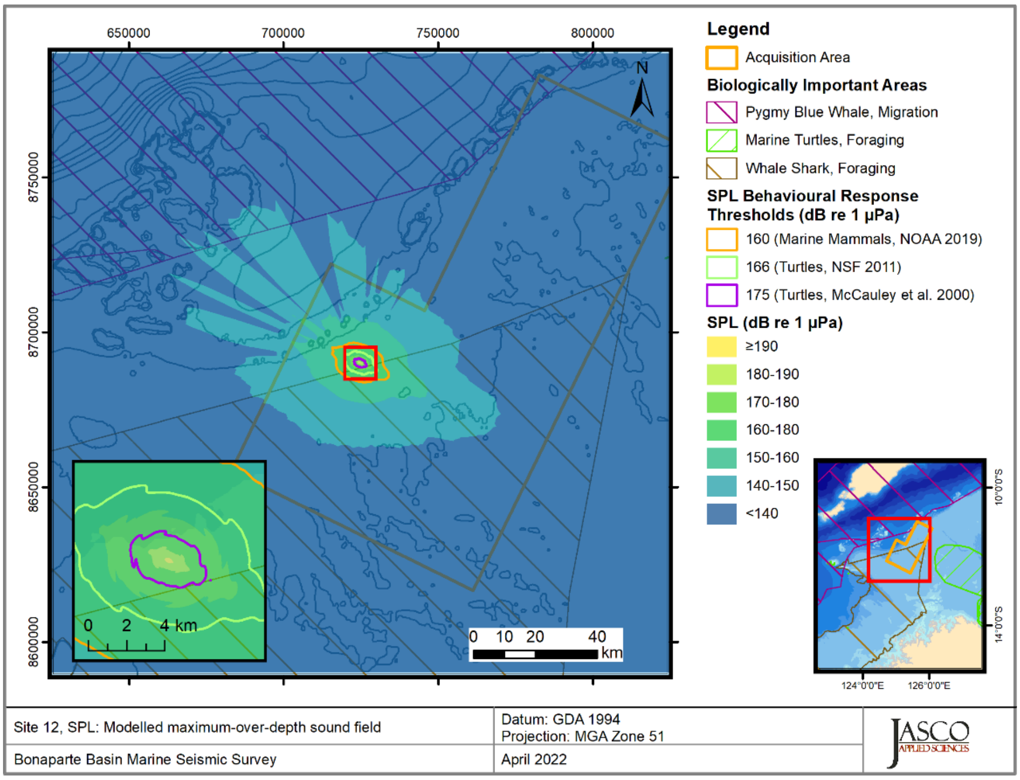


Figure 18. *Site 12, SPL, 3000 in³ source, tow azimuth 26°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

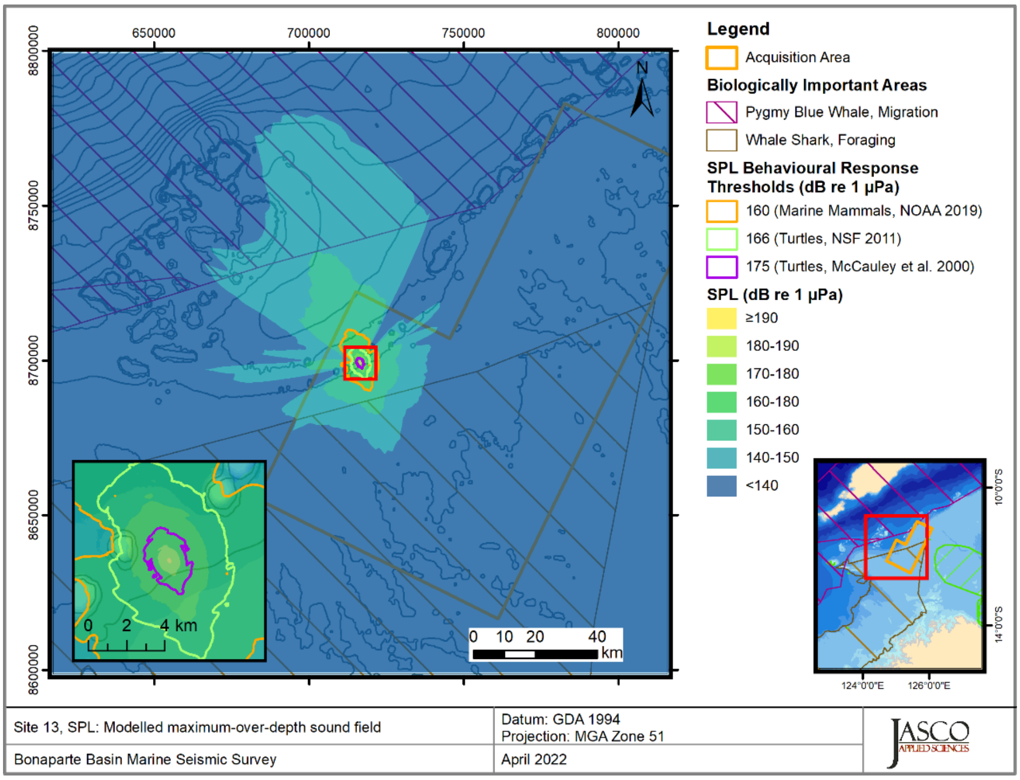


Figure 19. *Site 13, SPL, 3000 in³ source, tow azimuth 71°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

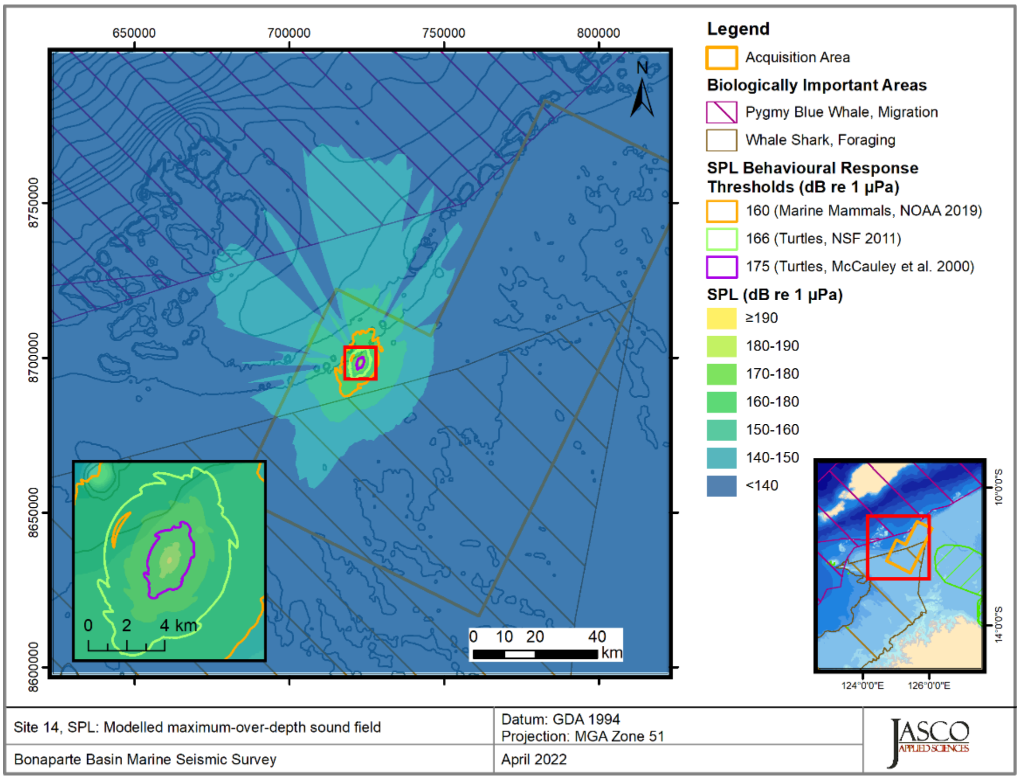


Figure 20. *Site 14, SPL, 3000 in³ source, tow azimuth 116°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

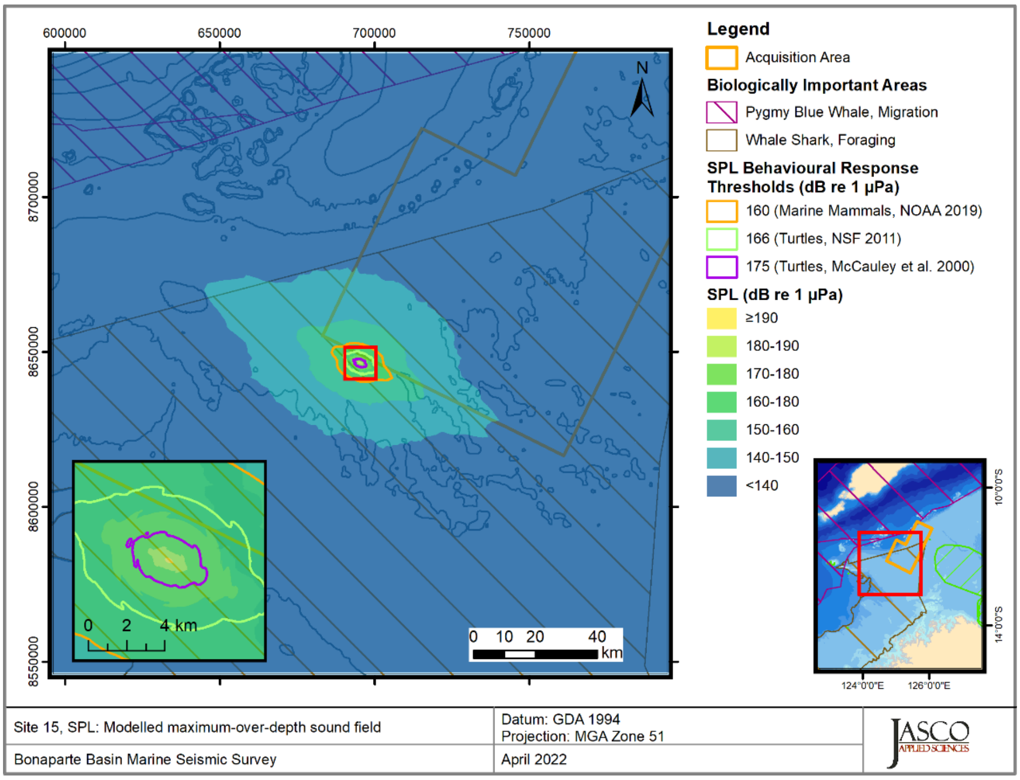


Figure 21. *Site 15, SPL, 3000 in³ source, tow azimuth 26°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

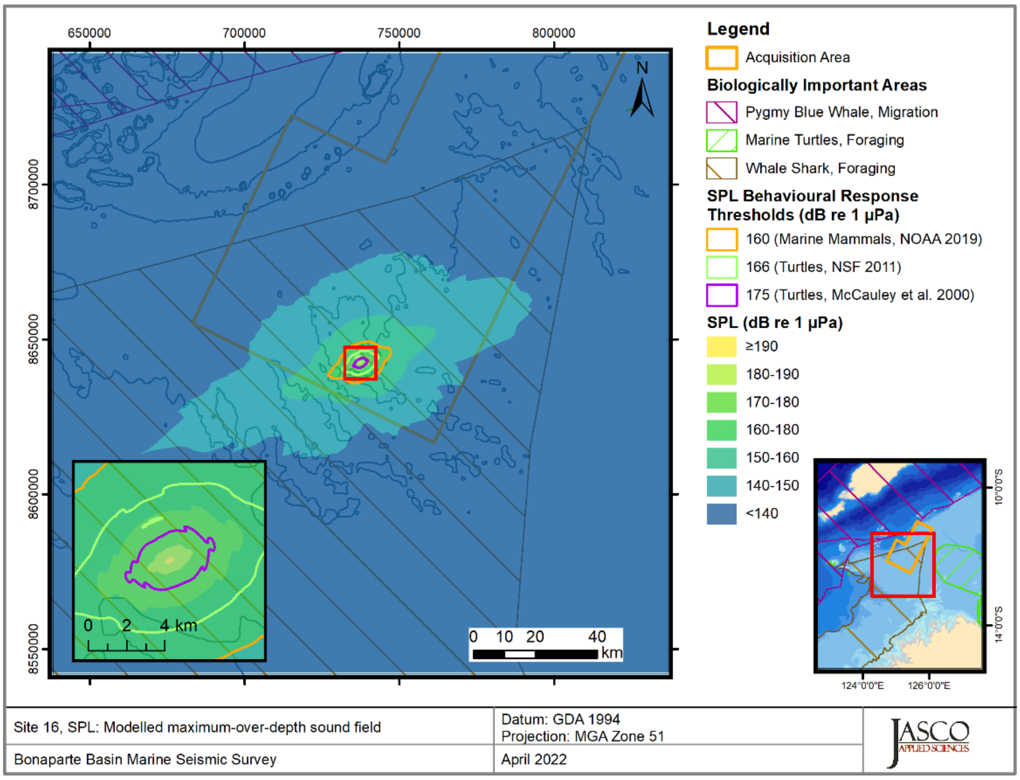


Figure 22. *Site 16, SPL, 3000 in³ source, tow azimuth 159°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

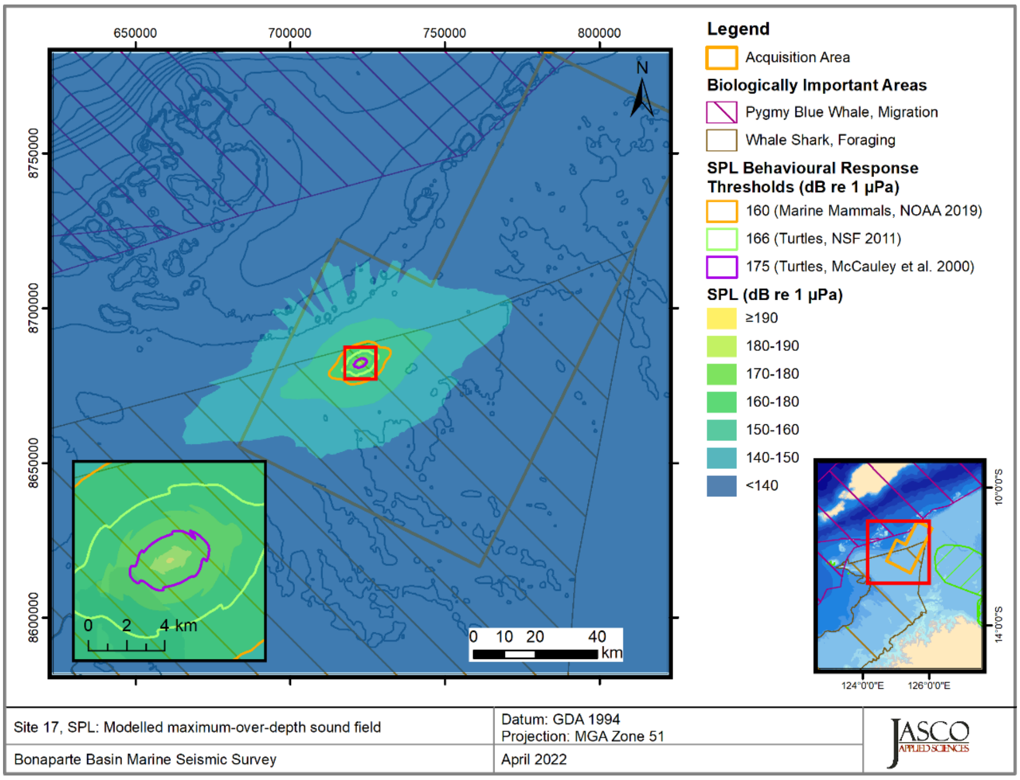


Figure 23. *Site 17, SPL, 3000 in³ source, tow azimuth 159°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

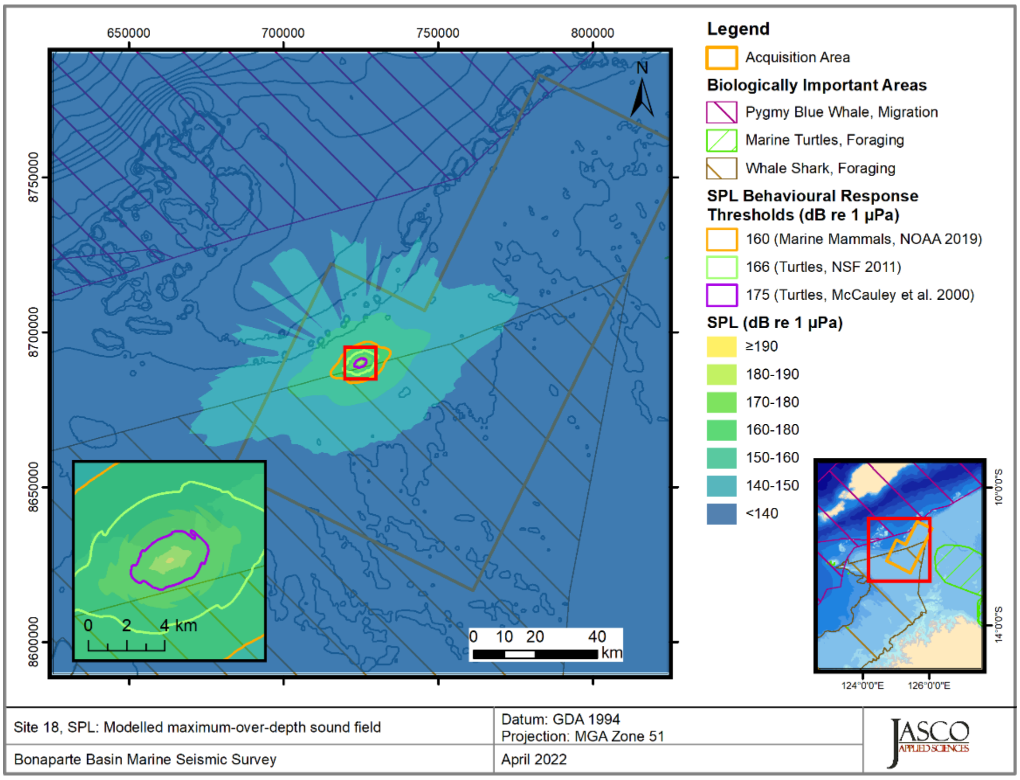


Figure 24. *Site 18, SPL, 3000 in³ source, tow azimuth 159°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

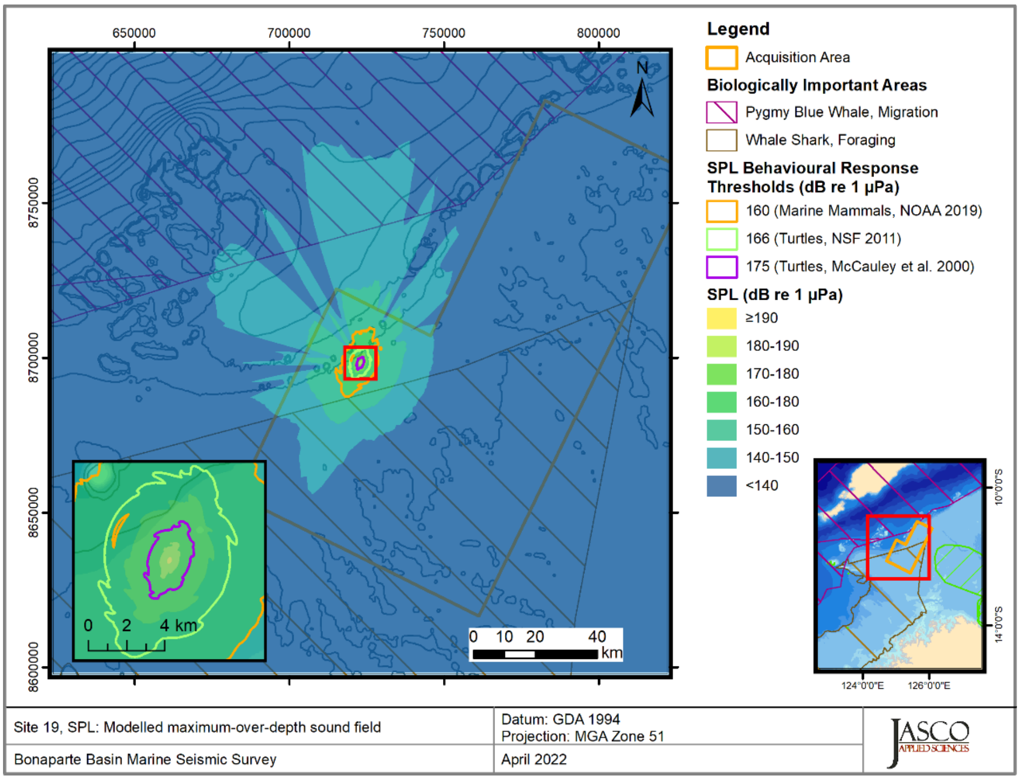


Figure 25. *Site 19, SPL, 3000 in³ source, tow azimuth 114°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

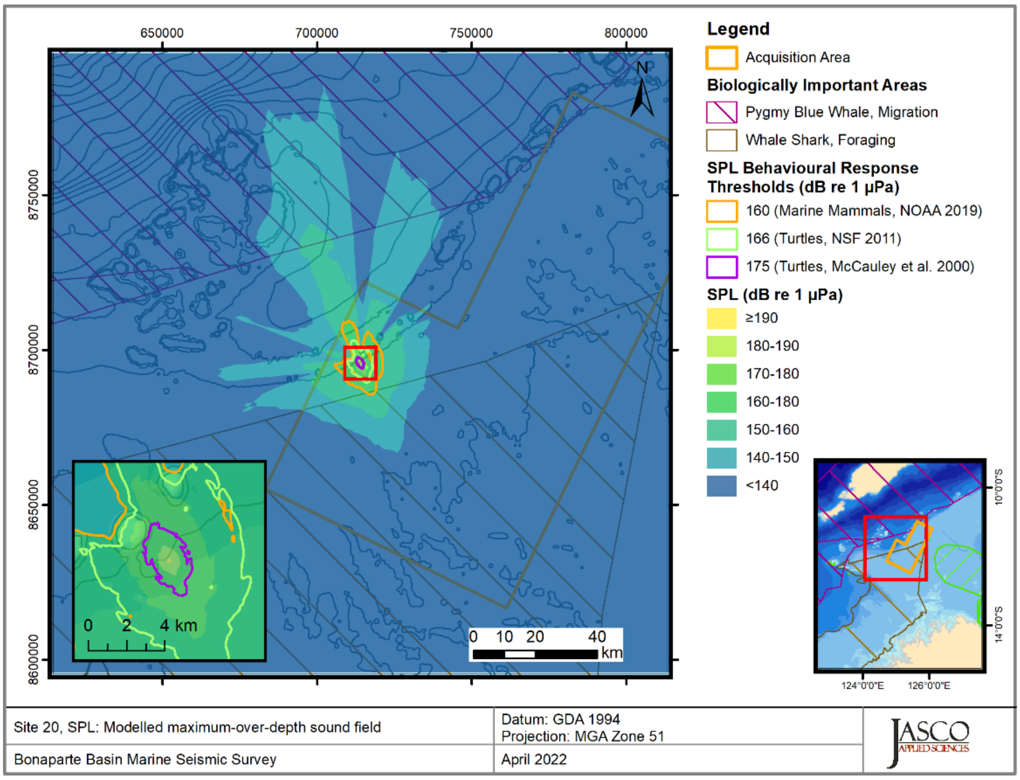


Figure 26. *Site 20, SPL, 3000 in³ source, tow azimuth 69°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

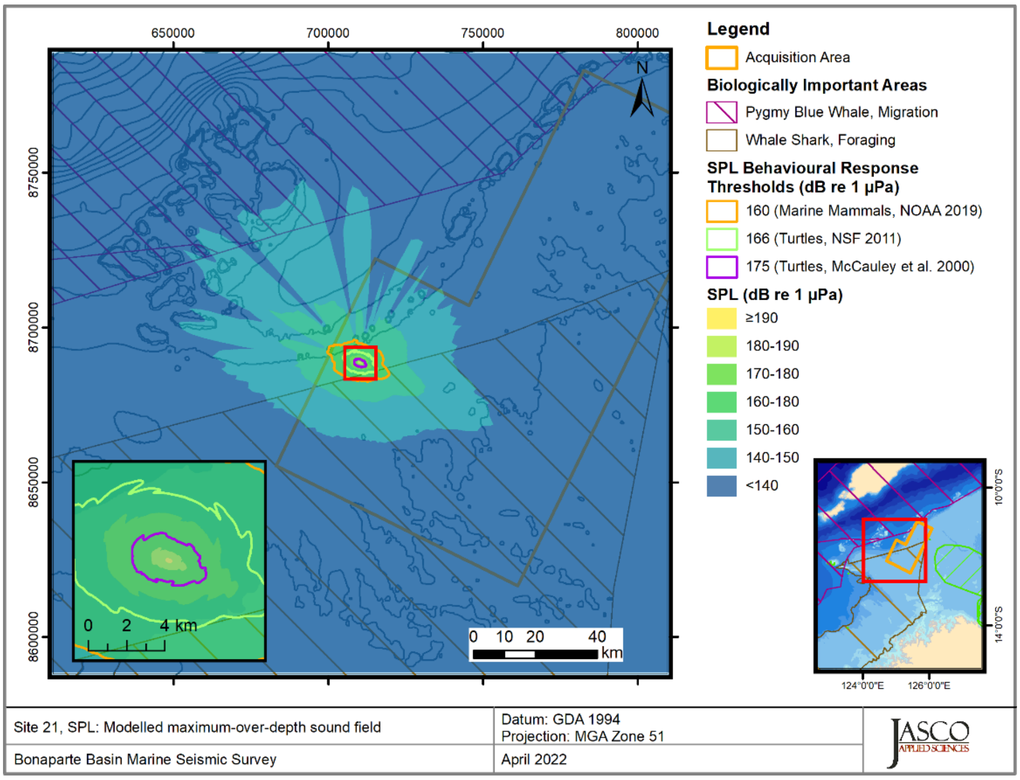


Figure 27. *Site 21, SPL, 3000 in³ source, tow azimuth 24°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

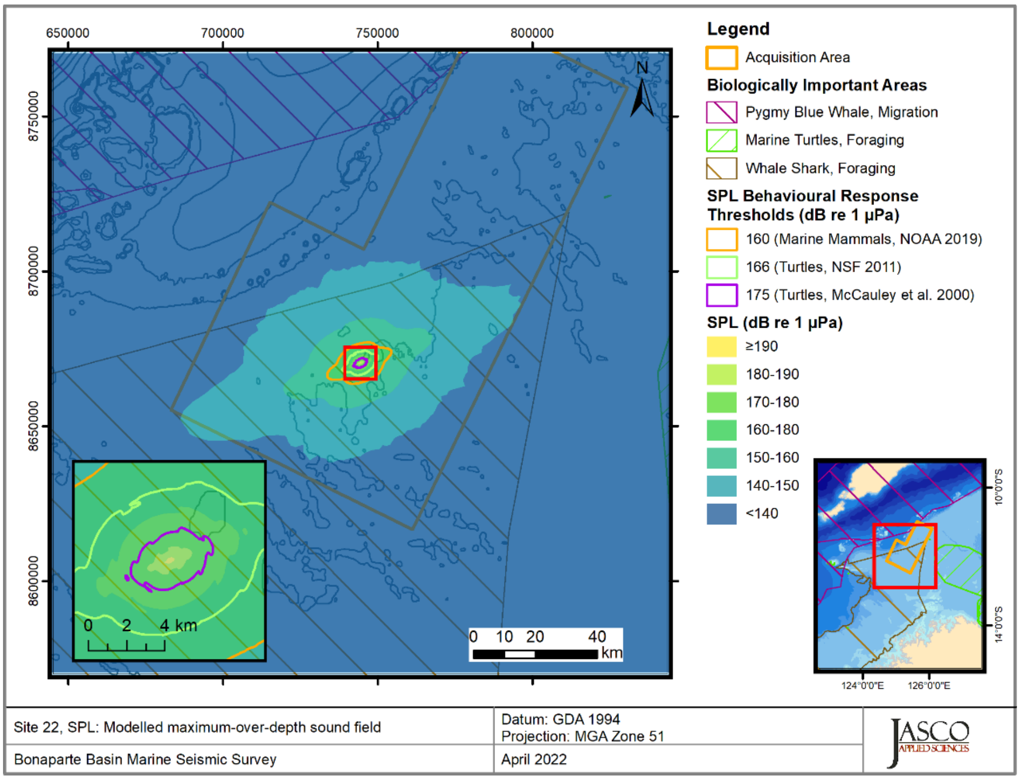


Figure 28. *Site 22, SPL, 3000 in³ source, tow azimuth 159°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

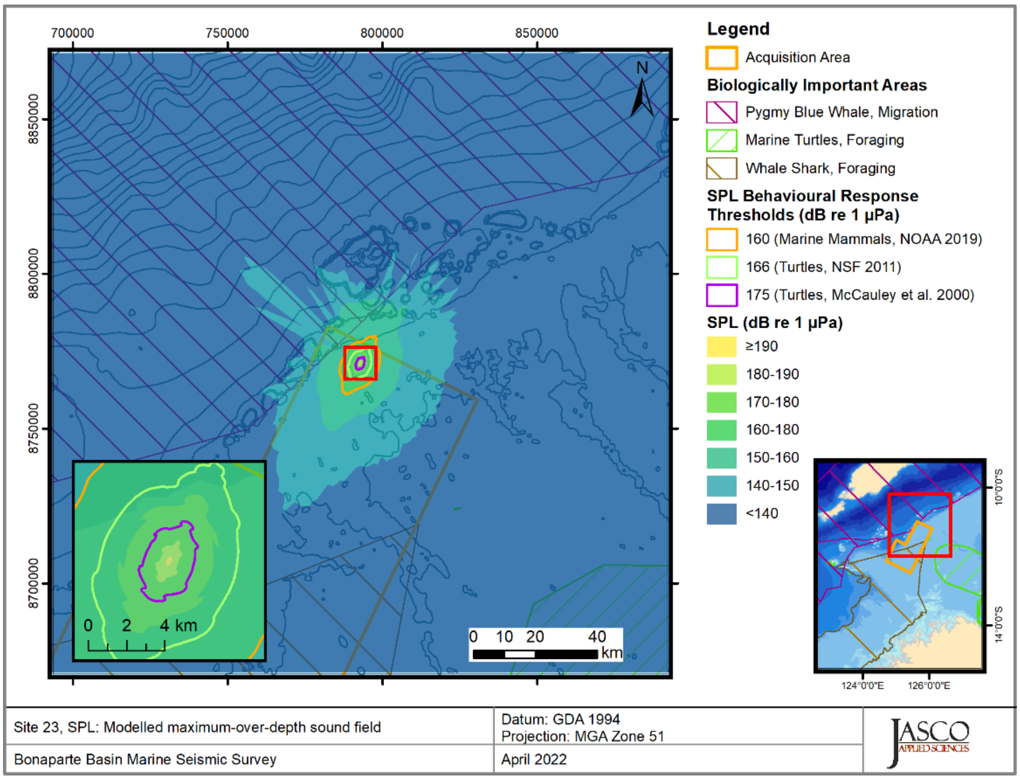


Figure 29. *Site 23, SPL, 3000 in³ source, tow azimuth 296°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

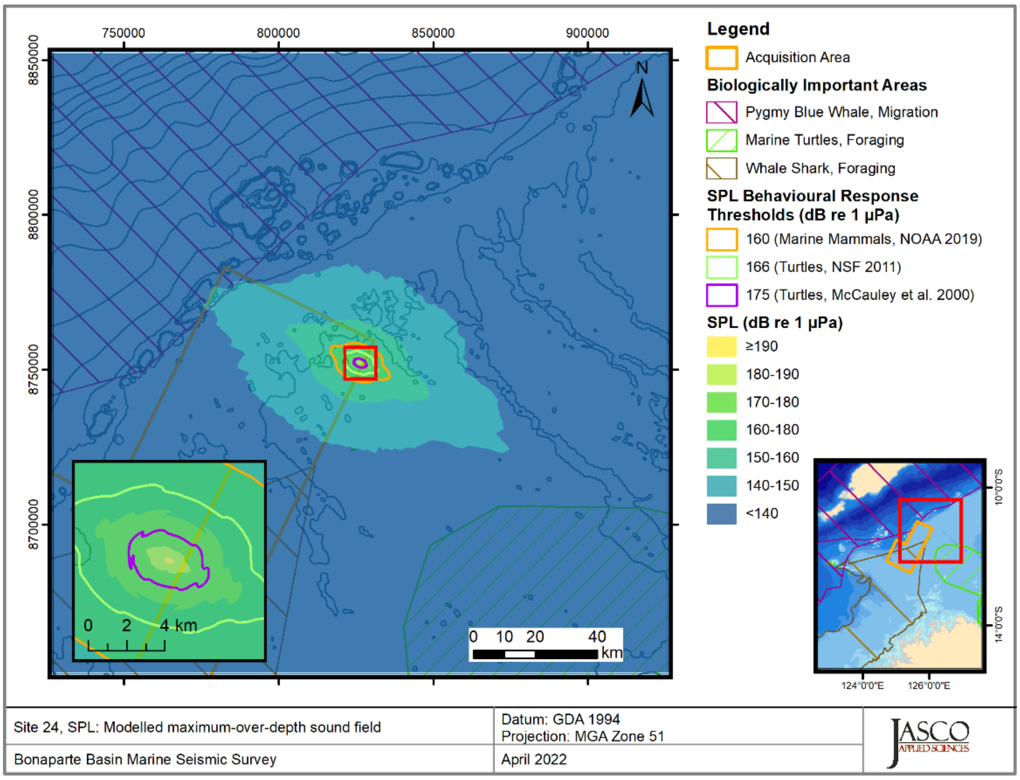


Figure 30. *Site 24, SPL, 3000 in³ source, tow azimuth 116°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

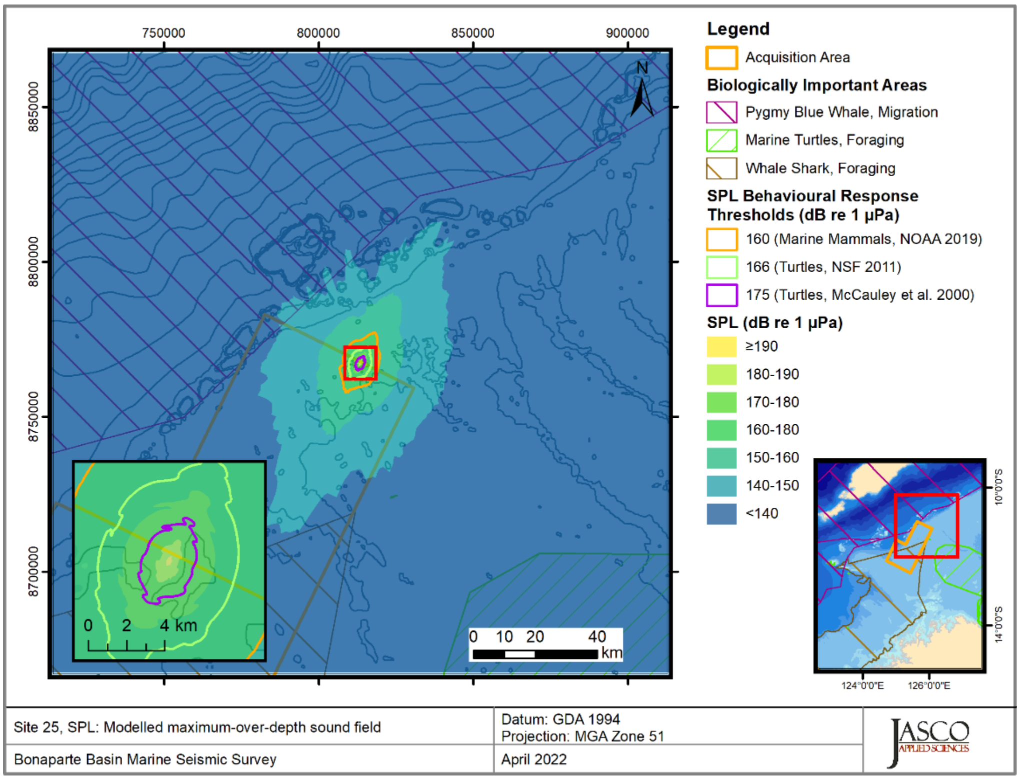


Figure 31. *Site 25, SPL, 3000 in³ source, tow azimuth 296°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

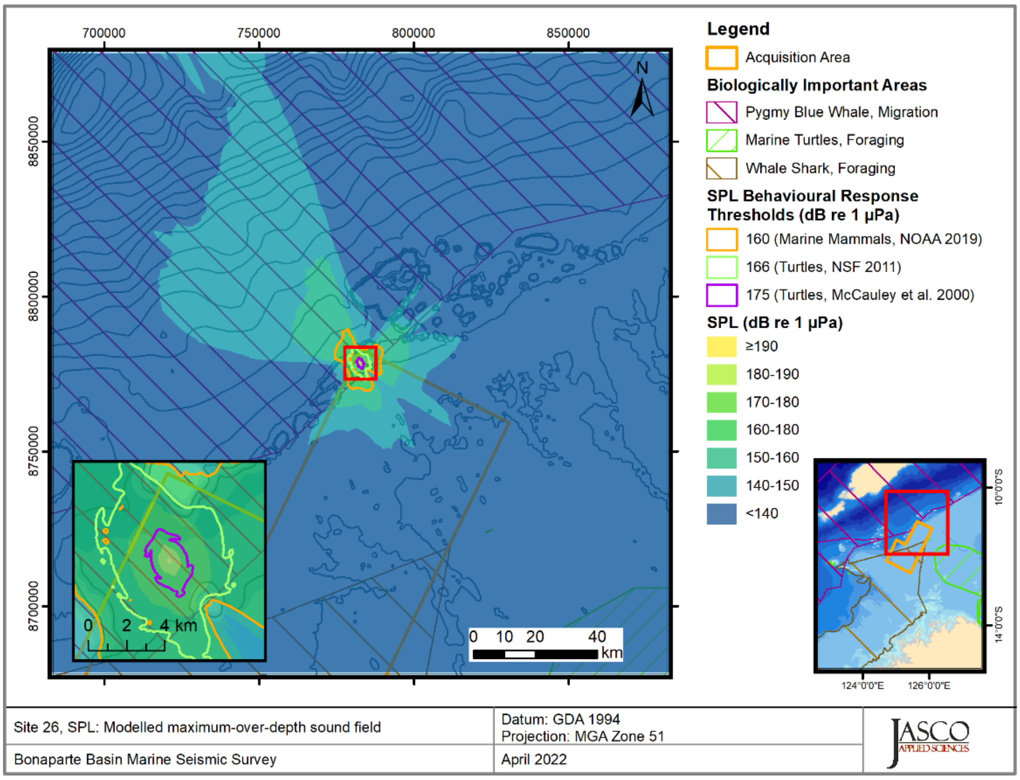


Figure 32. *Site 26, SPL, 3000 in³ source, tow azimuth 251°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

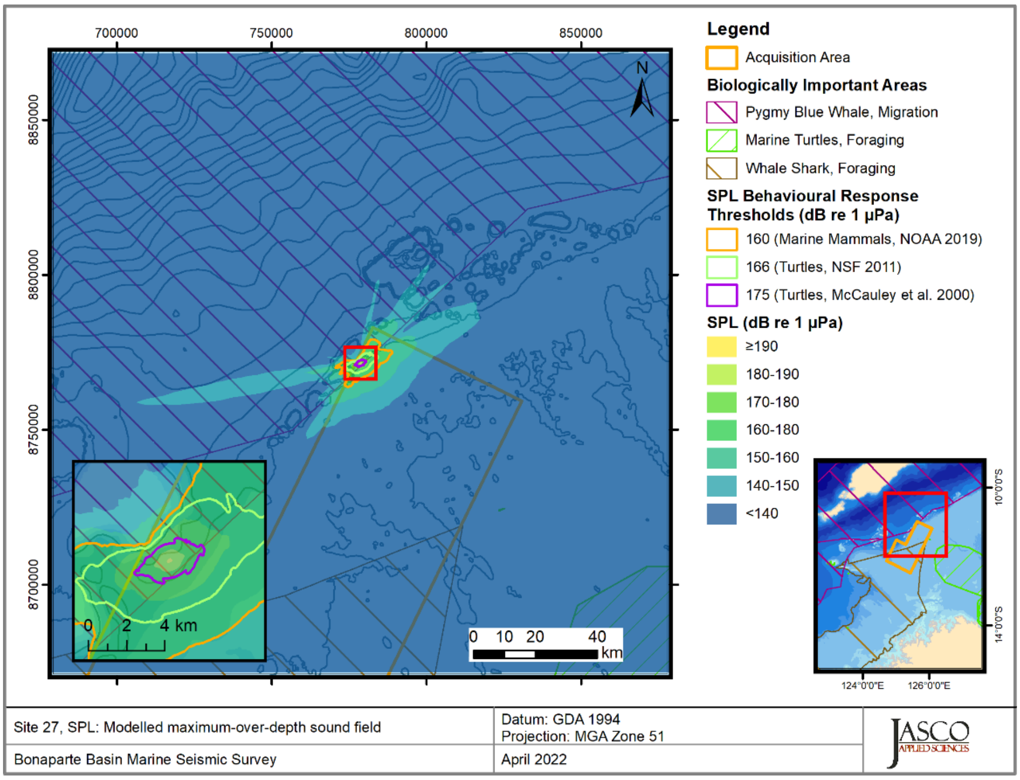


Figure 33. *Site 27, SPL, 3000 in³ source, tow azimuth 161°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

5.2.2.2. Vertical Slices of Modelled Sound Fields

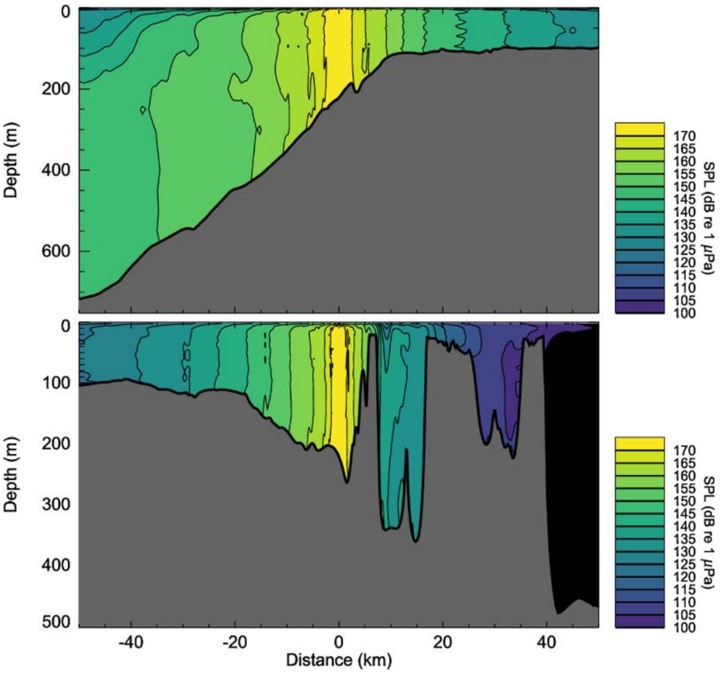


Figure 34. *Site 1, SPL, 3000 in³ source, tow azimuth 26°*: Sound level contours in vertical slice of the sound field , perpendicular to (broadside, top) and along the tow direction (endfire, bottom). The positive distance direction in each slice is 90° clockwise from the tow azimuth for broadside, and the tow azimuth for the endfire slice.

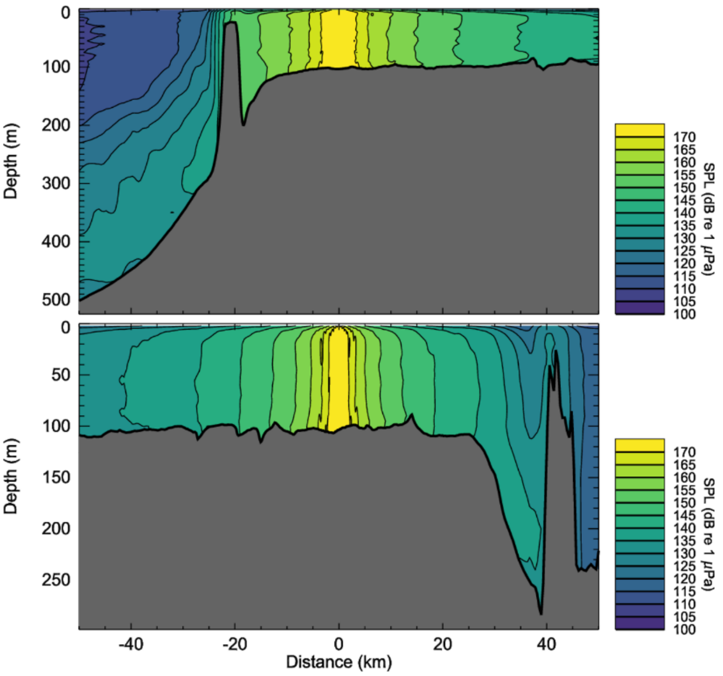


Figure 35. *Site 7, SPL, 3000 in³ source, tow azimuth 26°*: Sound level contours in vertical slice of the sound field , perpendicular to (broadside, top) and along the tow direction (endfire, bottom). The positive distance direction in each slice is 90° clockwise from the tow azimuth for broadside, and the tow azimuth for the endfire slice.

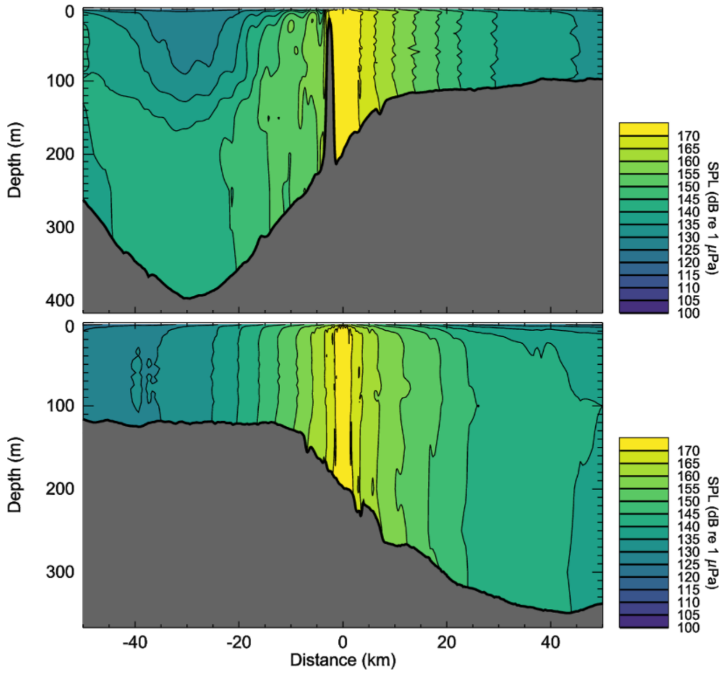


Figure 36. *Site 8, SPL, 3000 in³ source, tow azimuth 26°*: Sound level contours in vertical slice of the sound field , perpendicular to (broadside, top) and along the tow direction (endfire, bottom). The positive distance direction in each slice is 90° clockwise from the tow azimuth for broadside, and the tow azimuth for the endfire slice.

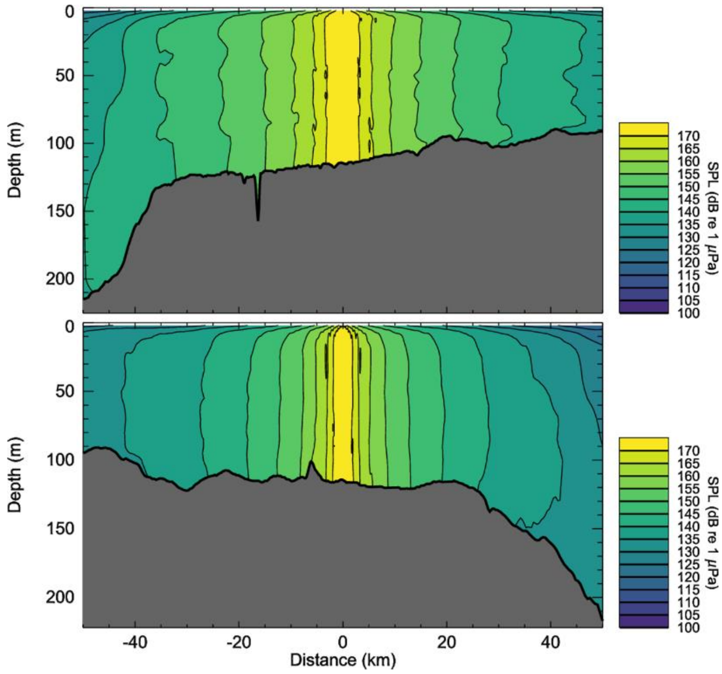


Figure 37. *Site 11, SPL, 3000 in³ source, tow azimuth 26°*: Sound level contours in vertical slice of the sound field , perpendicular to (broadside, top) and along the tow direction (endfire, bottom). The positive distance direction in each slice is 90° clockwise from the tow azimuth for broadside, and the tow azimuth for the endfire slice.

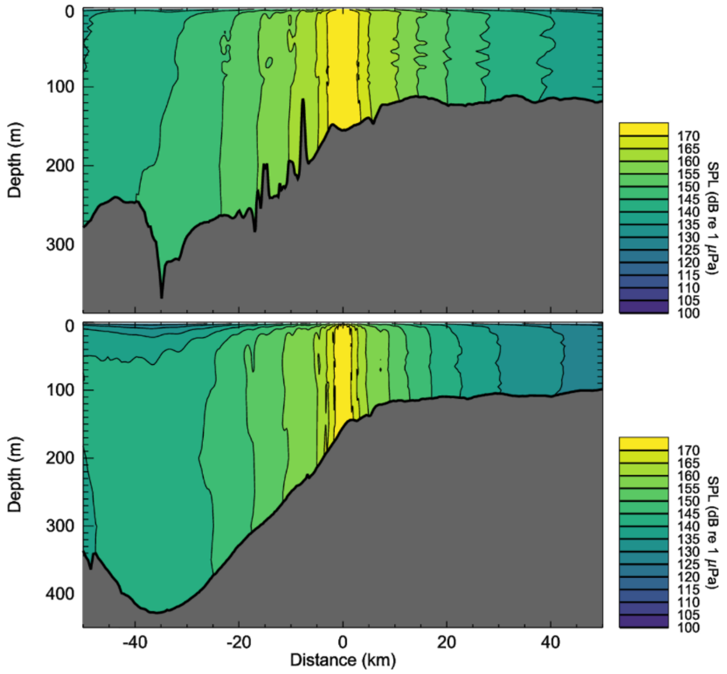


Figure 38. *Site 14, SPL, 3000 in³ source, tow azimuth 116*°: Sound level contours in vertical slice of the sound field , perpendicular to (broadside, top) and along the tow direction (endfire, bottom). The positive distance direction in each slice is 90° clockwise from the tow azimuth for broadside, and the tow azimuth for the endfire slice.

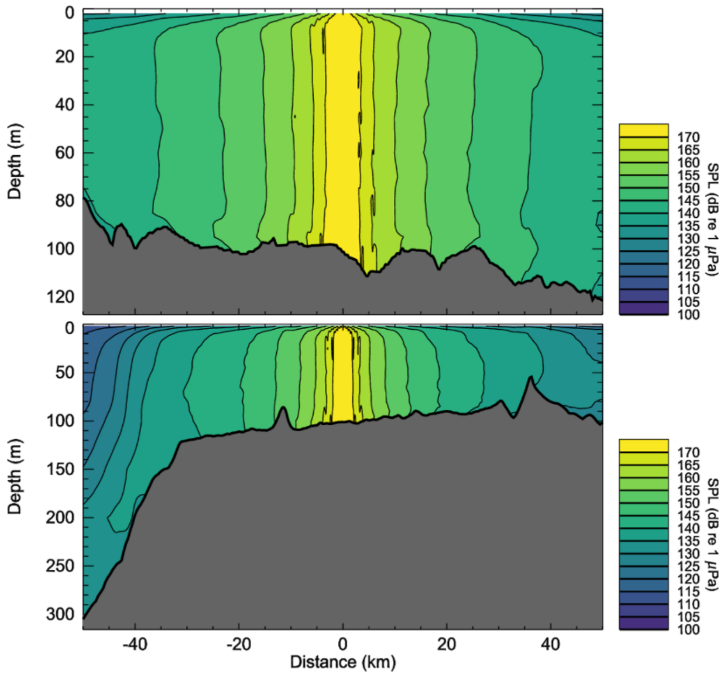


Figure 39. *Site 22, SPL, 3000 in³ source, tow azimuth 159*°: Sound level contours in vertical slice of the sound field , perpendicular to (broadside, top) and along the tow direction (endfire, bottom). The positive distance direction in each slice is 90° clockwise from the tow azimuth for broadside, and the tow azimuth for the endfire slice.

5.2.3. Particle Motion

Figures 40–42 show modelled maximum particle acceleration as a function of horizontal range in four perpendicular directions from the centre of the 3000 in³ seismic source at water depths of 75, 100, and 150 m. The modelling considered a resolution of 10 m, and a receiver positioned 5 cm off the seafloor. The maximum distance to a particle acceleration 37.57 ms^{-2} is predicted to occur at 10.5 m for a water depth of 75 m and is not predicted to occur at any other water depths considered.

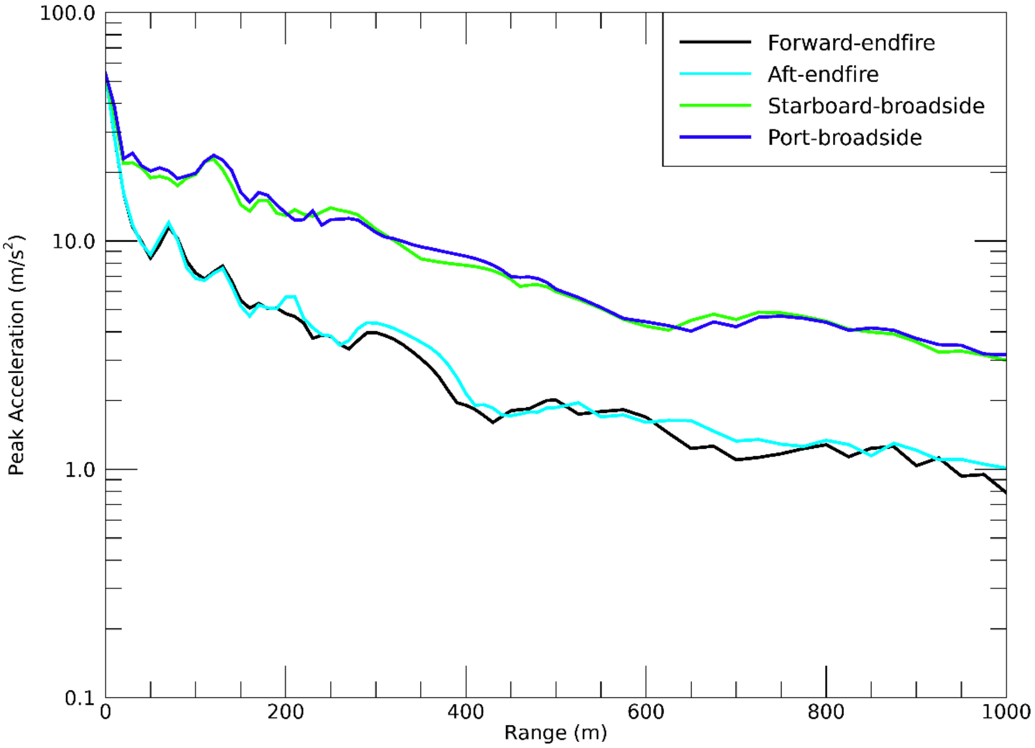


Figure 40. 3000 in^3 seismic source at 75 m water depth: Peak particle acceleration magnitude at the seafloor as a function of horizontal range from the centre of the seismic source along four directions.

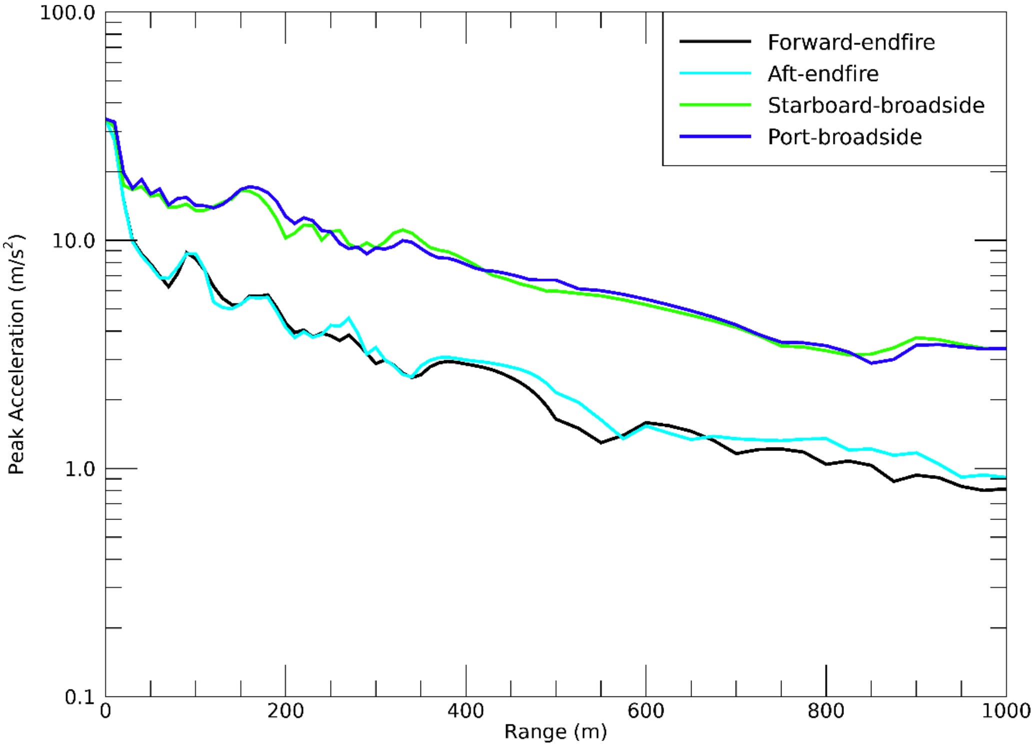


Figure 41. 3000 in^3 seismic source at 100 m water depth: Peak particle acceleration magnitude at the seafloor as a function of horizontal range from the centre of the seismic source along four directions.

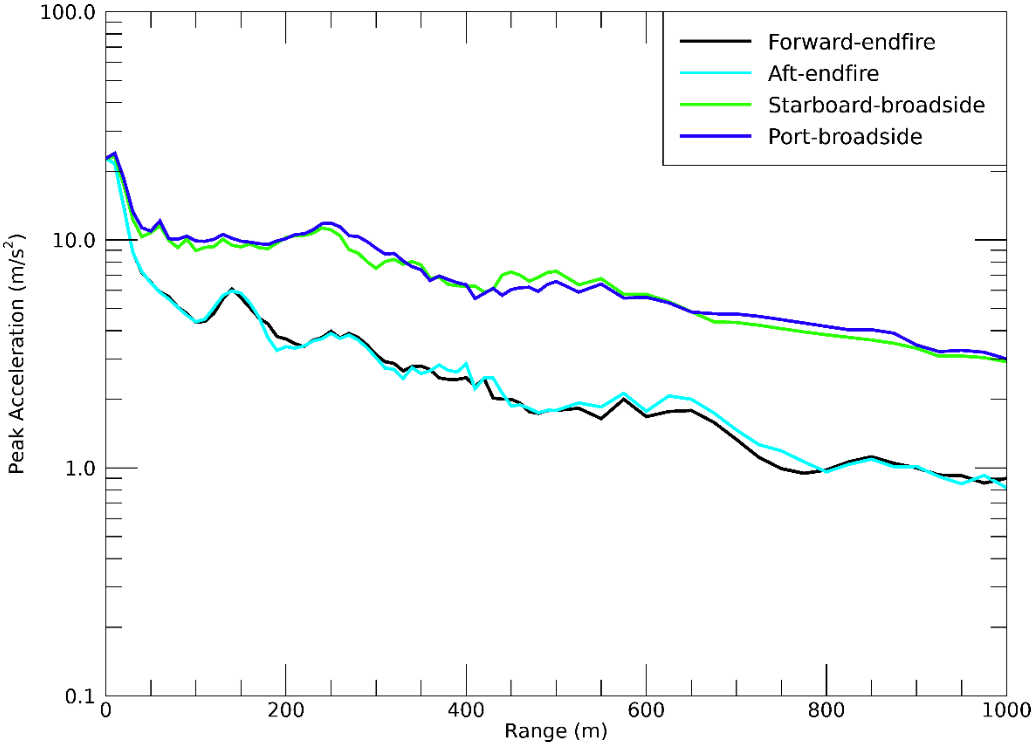


Figure 42. 3000 in^3 seismic source at 150 m water depth: Peak particle acceleration magnitude at the seafloor as a function of horizontal range from the centre of the seismic source along four directions.

5.3. Multiple Source Fields

This section presents the sound fields in terms of SEL accumulated over 24 h of survey, for the modelled scenarios (Section 2). Frequency-weighted SEL_{24h} sound fields were used to estimate the maximum horizontal distances (R_{max}) to marine mammal and sea turtle PTS and TTS thresholds (listed in Table 20), and to estimate maximum distance and the area for injury and TTS guidelines for fish (Tables 21–24).

The SEL_{24h} sound fields are presented as contour maps in Figures 43–50. These figures present the unweighted SEL_{24h} in 10 dB steps, as well as the isopleths corresponding to thresholds or guidelines for which R_{max} is greater than 20 m.

5.3.1. Tabulated Results

Table 20. Maximum-over-depth distances (in km) to frequency-weighted 24 h sound exposure level (SEL_{24h}) based permanent threshold shift (PTS) and temporary threshold shift (TTS) for marine mammals Southall et al. (2019b) and sea turtles (Finneran et al. 2017) using the 3000 in^3 seismic source for all scenarios. Maximum extents are in the broadside direction.

Hearing group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
PTS									
LF cetaceans	183	6.28	869	5.75	997	6.11	1173	6.84	1047
HF cetaceans	185	–	–	–	–	–	–	–	–
VHF cetaceans	155	0.08	3.04	0.08	3.64	0.08	3.58	0.08	3.48
Sea turtles	204	0.08	3.04	0.08	3.64	0.08	3.77	0.08	3.79
Sirenians	190	–	–	–	–	–	–	–	–
TTS									
LF cetaceans	168	40.6	7327	47.5	6076	45.0	6885	38.9	5588
HF cetaceans	170	0.08	1.81	0.08	2.15	0.08	2.29	0.07	2.12
VHF cetaceans	140	0.18	59.1	0.50	129	0.45	111	0.41	110
Sea turtles	189	1.82	479	5.75	759	6.11	691	5.37	585
Sirenians	175	0.08	2.55	0.08	2.63	0.08	2.90	0.08	2.67

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 21. *Scenario 1*, Distances to 24 hour sound exposure level (SEL_{24h}) based fish criteria in the water column and at the seafloor for the 3000 in^3 seismic source.

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Maximum-over-depth		Seafloor	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
Mortality and potential mortal injury					
I	219	0.08	3.04	*	*
II, fish eggs and fish larvae	210	0.08	3.04	*	*
III	207	0.08	3.04	*	*
Fish recoverable injury					
I	216	0.08	3.04	*	*
II, III	203	0.10	8.65	*	*
Fish temporary threshold shift (TTS)					
I, II, III	186	6.48	2290	6.48	2242

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.

Table 22. *Scenario 2*, Distances to 24 hour sound exposure level (SEL_{24h}) based fish criteria in the water column and at the seafloor for the 3000 in^3 seismic source.

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Maximum-over-depth		Seafloor	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
Mortality and potential mortal injury					
I	219	0.08	3.18	*	*
II, fish eggs and fish larvae	210	0.08	3.64	*	*
III	207	0.08	3.64	*	*
Fish recoverable injury					
I	216	0.08	3.64	*	*
II, III	203	0.10	10.7	*	*
Fish temporary threshold shift (TTS)					
I, II, III	186	10.5	1460	9.31	1423

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.

Table 23. *Scenario 3*, Distances to 24 hour sound exposure level (SEL_{24h}) based fish criteria in the water column and at the seafloor for the 3000 in^3 seismic source.

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Maximum-over-depth		Seafloor	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
Mortality and potential mortal injury					
I	219	0.08	3.44	*	*
II, fish eggs and fish larvae	210	0.08	3.76	*	*
III	207	0.08	3.77	*	*
Fish recoverable injury					
I	216	0.08	3.54	*	*
II, III	203	0.10	10.6	*	*
Fish temporary threshold shift (TTS)					
I, II, III	186	8.35	1686	8.16	1650

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.

Table 24. *Scenario 4*, Distances to 24 hour sound exposure level (SEL_{24h}) based fish criteria in the water column and at the seafloor for the 3000 in^3 seismic source.

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Maximum-over-depth		Seafloor	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
Mortality and potential mortal injury					
I	219	0.08	3.38	*	*
II, fish eggs and fish larvae	210	0.08	3.79	*	*
III	207	0.08	3.79	*	*
Fish recoverable injury					
I	216	0.08	3.48	*	*
II, III	203	0.10	10.0	*	*
Fish temporary threshold shift (TTS)					
I, II, III	186	8.31	1548	7.63	1506

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 Level Contour Maps

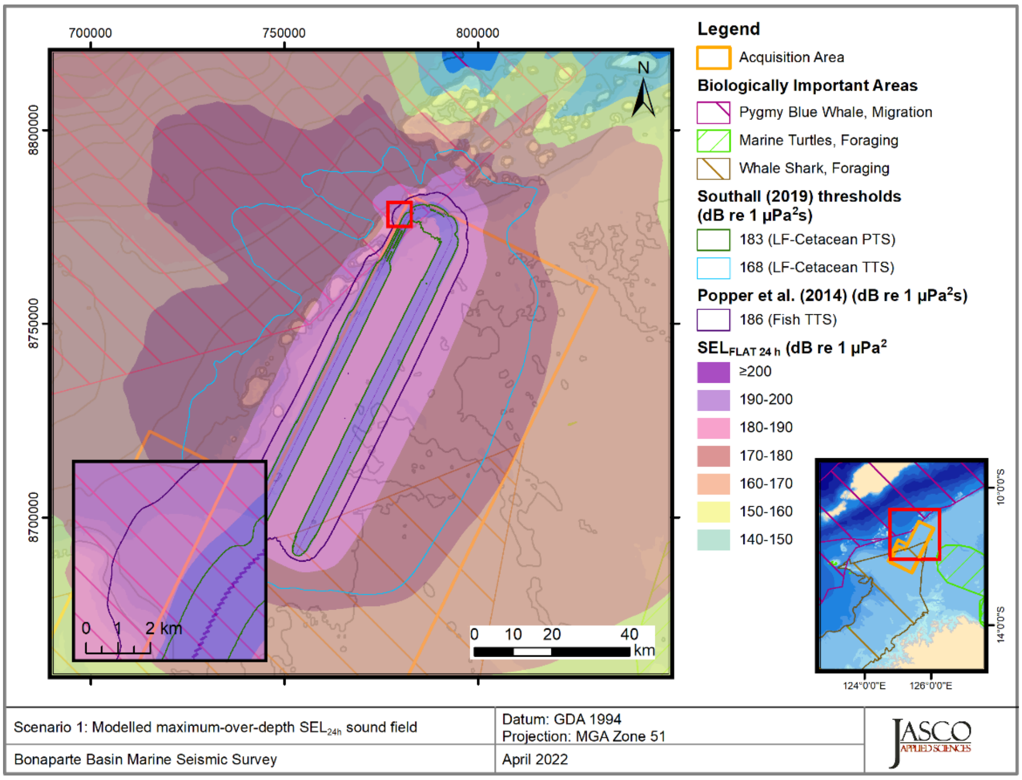


Figure 43. *Scenario 1*, sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for cetaceans and fish. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 20 for threshold distances.

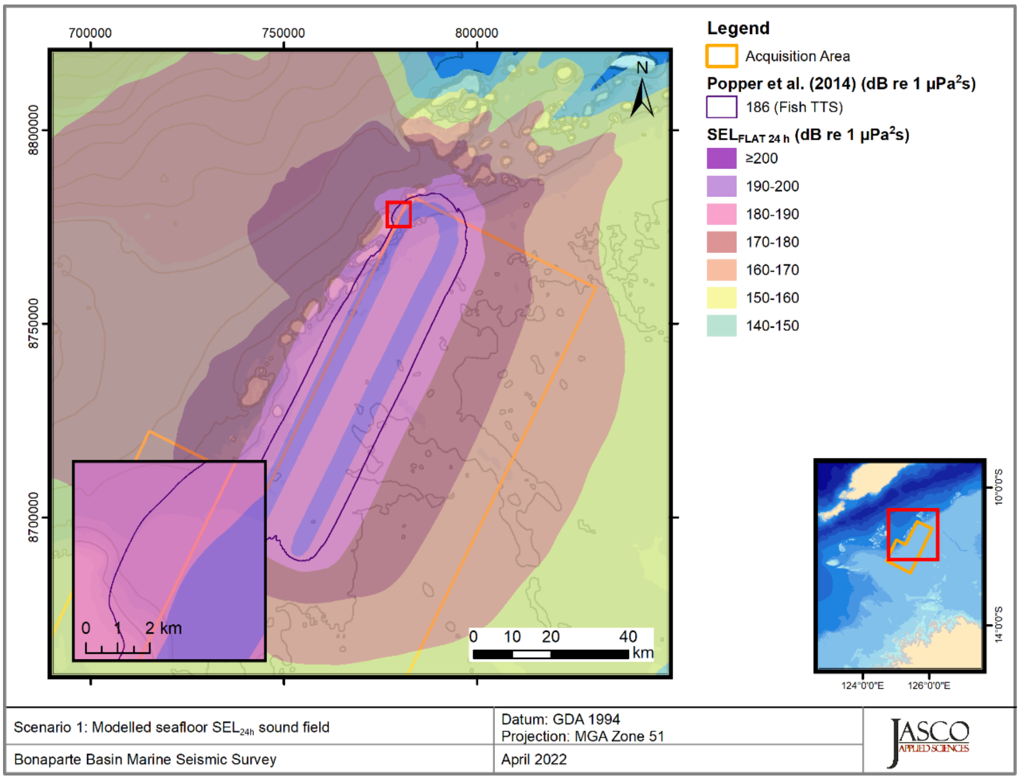


Figure 44. *Scenario 1*, sound level contour map of unweighted seafloor SEL_{24h} results along with the isopleth for fish temporary threshold shift (TTS). Thresholds omitted here were not reached or not large enough to display graphically. Refer to Tables 21–24 for threshold distances.

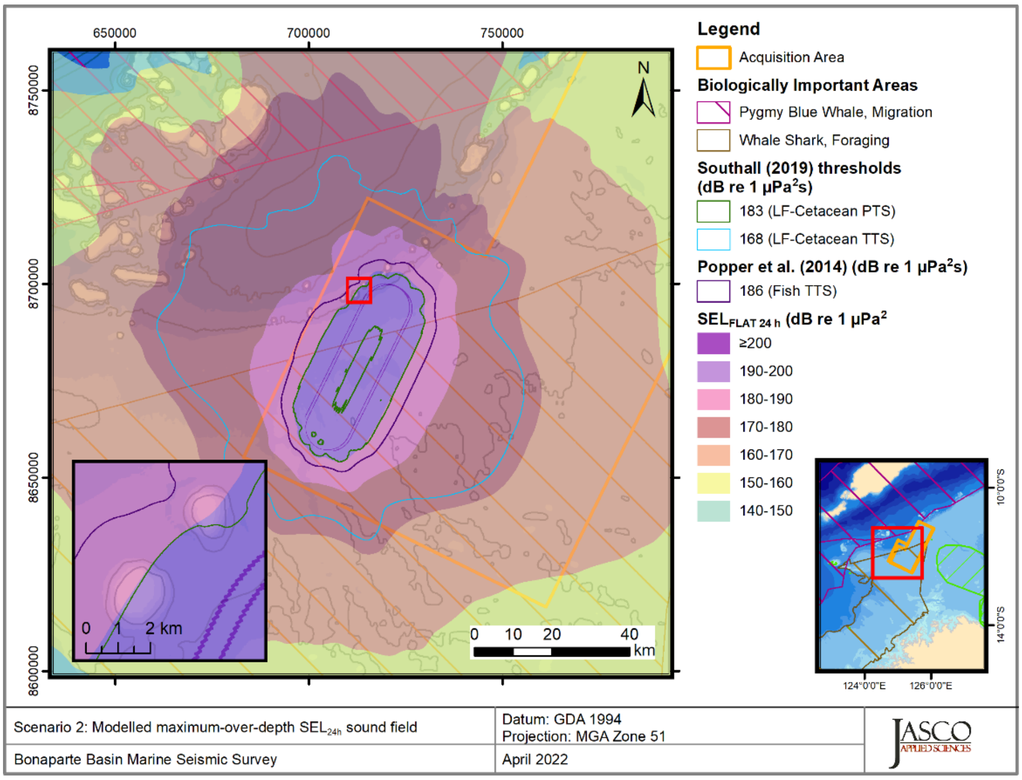


Figure 45. *Scenario 2*, sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for cetaceans and fish. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 20 for threshold distances.

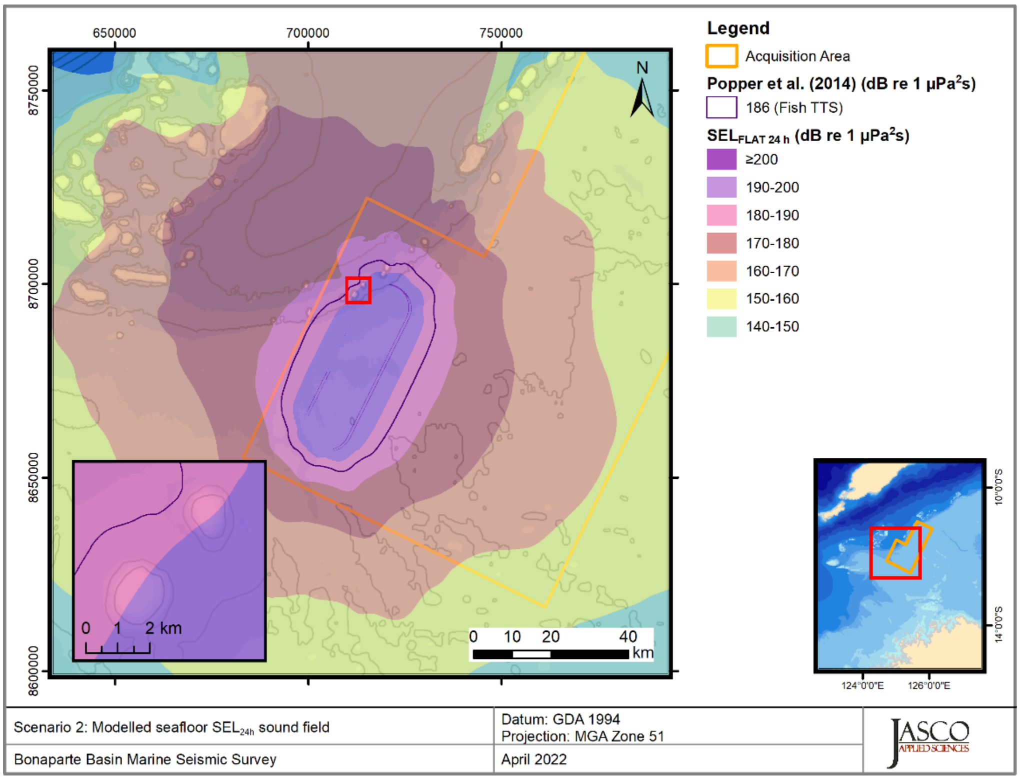


Figure 46. *Scenario 2*, sound level contour map of unweighted seafloor SEL_{24h} results along with the isopleth for fish temporary threshold shift (TTS). Thresholds omitted here were not reached or not large enough to display graphically. Refer to Tables 21–24 for threshold distances.

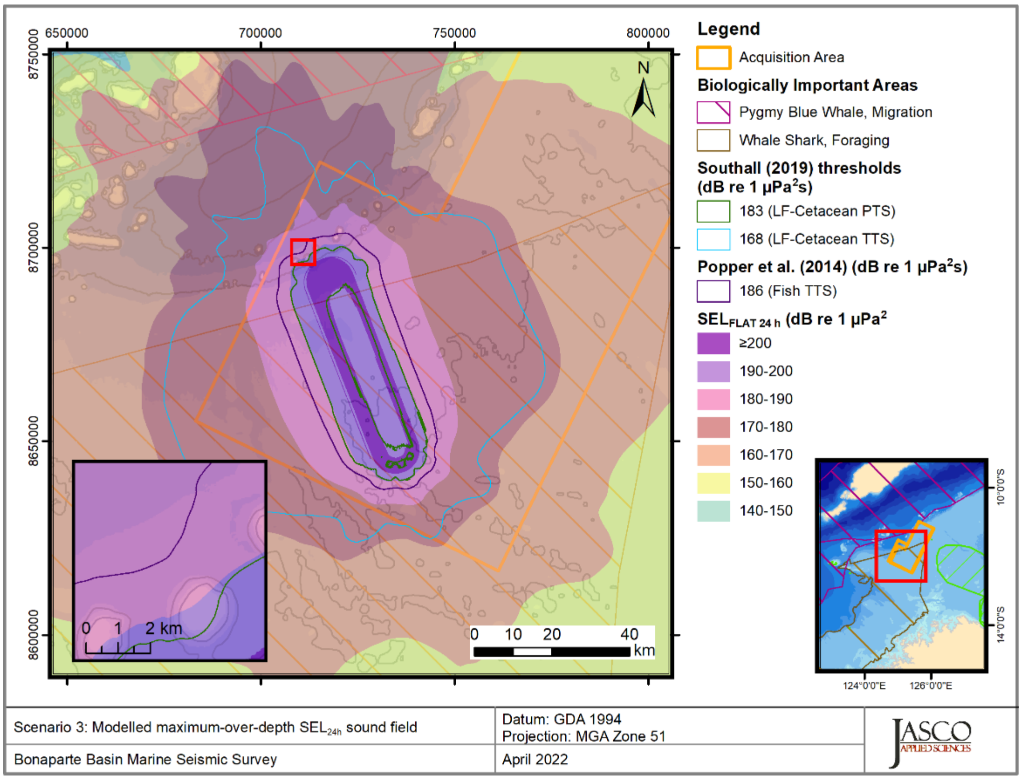


Figure 47. *Scenario 3*, sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for cetaceans and fish. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 20 for threshold distances.

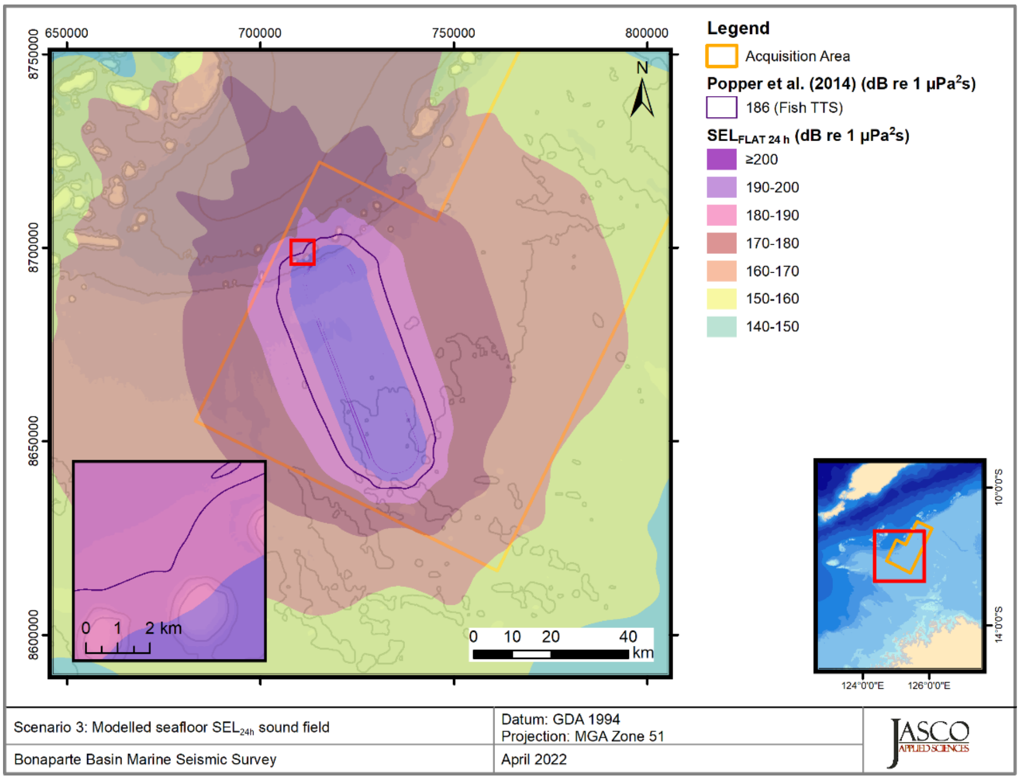


Figure 48. Scenario 3, sound level contour map of unweighted seafloor SEL24h results along with the isopleth for fish temporary threshold shift (TTS). Thresholds omitted here were not reached or not large enough to display graphically. Refer to Tables 21–24 for threshold distances.

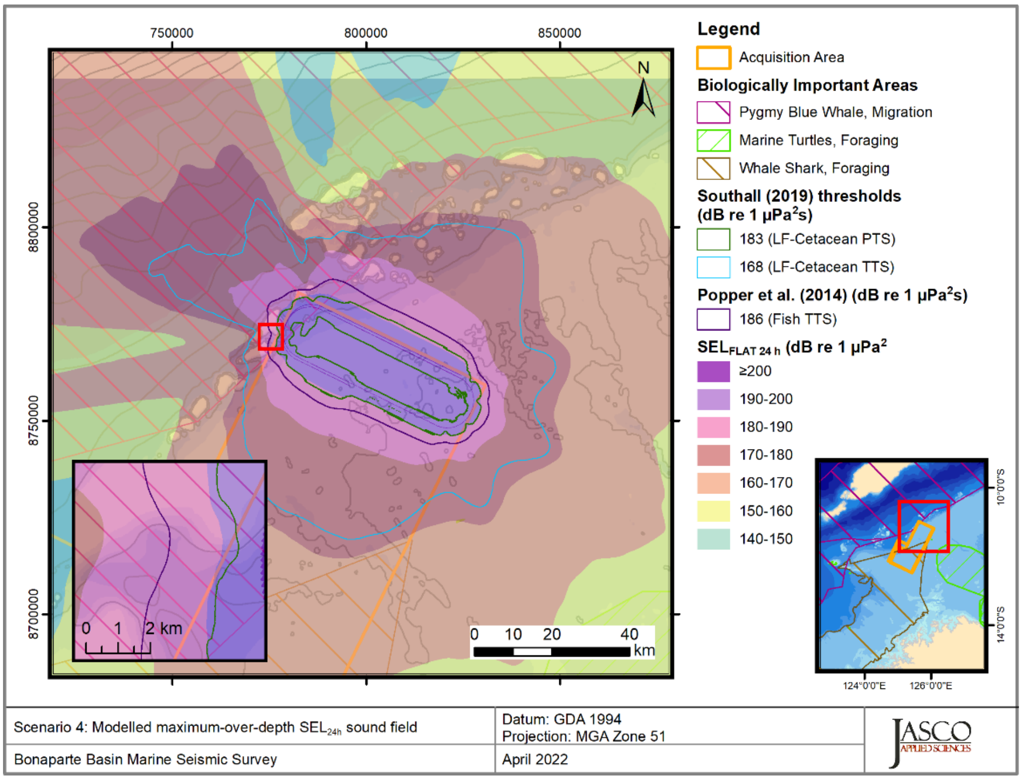


Figure 49. *Scenario 4*, sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for cetaceans and fish. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 20 for threshold distances.

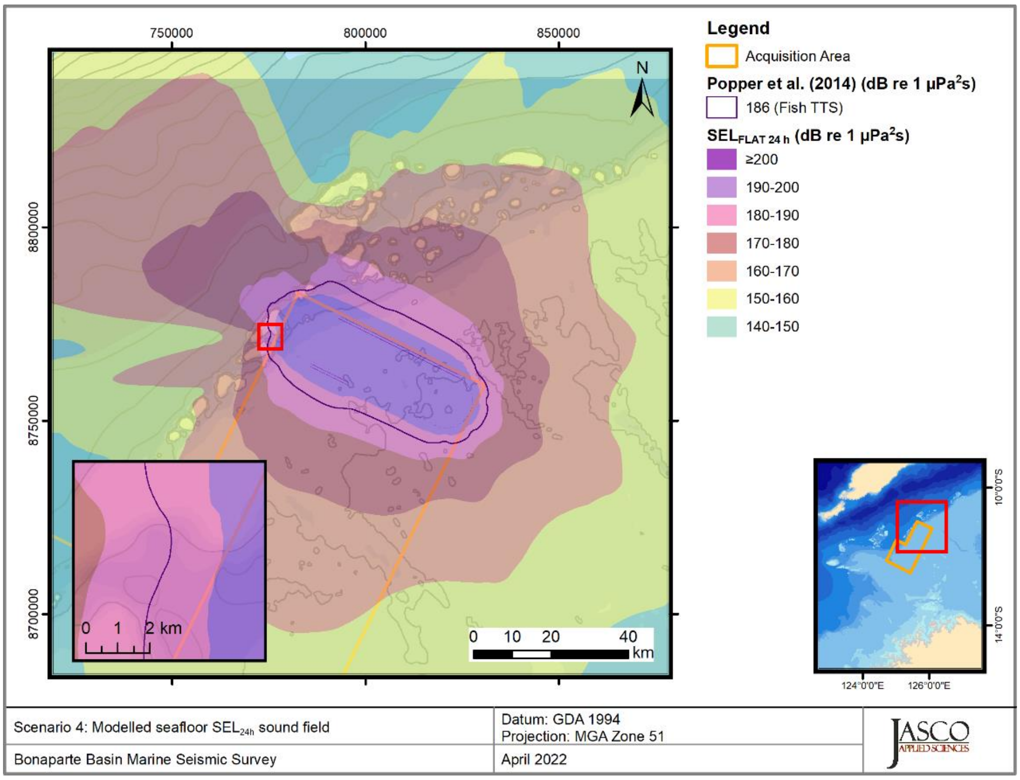


Figure 50. *Scenario 4*, sound level contour map of unweighted seafloor SEL24h results along with the isopleth for fish temporary threshold shift (TTS). Thresholds omitted here were not reached or not large enough to display graphically. Refer to Tables 21–24 for threshold distances.

5.4. Animal Movement Exposure Ranges

A summary of radial distances to exposure thresholds for migrating pygmy blue whales, along with probability of exposure for each modelled scenario (Section 2) are included below. Table 25 shows results for scenarios with animats restricted to the BIA, whilst Table 26 shows results for scenarios with unrestricted animat seeding. Results include $ER_{95\%}$ exposure ranges calculated for the 160 dB behavioural response threshold and SEL_{24h} thresholds for both TTS and PTS, and the probability of an animat being exposed above the threshold within the $ER_{95\%}$. Section 5.4.1 and 5.4.2 include histograms of CPA ranges to SEL_{24h} PTS, TTS, and the behavioural response threshold for all scenarios with results in Tables 25 and 26. Exposure ranges for TTS and PTS PK thresholds were not included in the exposure analysis since acoustic modelling predicted no PTS PK exceedance and ranges of less than 100 m for TTS PK (see Table 17).

Table 25. Summary of animat simulation results for pygmy blue whales with animats restricted to the BIA. The 95th percentile exposures ranges ($ER_{95\%}$) in km and probability of animats being exposed above threshold within the $ER_{95\%}$ (P_{exp} (%)) are provided. Dashes indicate no animats were exposed above threshold.

Threshold		Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
Description	Threshold level (dB)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)
PTS (SEL_{24h})[c]	183[a]	0.05	93	–	–	–	–	0.06	80	–	–
TTS (SEL_{24h})[c]	168[a]	14.00	63	–	–	–	–	11.70	58	–	–
Behavioural response (SPL)[d]	160[b]	11.47	86	–	–	–	–	11.42	85	–	–

[a] LF-weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)
[b] SPL (L_p; dB re 1 µPa)
[c] Southall et al. (2019a) criteria for marine fauna.
[d] NOAA (2019a) recommended unweighted behavioural threshold for marine mammals.

Table 26. Summary of animat simulation results for pygmy blue whales with unrestricted animat seeding. The 95th percentile exposures ranges ($ER_{95\%}$) in km and probability of animats being exposed above threshold within the $ER_{95\%}$ (P_{exp} (%)) are provided.

Threshold		Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
Description	Threshold level (dB)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)
PTS (SEL_{24h})[c]	183[a]	0.98	20	1.00	16	1.24	10	1.39	12	1.14	24
TTS (SEL_{24h})[c]	168[a]	15.04	75	14.75	82	17.11	75	14.57	70	16.99	71
Behavioural response (SPL)[d]	160[b]	9.74	93	9.22	95	9.51	96	9.73	89	9.32	95

[a] LF-weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)
[b] SPL (L_p; dB re 1 µPa)
[c] Southall et al. (2019a) criteria for marine fauna.
[d] NOAA (2019a) recommended unweighted behavioural threshold for marine mammals.

5.4.1. Exposure Range Histograms: BIA Restricted Seeding

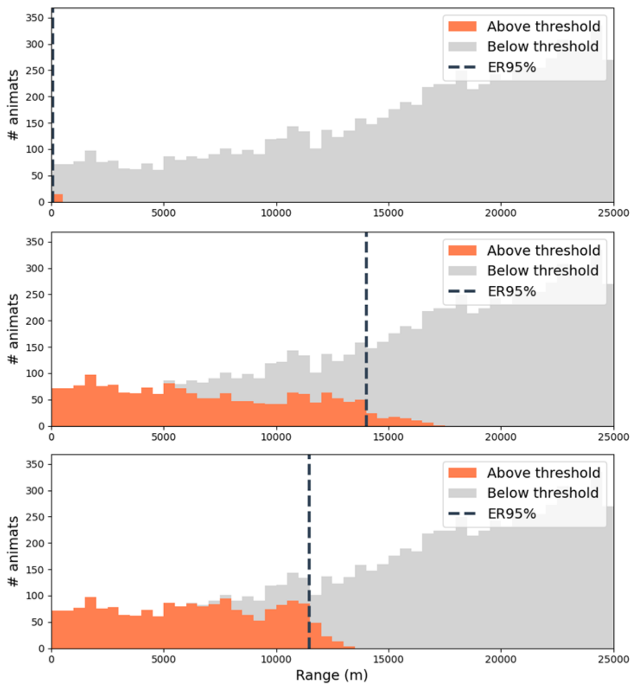


Figure 51. *Scenario 1, BIA restricted seeding*: CPA range histogram for animats, SEL_{24h} PTS threshold (top panel), SEL_{24h} TTS threshold (middle panel), SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold.

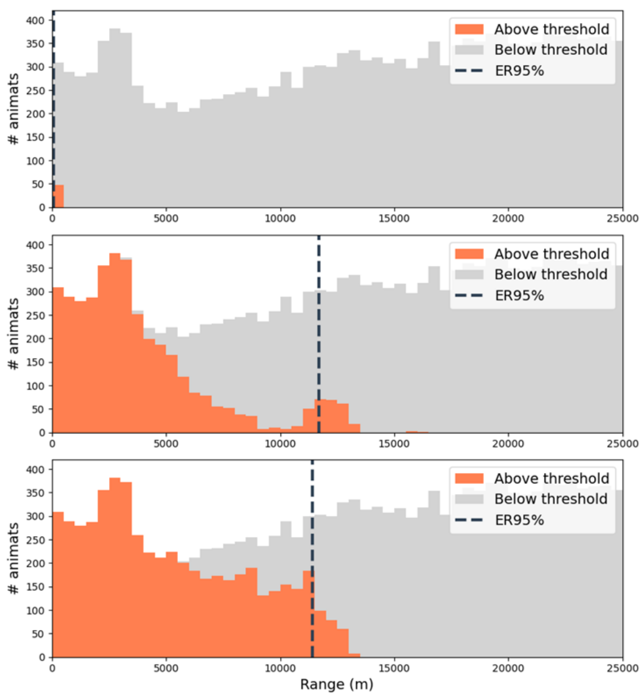


Figure 52. *Scenario 4, BIA restricted seeding*: CPA range histogram for animats, SEL_{24h} PTS threshold (top panel), SEL_{24h} TTS threshold (middle panel), SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold.

5.4.2. Exposure Range Histograms: Unrestricted Seeding

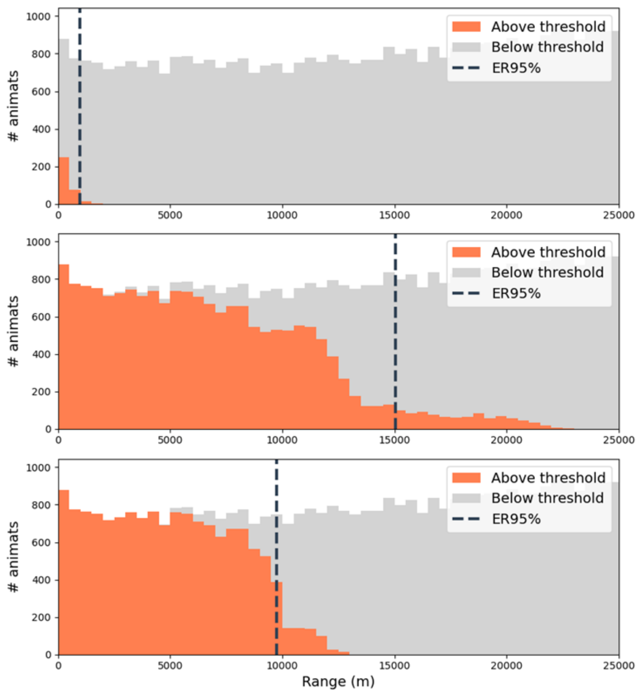


Figure 53. *Scenario 1, unrestricted seeding*: CPA range histogram for animats, SEL_{24h} PTS threshold (top panel), SEL_{24h} TTS threshold (middle panel), SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold.

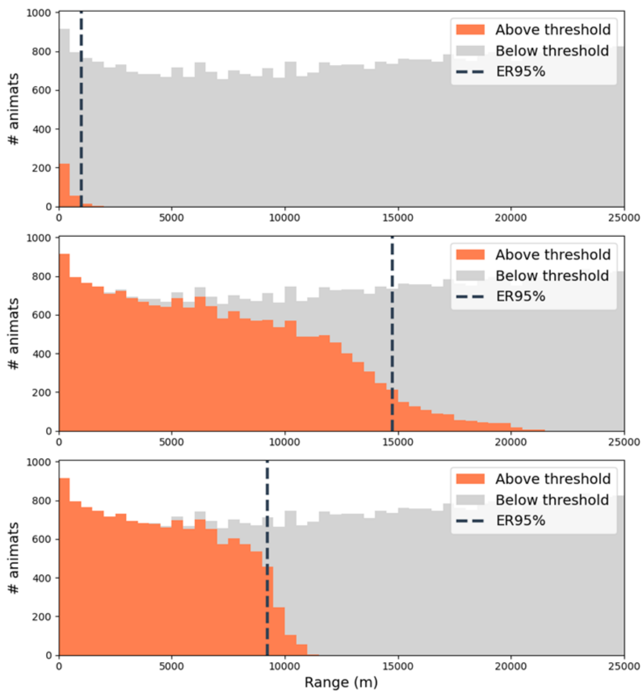


Figure 54. *Scenario 2, unrestricted seeding*: CPA range histogram for animats, SEL_{24h} PTS threshold (top panel), SEL_{24h} TTS threshold (middle panel), SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold.

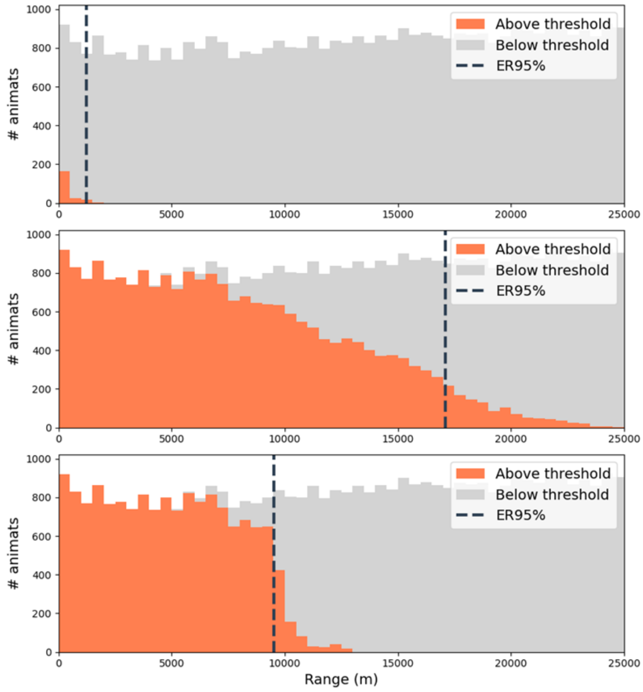


Figure 55. *Scenario 3, unrestricted seeding*: CPA range histogram for animats, SEL_{24h} PTS threshold (top panel), SEL_{24h} TTS threshold (middle panel), SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold.

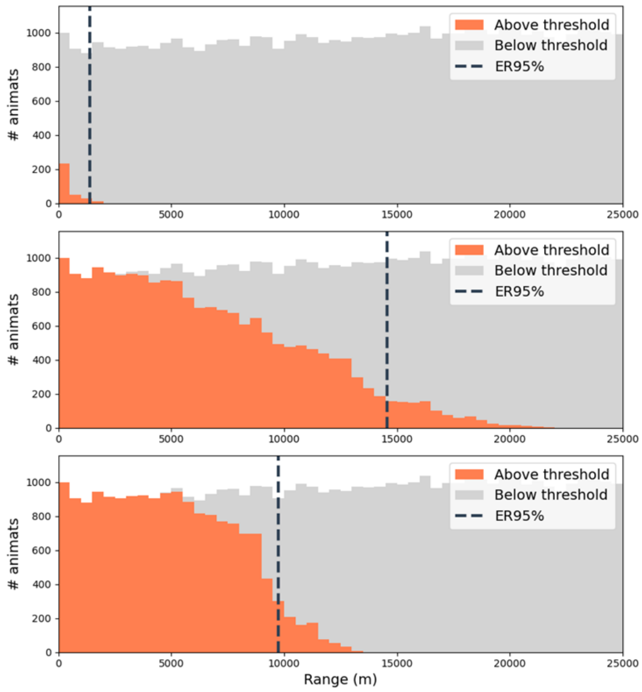


Figure 56. *Scenario 4, unrestricted seeding*: CPA range histogram for animats, SEL_{24h} PTS threshold (top panel), SEL_{24h} TTS threshold (middle panel), SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold.

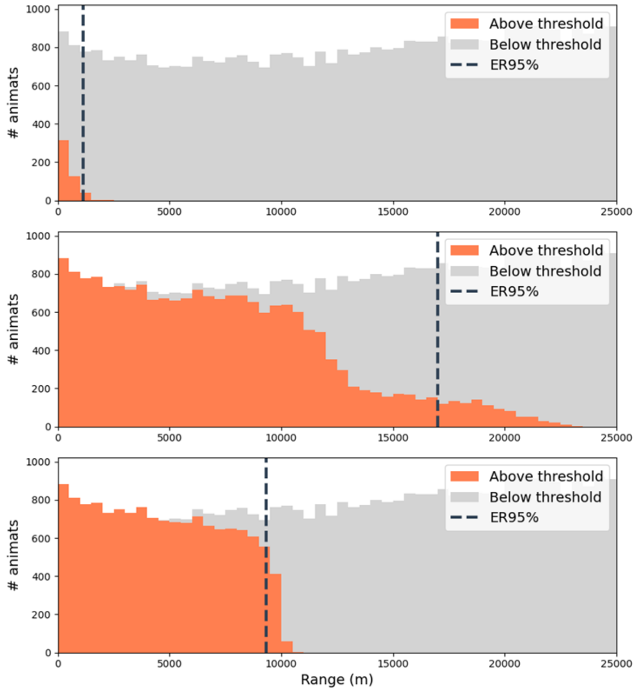


Figure 57. *Scenario 5, unrestricted seeding*: CPA range histogram for animats, SEL_{24h} PTS threshold (top panel), SEL_{24h} TTS threshold (middle panel), SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold.

6. Discussion and Summary

The modelling study predicted underwater sound levels associated with the planned Schlumberger Bonaparte Basin MSS. The underwater sound field was modelled for a 3000 in^3 seismic source (Appendix B.2). An analysis of seasonal sound speed profiles and associated sensitivity analysis indicated that March was likely to be the month most conducive to sound propagation; as such it was selected to ensure a conservative estimation of distances to received sound level thresholds over the potential survey periods (Appendix D.3.2). Modelling also accounted for site-specific bathymetric variations (Appendix D.3.1) and local geoacoustic properties (Appendix D.3.3).

Most acoustic energy from a seismic source is output at lower frequencies, in the tens to hundreds of hertz. The modelled array had a pronounced broadside directivity for decidecade bands between ~100 to 400 Hz (Appendix B.3), which caused a noticeable axial bulge in the modelled acoustic footprints. The overall broadband (10-25000 Hz) unweighted per-pulse SEL and peak pressure source levels of the seismic source operating at 8 m depth are detailed in Table 8.

6.1. Per-Pulse Sound Fields

The modelled sites encompassed water depths from 95 to 211 m across one defined geological area. At all single impulse sites, the distances to identified isopleths were generally greater in the broadside direction. The array directionality and frequency content coupled with the bathymetry had a considerable effect on propagation at longer distances, with generally larger lobes of sound energy extending in the broadside direction where no shoals intersected the propagation path, as shown in most footprint maps in Section 5.2.2.1. The maps and vertical slice plots for the modelling sites closest to the shoals, such as Sites 1 and 2 (for Figures 7 and 8) demonstrate the truncation of isopleths due to steep slopes and shallowing waters in the vicinity of a shoal. Where shoals are present along a propagation path, they can block the propagation of acoustic energy. This can be observed in the footprint maps and cross-sections in Section 5.2.1. The steep bathymetric gradient (relative to the water depth) present for Sites 1 and 2, serves to strip propagating sound energy from the water column and enhance transmission into the seabed, resulting in an increase in loss as sound propagates upslope. The rate of loss is primarily dependent, the magnitude of the water depth change, the bathymetric gradient, and the geoacoustic properties of the seabed (Jensen et al. 2011). These parameters have been incorporated into the acoustic models to provide a realistic estimate of the received levels predictions.

Isopleth shapes are significantly influenced by the presence of shoals, with propagation in the direction of the pygmy blue whale BIA only supported between the gaps in the shoals. The vertical slice plots (Section 5.2.2.2) assist in demonstrating the influence of the bathymetry, source location and sound speed profile on the predicted sound field. Ranges to isopleths at the different sites therefore depend upon the transmission pathway to open water, as well as the depth of the water the source is operational in. Sources located in deeper water have a lower “cut-off frequency (f_c)” than sources in shallower water. The cut-off frequency is a single number that describes how much acoustic energy can propagate with minimal loss between then sea-surface and seafloor interfaces. For a given acoustic signal, frequencies below f_c are subject to higher loss compared to frequencies above the f_c (Jensen et al. 2011). For the considered modelled sites in waters between 95 and 221 m deep the cut off frequencies are approximately 20257 Hz. Deeper water has a lower f_c allowing more low-frequency energy to propagate when compared with shallower water on the continental shelf.

The bathymetry within survey area varied gradually from east to west across the shelf, with the highest rates of change in the north-west corner of the Operational Area, where the water depths increase as the continental shelf transitions into a deeper water slope environment. The combination of low-frequency content from the seismic source and the water depths within the survey area resulted in the sound field substantially interacting with the seabed. The maximum-over-depth sound footprint maps and vertical slice plots (Sections 5.2.2.1 and 5.2.2.2) assist in demonstrating the influence of the bathymetry and seabed composition on the sound field.

The distances to PK and PK-PK based criteria (Section 3.2 and 3.4) for fish, benthic crustaceans, and bivalves at the seafloor generally increased with increasing water depth (Tables 18-19). However, distances to these criteria did not always consistently change with increasing depth. In general, the number of modelled sites and water depths considered within the Operational Area provides a good representation of potential variability for seabed receptors.

6.2. Multiple Pulse Sound Fields

The accumulated SEL over 24 hours of seismic source operation was modelled considering four acoustic scenarios and five animal movement modelling scenarios, each with a realistic acquisition pattern, representative of the entire survey. The modelling predicted the accumulation of sound energy, considering the change in location and the azimuth of the source at each pulse point, which was used to assess possible injury in marine mammals and the SEL_{24h} based fish 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).

Continuous line acquisition proposed for this MSS involves the seismic source operating at full power on turns as well as the lines. The operation of the seismic source on the turns can create a focussing effect towards the centre of the curved track, which can result in the R_{max} and $R_{95\%}$ to occur at the focus of a turn as shown in the sound level contour maps in Section 5.3.2, rather than the perpendicular to the main survey lines.

The footprints and range maxima for all accumulated SEL thresholds are influenced by the seabed compositions along acquisition lines. The discussion above regarding ranges to isopleths also applies to the accumulated SEL calculations. The furthest ranges to thresholds for PTS and TTS were in the broadside direction, driven by the bathymetry.

6.3. Acoustic Results Summary

This section presents summary of the distances to the noise effect criteria applied in this study (Section 3) as relevant to the impact assessment. The effect criteria for impairment of marine mammals, fish and sea turtles use dual metrics (PK and SEL_{24h}), and the longest distance associated with either metric is required to be applied, and thus is presented in this summary.

The SEL_{24h} is a cumulative metric that reflects the dosimetric effect of noise levels within 24 h based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. Where the corresponding SEL_{24h} radii are larger than those for peak pressure criteria, they often represent an unlikely worst-case scenario. More realistically, marine mammals, fish and sea turtles would not stay in the same location for 24 hours, but rather a shorter period, depending upon their behaviour, the proximity and movements of the source. Therefore, a reported radius for SEL_{24h} criteria does not mean that marine fauna travelling within this radius of the source will be impaired, but rather that an animal could be exposed to the sound level associated with impairment (either PTS or TTS) if it remained in that location for 24 h. A more realistic representation of the potential exposures was undertaken using animal movement modelling (‘animat modelling’), with the results summarised separately below in Section 6.4.

A summary of predicted distances to criteria from acoustic modelling are presented below.

Marine mammals

Table 27 summarises the distances to criteria for marine mammals, note that these distances are primarily associated with the broadside aspect of the array. Results for PK are presented in Table 17, while SEL_{24h} results are in Table 20.

Table 27. Summary of maximum (R_{max}) horizontal distances (in km) from modelled sites or scenarios to behavioural response thresholds and temporary threshold shift (TTS) and permanent threshold shift (PTS) for marine mammals. Maximum extents are in the broadside direction of the 3000 in^3 seismic source.

Hearing group	Modelled distance to effect threshold (R_{max})		
	Behavioural response[1]	Impairment: TTS[2]	Impairment: PTS[2]
LF cetaceans	14.3	47.5 (SEL_{24h})	6.84 (SEL_{24h})
HF cetaceans		0.08 (SEL_{24h})	–
VHF cetaceans		0.92 (PK)	0.48 (PK)
Sirenians		0.08 (SEL_{24h})	–

Noise exposure criteria: [1] NOAA (2019b) and [2] Southall et al. (2019b).
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Sea turtles

Table 28 summarises the distances to criteria for sea turtles, with the results for behavioural thresholds presented in Tables 13–16 while SEL_{24h} results are in Table 20.

Table 28. Summary of horizontal distances (in km) to turtle behavioural response criteria, temporary threshold shift (TTS), and permanent threshold shift (PTS).

Hearing group	Modelled distance to effect threshold (R_{max})			
	Behavioural response[1]	Behavioural disturbance[2]	Impairment: TTS[3]	Impairment: PTS[3]
Sea Turtles	7.68	2.44	6.11	0.08

Noise exposure criteria: [1] NSF (2011), [2] McCauley et al. (2000a), and [3] Finneran et al. (2017)

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 29 summarises distances to effect criteria for fish, fish eggs, and fish larvae along with the relevant metric. Results for PK are presented in Tables 17 and 18, whilst SEL_{24h} results are in Tables 21–24.

Table 29. Summary of maximum fish, fish eggs, and larvae injury and temporary threshold shift (TTS) onset distances for single impulse and 24 hour sound exposure level (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	Recoverable injury	PK	0.08	PK	0.08
	TTS	SEL_{24h}	10.5	SEL_{24h}	9.31
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing	Recoverable injury	PK	0.20	PK	0.25
	TTS	SEL_{24h}	10.5	SEL_{24h}	9.31
Fish eggs, and larvae	Injury	PK	0.20	PK	0.25

Benthic invertebrates, Sponges, Coral, and Plankton

To assist with assessing the potential effects on these receptors, the following results were determined:

- Crustaceans: The sound level of 202 dB re 1 µPa PK-PK from Payne et al. (2008) which is representative of no effects, was considered for seafloor sound levels; the sound level was reached at ranges between 307 and 426 m for the 3000 in^3 source; results presented in Table 19.
- 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). This particle acceleration was reached at a range of 10.5 m for depth 75 m and was not reached at any of the other considered depths; results presented in Section 5.2.3.
- 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 not reached as presented in Table 18.

6.4. Animal Movement Modelling

The estimated sound fields produced by source and propagation models for the planned Schlumberger Bonaparte Basin seismic survey were incorporated into a sound exposure model for pygmy blue whales to estimate the radial distance within which 95% of the exposure exceedances occur ($ER_{95\%}$), along with the probability that an animat with the closest point of approach within that distance would be exposed above the relevant threshold (P_{exp}).

For the exposure analysis, each of the five scenarios was run both with BIA-restricted animat seeding and unrestricted seeding. Of the five scenarios considered, only Scenarios 1 and 4 had partial overlap with the BIA. Because of the large distance between Scenarios 2, 3, and 5 and the BIA, no exposures above threshold are predicted for these scenarios for the BIA-restricted simulations, however the information can be used to define buffer zones to the BIA. Sections 6.4.1 and 6.4.2 summarise the PTS, TTS, and behavioural exposure range results, with the tabulated results presented in Tables 25 and 26.

6.4.1. PTS and TTS

Exposure ranges from animal movement modelling for PTS and TTS criteria are typically shorter than those predicted using acoustic propagation modelling because of the shorter dwell time of the moving animats. In all scenarios, for both BIA-restricted and unrestricted cases, PTS and TTS exposure ranges were substantially shorter than acoustic ranges to threshold.

Of the BIA-restricted seeding scenarios, only Scenarios 1 and 4 resulted in exposures above threshold, and therefore exposure ranges. The maximum $ER_{95\%}$ for SEL_{24h} thresholds was 14.0 km for TTS and 0.06 km for PTS. All of the unrestricted seeding scenarios resulted in TTS and PTS exposures above threshold. The maximum $ER_{95\%}$ for unrestricted scenarios was 17.11 km for TTS and 1.39 km for PTS. Exposure ranges are, on average, slightly longer for TTS and PTS for unrestricted vs BIA-restricted scenarios because unrestricted animats have more opportunities to be exposed to sound fields for a longer time, which effectively lengthens their dwell time.

The probability of exposure within $ER_{95\%}$ varied between 58 and 93% for BIA-restricted scenarios and 10-96% for unrestricted scenarios, indicating that some, but not all, animats exposed within the 95th percentile range were exposed above threshold. This is because animats can move in and out of the modelling range as well as their vertical position in the water column, thus potentially limiting the length of time they are within the exposure radius. For example, an animat might approach within the predicted exposure range but if they are traveling more quickly on average than other animats, they may not accumulate as much exposure, or they may be spending more time at depths with quieter sound levels.

6.4.2. Behavioural Effects

Exposure ranges ($ER_{95\%}$) for single exposure metrics, such as the SPL behavioural response criteria, are typically comparable to the predicted acoustic ranges. Acoustic ranges are conservatively calculated using the maximum-over-depth sound fields and assuming static receivers, while exposure ranges account for animats sampling the sound field vertically and horizontally based on species-specific diving parameters, so exposure ranges are generally slightly lower than the R_{max} acoustic ranges and in this case are fairly aligned with the $R_{95\%}$ acoustic ranges. The behavioural results from this study are consistent with this pattern. For the BIA restricted seeding scenarios, behavioural exposure ranges were similar, at 11.47 km and 11.42 km for Scenarios 1 and 4, respectively with the probabilities of exposure being 86% and 85%. For unrestricted scenarios, the exposure ranges varied minimally from 9.22–9.74 km. These are shorter, on average, than the exposure ranges for the BIA-restricted scenarios. This occurs because the unrestricted seeding allows more animats to get closer to source locations, thereby shifting the bulk of the distribution lower (e.g., Figure 56 vs. Figure 52).

Glossary

Unless otherwise stated in an entry, these definitions are consistent with ISO 80000-3 (2017).

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).

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.

A-weighting

Frequency-selective weighting for human hearing in air that is derived from the inverse of the idealized 40-phon equal loudness hearing function across frequencies.

absorption

The reduction of acoustic pressure amplitude due to acoustic particle motion energy converting to heat in the propagation medium.

attenuation

The gradual loss of acoustic energy from absorption and scattering as sound propagates through a medium.

auditory frequency weighting

The process of applying an auditory frequency weighting function. In human audiometry, C-weighting is the most commonly used function, an example for marine mammals are the auditory frequency weighting functions published by Southall et al. (2007).

auditory frequency weighting function

Frequency weighting function describing a compensatory approach accounting for a species' (or functional hearing group's) frequency-specific hearing sensitivity. Example hearing groups are low-, mid-, and high-frequency cetaceans, phocid and otariid pinnipeds.

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.

bandwidth

The range of frequencies over which a sound occurs. Broadband refers to a source that produces sound over a broad range of frequencies (e.g., seismic airguns, vessels) whereas narrowband sources produce sounds over a narrow frequency range (e.g., sonar) (ANSI S1.13-2005 (R2010)).

bar

Unit of pressure equal to 100 kPa, which is approximately equal to the atmospheric pressure on Earth at sea level. 1 bar is equal to 10^5 Pa or 10^{11} µPa.

boxcar averaging

A signal smoothing technique that returns the averages of consecutive segments of a specified width.

broadband level

The total level measured over a specified frequency range.

broadside direction

Perpendicular to the travel direction of a source. Compare with endfire direction.

cetacean

Any animal in the order Cetacea. These are aquatic species 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.

conductivity-temperature-depth (CTD)

Measurement data of the ocean's conductivity, temperature, and depth; used to compute sound speed and salinity.

decade

Logarithmic frequency interval whose upper bound is ten times larger than its lower bound (ISO 80000-3:2006).

decidecade

One tenth of a decade. *Note*: An alternative name for decidecade (symbol ddec) is "one-tenth decade". A decidecade is approximately equal to one third of an octave (1 ddec ≈ 0.3322 oct) and for this reason is sometimes referred to as a "one-third octave".

decidecade band

Frequency band whose bandwidth is one decidecade. *Note*: The bandwidth of a decidecade band increases with increasing centre frequency.

decibel (dB)

Unit of level used to express the ratio of one value of a power quantity to another on a logarithmic scale. Unit: dB.

duty cycle

The time when sound is periodically recorded by an acoustic recording system.

endfire direction

Parallel to the travel direction of a source. Also see **broadside direction**.

energy source level

A property of a sound source obtained by adding to the sound exposure level measured in the far field the propagation loss from the acoustic centre of the source to the receiver position. Unit: decibel (dB). Reference value: 1 $\mu Pa^2 m^2 s$.

energy spectral density source level

A property of a sound source obtained by adding to the energy spectral density level of the sound pressure measured in the far field the propagation loss from the acoustic centre of the source to the receiver position. Unit: decibel (dB). Reference value: 1 $\mu Pa^2 m^2 s/Hz$.

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.

Fourier transform (or Fourier synthesis)

A mathematical technique which, although it has varied applications, is referenced in the context of this report as a method used in the process of deriving a spectrum estimate from time-series data (or the reverse process, termed the inverse Fourier transform). A computationally efficient numerical algorithm for computing the Fourier transform is known as fast Fourier transform (FFT).

flat weighting

Term indicating that no frequency weighting function is applied. Synonymous with unweighted.

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.

frequency weighting

The process of applying a frequency weighting function.

frequency-weighting function

The squared magnitude of the sound pressure transfer function. For sound of a given frequency, the frequency weighting function is the ratio of output power to input power of a specified filter, sometimes expressed in decibels. Examples include the following:

- *Auditory frequency weighting function*: compensatory frequency weighting function accounting for a species' (or functional hearing group's) frequency-specific hearing sensitivity.
- *System frequency weighting function*: frequency weighting function describing the sensitivity of an acoustic acquisition system, typically consisting of a hydrophone, one or more amplifiers, and an analogue to digital converter.

geoacoustic

Relating to the acoustic properties of the seabed.

harmonic

A sinusoidal sound component that has a frequency that is an integer multiple of the frequency of a sound to which it is related. For example, the second harmonic of a sound has a frequency that is double the fundamental frequency of the sound.

hearing group

Category of animal species when classified according to their hearing sensitivity and to the susceptibility to sound. Examples for marine mammals include very low-frequency (VLF) cetaceans, low-frequency (LF) cetaceans, mid-frequency (MF) cetaceans, high-frequency (HF) cetaceans, very high-frequency (VHF) cetaceans, otariid pinnipeds in water (OPW), phocid pinnipeds in water (PPW), sirenians (SI), other marine carnivores in air (OCA), and other marine carnivores in water (OCW) (NMFS 2018, Southall et al. 2019b). See **auditory frequency weighting functions**, which are often applied to these groups. Examples for fish include species for which the swim bladder is involved in hearing, species for which the swim bladder is not involved in hearing, and species without a swim bladder (Popper et al. 2014).

hearing threshold

The sound pressure level for any frequency of the hearing group that is barely audible for a given individual for specified background noise during a specific percentage of experimental trials.

hertz (Hz)

A unit of frequency defined as one cycle per second.

high-frequency (HF) cetacean

See **hearing group**.

intermittent sound

A sound whose level abruptly drops below the background noise level several times during an observation period.

impulsive sound

Qualitative term meaning sounds that are typically transient, brief (less than 1 second), broadband, with rapid rise time and rapid decay. They can occur in repetition or as a single event. Examples of impulsive sound sources include explosives, seismic airguns, and impact pile drivers.

isopleth

A line drawn on a map through all points having the same value of some quantity.

knot

One nautical mile per hour. Symbol: kn.

level

A measure of a quantity expressed as the logarithm of the ratio of the quantity to a specified reference value of that quantity. Examples include sound pressure level, sound exposure level, and peak sound pressure level. For example, a value of sound exposure level with reference to 1 μPa^2 s can be written in the form *x* dB re 1 μPa^2 s.

low-frequency (LF) cetacean

See **hearing group**.

median

The 50th percentile of a statistical distribution.

mid-frequency (MF) cetacean

See **hearing group**.

M-weighting

See **auditory frequency weighting function** (as proposed by Southall et al. 2007).

mysticete

A suborder of cetaceans that use baleen plates to filter food from water. Members of this group include rorquals (Balaenopteridae), right whales (Balaenidae), and grey whales (*Eschrichtius robustus*).

non-impulsive sound

Sound that is not an impulsive sound. A non-impulsive sound is not necessarily a continuous sound.

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.

otariid

A common term used to describe members of the Otariidae, eared seals, commonly called sea lions and fur seals. Otariids are adapted to a semi-aquatic life; they use their large fore flippers for propulsion. Their ears distinguish them from phocids. Otariids are one of the three main groups in the superfamily Pinnipedia; the other two groups are phocids and walrus.

otariid pinnipeds in water (OPW)

See **hearing group**.

other marine carnivores in air (OCA)

See **hearing group**.

other marine carnivores in water (OCW)

See **hearing group**.

parabolic equation method

A computationally efficient solution to the acoustic wave equation that is used to model propagation loss. The parabolic equation approximation omits effects of back-scattered sound, simplifying the computation of propagation loss. The effect of back-scattered sound is negligible for most ocean-acoustic propagation problems.

peak sound pressure level (zero-to-peak sound pressure level)

The level ($L_{p,pk}$ or L_{pk}) of the squared maximum magnitude of the sound pressure (p_{pk}^2). Unit: decibel (dB). Reference value (p_0^2) for sound in water: 1 µPa^2.

$$L_{p,\mathrm{pk}} := 10\log_{10}\left(p_{\mathrm{pk}}^2/p_0^2\right)\,\mathrm{dB} \;= 20\log_{10}\left(p_{\mathrm{pk}}/p_0\right)\,\mathrm{dB}$$

The frequency band and time window should be specified. Abbreviation: PK or L_{pk}.

peak-to-peak sound pressure

The difference between the maximum and minimum sound pressure over a specified frequency band and time window. Unit: pascal (Pa).

permanent threshold shift (PTS)

An irreversible loss of hearing sensitivity caused by excessive noise exposure. PTS is considered auditory injury.

phocid

A common term used to describe all members of the family Phocidae. These true/earless seals are more adapted to in-water life than are otariids, which have more terrestrial adaptations. Phocids use their hind flippers to propel themselves. Phocids are one of the three main groups in the superfamily Pinnipedia; the other two groups are otariids and walrus.

phocid pinnipeds in water (PPW)

See **hearing group**.

pinniped

A common term used to describe all three groups that form the superfamily Pinnipedia: phocids (true seals or earless seals), otariids (eared seals or fur seals and sea lions), and walrus.

point source

A source that radiates sound as if from a single point.

pressure, acoustic

The deviation from the ambient pressure caused by a sound wave. Also called sound pressure. Unit: pascal (Pa).

pressure, hydrostatic

The pressure at any given depth in a static liquid that is the result of the weight of the liquid acting on a unit area at that depth, plus any pressure acting on the surface of the liquid. Unit: pascal (Pa).

propagation loss (PL)

Difference between a source level (SL) and the level at a specified location, PL(x) = SL − L(x). Also see **transmission loss**.

received level

The level measured (or that would be measured) at a defined location. The type of level should be specified.

reference values

standard underwater references values used for calculating sound **levels**, e.g., the reference value for expressing sound pressure level in decibels is 1 µPa.

Quantity	Reference value
Sound pressure	1 µPa
Sound exposure	1 μPa^2 s
Sound particle displacement	1 pm
Sound particle velocity	1 nm/s
Sound particle acceleration	1 $\mu m/s^2$

rms

abbreviation for 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 a 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.

sound

A time-varying disturbance in the pressure, stress, or material displacement of a medium propagated by local compression and expansion of the medium.

sound exposure

Time integral of squared sound pressure over a stated time interval. The time interval can be a specified time duration (e.g., 24 hours) or from start to end of a specified event (e.g., a pile strike, an airgun pulse, a construction operation). Unit: Pa^2 s.

sound exposure level

The level (L_E) of the sound exposure (E). Unit: decibel (dB). Reference value (E_0) for sound in water: 1 μPa^2 s.

$$L_E := 10 \log_{10}(E/E_0)\,\text{dB} \;= 20 \log_{10}\left(E^{1/2}/E_0^{1/2}\right)\,\text{dB}$$

The frequency band and integration time should be specified. Abbreviation: 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. Unit: Pa^2 s/Hz.

sound field

Region containing sound waves.

sound intensity

Product of the sound pressure and the sound particle velocity. The magnitude of the sound intensity is the sound energy flowing through a unit area perpendicular to the direction of propagation per unit time.

sound particle acceleration

The rate of change of sound particle velocity. Unit: metre per second squared (m/s^2). Symbol: *a*.

sound particle motion

smallest volume of a medium that represents its mean physical properties.

sound particle displacement

Displacement of a material element caused by the action of sound, where a material element is the smallest element of the medium that represents the medium's mean density.

sound particle velocity

The velocity of a particle in a material moving back and forth in the direction of the pressure wave. Unit: metre per second (m/s). Symbol: *v*.

sound pressure

The contribution to total pressure caused by the action of sound.

sound pressure level (rms sound pressure level)

The level ($L_{p,\mathrm{rms}}$) of the time-mean-square sound pressure (p^2_{rms}). Unit: decibel (dB). Reference value (p_0^2) for sound in water: 1 μPa^2.

$$L_{p,\mathrm{rms}} := 10\log_{10}(p^2_{\mathrm{rms}}/p_0^2)\ \mathrm{dB}\ = 20\log_{10}(p_{\mathrm{rms}}/p_0)\ \mathrm{dB}$$

The frequency band and averaging time should be specified. Abbreviation: SPL or Lrms.

sound speed profile

The speed of sound in the water column as a function of depth below the water surface.

soundscape

The characterization of the ambient sound in terms of its spatial, temporal, and frequency attributes, and the types of sources contributing to the sound field.

source level (SL)

A property of a sound source obtained by adding to the sound pressure level measured in the far field the propagation loss from the acoustic centre of the source to the receiver position. Unit: decibel (dB). Reference value: 1 μPa^{2}m^2.

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)

Reversible loss of hearing sensitivity. TTS can be caused by 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 difference between a specified level at one location and that at a different location, TL(x1,x2) = L(x1) − L(x2). Also see **propagation loss**.

unweighted

Term indicating that no frequency weighting function is applied. Synonymous with flat weighting.

very high-frequency (VHF) cetacean

See **hearing group**.

very low-frequency (VLF) cetacean

See **hearing group**.

wavelength

Distance over which a wave completes one cycle of oscillation. Unit: metre (m). Symbol: λ.

Literature Cited

[ANSI] American National Standards Institute and [ASA] Acoustical Society of America. S1.13-2005 (R2010). *American National Standard: Measurement of Sound Pressure Levels in Air*. NY, USA. https://webstore.ansi.org/Standards/ASA/ANSIASAS1132005R2010.

[DEWHA] Department of the Environment Water Heritage and the Arts. 2008. *EPBC Act Policy Statement 2.1 - Interaction Between Offshore Seismic Exploration and Whales*. *In*: Australian Government - Department of the Environment, Water, Heritage and the Arts. 14 p. http://www.environment.gov.au/resource/epbc-act-policy-statement-21-interaction-between-offshore-seismic-exploration-and-whales.

[HESS] High Energy Seismic Survey. 1999. *High Energy Seismic Survey Review Process and Interim Operational Guidelines for Marine Surveys Offshore Southern California*. Prepared for the California State Lands Commission and the United States Minerals Management Service Pacific Outer Continental Shelf Region by the High Energy Seismic Survey Team, Camarillo, CA, USA. 98 p. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB2001100103.xhtml.

[ISO] International Organization for Standardization. 2006. *ISO 80000-3:2006 Quantities and units – Part 3: Space and time*. https://www.iso.org/standard/31888.html.

[ISO] International Organization for Standardization. 2017. *ISO 18405:2017. Underwater acoustics – Terminology*. Geneva. https://www.iso.org/standard/62406.html.

[NMFS] National Marine Fisheries Service (US). 1998. *Acoustic Criteria Workshop*. Dr. Roger Gentry and Dr. Jeanette Thomas Co-Chairs.

[NMFS] National Marine Fisheries Service (US). 2016. *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts*. US Department of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-55. 178 p.

[NMFS] National Marine Fisheries Service (US). 2018. *2018 Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts*. US Department of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-59. 167 p. https://media.fisheries.noaa.gov/dam-migration/tech_memo_acoustic_guidance_(20)_(pdf)_508.pdf.

[NOAA] National Oceanic and Atmospheric Administration (US). 2013. *Draft guidance for assessing the effects of anthropogenic sound on marine mammals: Acoustic threshold levels for onset of permanent and temporary threshold shifts*. National Oceanic and Atmospheric Administration, US Department of Commerce, and NMFS Office of Protected Resources, Silver Spring, MD, USA. 76 p.

[NOAA] National Oceanic and Atmospheric Administration (US). 2015. *Draft guidance for assessing the effects of anthropogenic sound on marine mammal hearing: Underwater acoustic threshold levels for onset of permanent and temporary threshold shifts*. NMFS Office of Protected Resources, Silver Spring, MD, USA. 180 p.

[NOAA] National Oceanic and Atmospheric Administration (US). 2016. *Document Containing Proposed Changes to the NOAA Draft Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Threshold Levels for Onset of Permanent and Temporary Threshold Shifts*. National Oceanic and Atmospheric Administration and US Department of Commerce. 24 p.

[NOAA] National Oceanic and Atmospheric Administration (US). 2018. Takes of Marine Mammals Incidental to Specified Activities; Taking Marine Mammals Incidental to Marine Site Characterization Surveys off of Delaware. *Federal Register* 83(65): 14417-14443. https://www.federalregister.gov/d/2018-12225.

[NOAA] National Oceanic and Atmospheric Administration (US). 2019a. *ESA Section 7 Consultation Tools for Marine Mammals on the West Coast* (webpage), 27 Sep 2019. https://www.fisheries.noaa.gov/west-coast/endangered-species-conservation/esa-section-7-consultation-tools-marine-mammals-west.

[NOAA] National Oceanic and Atmospheric Administration (US). 2019b. *ESA Section 7 Consultation Tools for Marine Mammals on the West Coast* (webpage), 27 Sep 2019. https://www.fisheries.noaa.gov/west-coast/endangered-species-conservation/esa-section-7-consultation-tools-marine-mammals-west. (Accessed 10 Mar 2020).

[NSF] National Science Foundation (US), Geological Survey (US), and [NOAA] National Oceanic and Atmospheric Administration (US). 2011. *Final Programmatic Environmental Impact Statement/Overseas. Environmental Impact Statement for Marine Seismic Research Funded by the National Science Foundation or Conducted by the US Geological Survey*. National Science Foundation, Arlington, VA, USA. https://www.nsf.gov/geo/oce/envcomp/usgs-nsf-marine-seismic-research/nsf-usgs-final-eis-oeis_3june2011.pdf.

[ONR] Office of Naval Research. 1998. *ONR Workshop on the Effect of Anthropogenic Noise in the Marine Environment*. Dr. R. Gisiner, Chair.

Aerts, L.A.M., M. Blees, S.B. Blackwell, C.R. Greene, Jr., K.H. Kim, D.E. Hannay, and M.E. Austin. 2008. *Marine mammal monitoring and mitigation during BP Liberty OBC seismic survey in Foggy Island Bay, Beaufort Sea, July-August 2008: 90-day report*. Document Number P1011-1. Report by LGL Alaska Research Associates Inc., LGL Ltd., Greeneridge Sciences Inc., and JASCO Applied Sciences for BP Exploration Alaska. 199 p. ftp://ftp.library.noaa.gov/noaa_documents.lib/NMFS/Auke%20Bay/AukeBayScans/Removable%20Disk/P1011-1.pdf.

ANSI S1.1-2013. R2013. *American National Standard Acoustical Terminology*. American National Standards Institute, NY, USA.

Austin, M.E. and G.A. Warner. 2012. *Sound Source Acoustic Measurements for Apache's 2012 Cook Inlet Seismic Survey*. Version 2.0. Technical report by JASCO Applied Sciences for Fairweather LLC and Apache Corporation.

Austin, M.E. and L. Bailey. 2013. *Sound Source Verification: TGS Chukchi Sea Seismic Survey Program 2013*. Document Number 00706, Version 1.0. Technical report by JASCO Applied Sciences for TGS-NOPEC Geophysical Company.

Austin, M.E., A. McCrodan, C. O'Neill, Z. Li, and A.O. MacGillivray. 2013. *Marine mammal monitoring and mitigation during exploratory drilling by Shell in the Alaskan Chukchi and Beaufort Seas, July–November 2012: 90-Day Report*. *In*: Funk, D.W., C.M. Reiser, and W.R. Koski (eds.). Underwater Sound Measurements. LGL Rep. P1272D–1. Report from LGL Alaska Research Associates Inc. and JASCO Applied Sciences, for Shell Offshore Inc., National Marine Fisheries Service (US), and US Fish and Wildlife Service. 266 pp plus appendices.

Austin, M.E. 2014. Underwater noise emissions from drillships in the Arctic. *In*: Papadakis, J.S. and L. Bjørnø (eds.). *UA2014 - 2nd International Conference and Exhibition on Underwater Acoustics*. 22-27 Jun 2014, Rhodes, Greece. pp. 257-263.

Austin, M.E., H. Yurk, and R. Mills. 2015. *Acoustic Measurements and Animal Exclusion Zone Distance Verification for Furie's 2015 Kitchen Light Pile Driving Operations in Cook Inlet*. Version 2.0. Technical report by JASCO Applied Sciences for Jacobs LLC and Furie Alaska.

Austin, M.E. and Z. Li. 2016. *Marine Mammal Monitoring and Mitigation During Exploratory Drilling by Shell in the Alaskan Chukchi Sea, July–October 2015: Draft 90-day report*. *In*: Ireland, D.S. and L.N. Bisson (eds.). Underwater Sound Measurements. LGL Rep. P1363D. Report from LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Applied Sciences Ltd. For Shell Gulf of Mexico Inc, National Marine Fisheries Service, and US Fish and Wildlife Service. 188 pp + appendices.

Bartol, S.M. and D.R. Ketten. 2006. *Turtle and tuna hearing*. *In*: Swimmer, Y. and R. Brill (eds.). Sea turtle and pelagic fish sensory biology: Developing techniques to reduce sea turtle bycatch in longline fisheries. Volume December 2006. NOAA Technical Memorandum NMFS-PIFSC-7. 98-103 p. http://www.sefsc.noaa.gov/turtles/TM_NMFS_PIFSC_7_Swimmer_Brill.pdf#page=108.

Buckingham, M.J. 2005. Compressional and shear wave properties of marine sediments: Comparisons between theory and data. *Journal of the Acoustical Society of America* 117: 137-152. https://doi.org/10.1121/1.1810231.

Carnes, M.R. 2009. *Description and Evaluation of GDEM-V 3.0*. US Naval Research Laboratory, Stennis Space Center, MS. NRL Memorandum Report 7330-09-9165. 21 p. https://apps.dtic.mil/dtic/tr/fulltext/u2/a494306.pdf.

Collins, M.D. 1993. A split-step Padé solution for the parabolic equation method. *Journal of the Acoustical Society of America* 93(4): 1736-1742. https://doi.org/10.1121/1.406739.

Collins, M.D., R.J. Cederberg, D.B. King, and S. Chin-Bing. 1996. Comparison of algorithms for solving parabolic wave equations. *Journal of the Acoustical Society of America* 100(1): 178-182. https://doi.org/10.1121/1.415921.

Coppens, A.B. 1981. Simple equations for the speed of sound in Neptunian waters. *Journal of the Acoustical Society of America* 69(3): 862-863. https://doi.org/10.1121/1.382038.

Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, K. Hartmann, J.M. Semmens, and Institute for Marine and Antarctic Studies. 2016a. *Assessing the Impact of Marine Seismic Surveys on Southeast Australian Scallop and Lobster Fisheries*. Impacts of Marine Seismic Surveys on Scallop and Lobster Fisheries. Fisheries Ressearch & Development Corporation. FRDC Project No 2012/008, University of Tasmania, Hobart. 159 p.

Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, and J.M. Semmens. 2016b. Seismic air gun exposure during early-stage embryonic development does not negatively affect spiny lobster *Jasus edwardsii larvae* (Decapoda:Palinuridae). *Scientific Reports* 6: 1-9. https://doi.org/10.1038/srep22723.

Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, K. Hartmann, and J.M. Semmens. 2017. Exposure to seismic air gun signals causes physiological harm and alters behavior in the scallop *Pecten fumatus*. *Proceedings of the National Academy of Sciences of the United States of America* 114(40): E8537-E8546. https://doi.org/10.1073/pnas.1700564114.

Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, K. Hartmann, and J.M. Semmens. 2019. Seismic air guns damage rock lobster mechanosensory organs and impair righting reflex. *Proceedings of the Royal Society B* 286(1907). https://doi.org/10.1098/rspb.2019.1424.

Department of the Environment (Australian Government). 2015-2025. *Conservation Management Plan for the Blue Whale: A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999*. Department of the Environment, 2015. 57 p. http://www.environment.gov.au/system/files/resources/9c058c02-afd1-4e5d-abff-11cac2ebc486/files/blue-whale-conservation-management-plan.pdf.

Department of the Environment and Energy, NSW Government, and Queensland Government. 2017. *Recovery Plan for Marine Turtles in Australia*. https://www.environment.gov.au/marine/publications/recovery-plan-marine-turtles-australia-2017.

Double, M.C., V. Andrews-Goff, K.C.S. Jenner, M.-N. Jenner, S.M. Laverick, T.A. Branch, and N.J. Gales. 2014. Migratory Movements of Pygmy Blue Whales (*Balaenoptera musculus brevicauda*) between Australia and Indonesia as Revealed by Satellite Telemetry. *PLOS ONE* 9(4). https://doi.org/10.1371/journal.pone.0093578.

Dow Piniak, W.E., S.A. Eckert, C.A. Harms, and E.M. Stringer. 2012. *Underwater hearing sensitivity of the leatherback sea turtle (Dermochelys coriacea): Assessing the potential effect of anthropogenic noise*. US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2012-00156. 35 p.

Dragoset, W.H. 1984. A comprehensive method for evaluating the design of airguns and airgun arrays. *16th Annual Offshore Technology Conference* Volume 3, 7–9 May 1984. OTC 4747, Houston, TX, USA. pp. 75–84. https://doi.org/10.4043/4783-MS.

Ellison, W.T., C.W. Clark, and G.C. Bishop. 1987. *Potential use of surface reverberation by bowhead whales, Balaena mysticetus, in under-ice navigation: Preliminary considerations*. Report of the International Whaling Commission. Volume 37. 329-332 p.

Ellison, W.T. and P.J. Stein. 1999. *SURTASS LFA High Frequency Marine Mammal Monitoring (HF/M3) Sonar: Sustem Description and Test & Evaluation*. Under US Navy Contract N66604-98-D-5725. http://www.surtass-lfa-eis.com/wp-content/uploads/2018/02/HF-M3-Ellison-Report-2-4a.pdf.

Ellison, W.T. and A.S. Frankel. 2012. A common sense approach to source metrics. *In* Popper, A.N. and A.D. Hawkins (eds.). *The Effects of Noise on Aquatic Life*. Volume 730. Springer, New York. pp. 433-438. https://doi.org/10.1007/978-1-4419-7311-5_98.

Fields, D.M., N.O. Handegard, J. Dalen, C. Eichner, K. Malde, Ø. Karlsen, A.B. Skiftesvik, C.M.F. Durif, and H.I. Browman. 2019. Airgun blasts used in marine seismic surveys have limited effects on mortality, and no sublethal effects on behaviour or gene expression, in the copepod *Calanus finmarchicus*. *ICES Journal of Marine Science* 76(7): 2033–2044. https://doi.org/10.1093/icesjms/fsz126.

Finneran, J.J. and C.E. Schlundt. 2010. Frequency-dependent and longitudinal changes in noise-induced hearing loss in a bottlenose dolphin (*Tursiops truncatus*). *Journal of the Acoustical Society of America* 128(2): 567-570. https://doi.org/10.1121/1.3458814.

Finneran, J.J. and A.K. Jenkins. 2012. *Criteria and thresholds for U.S. Navy acoustic and explosive effects analysis*. SPAWAR Systems Center Pacific, San Diego, CA, USA. 64 p.

Finneran, J.J. 2015. *Auditory weighting functions and TTS/PTS exposure functions for cetaceans and marine carnivores*. Technical report by SSC Pacific, San Diego, CA, USA.

Finneran, J.J. 2016. *Auditory weighting functions and TTS/PTS exposure functions for marine mammals exposed to underwater noise*. Technical Report for Space and Naval Warfare Systems Center Pacific, San Diego, CA, USA. 49 p. https://apps.dtic.mil/dtic/tr/fulltext/u2/1026445.pdf.

Finneran, J.J., E.E. Henderson, D.S. Houser, K. Jenkins, S. Kotecki, and J. Mulsow. 2017. *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III)*. Technical report by Space and Naval Warfare Systems Center Pacific (SSC Pacific). 183 p. https://nwtteis.com/portals/nwtteis/files/technical_reports/Criteria_and_Thresholds_for_U.S._Navy_Acoustic_and_Explosive_Effects_Analysis_June2017.pdf.

Fisher, F.H. and V.P. Simmons. 1977. Sound absorption in sea water. *Journal of the Acoustical Society of America* 62(3): 558-564. https://doi.org/10.1121/1.381574.

Frankel, A.S., W.T. Ellison, and J. Buchanan. 2002. Application of the acoustic integration model (AIM) to predict and minimize environmental impacts. *OCEANS'02 MTS/IEEE*. pp. 1438-1443.

Funk, D.W., D.E. Hannay, D.S. Ireland, R. Rodrigues, and W.R. Koski. 2008. *Marine mammal monitoring and mitigation during open water seismic exploration by Shell Offshore Inc. in the Chukchi and Beaufort Seas, July–November 2007: 90-day report*. LGL Report P969-1. Prepared by LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Research Ltd. for Shell Offshore Inc., National Marine Fisheries Service (US), and US Fish and Wildlife Service. 218 p. http://www-static.shell.com/static/usa/downloads/alaska/shell2007_90-d_final.pdf.

Goldbogen, J.A., J. Calambokidis, E. Oleson, J. Potvin, N.D. Pyenson, G. Schorr, and R.E. Shadwick. 2011. Mechanics, hydrodynamics and energetics of blue whale lunge feeding: Efficiency dependence on krill density. *Journal of Experimental Biology* 214: 131-146. https://doi.org/10.1242/jeb.054726.

Hannay, D.E. and R. Racca. 2005. *Acoustic Model Validation*. Document Number 0000-S-90-04-T-7006-00-E, Revision 02, Version 1.3. Technical report by JASCO Research Ltd. for Sakhalin Energy Investment Company Ltd. 34 p.

Heap, A.D. 2009. *Marine Sediments (MARS) Database* (webpage). Commonwealth of Australia (Geoscience Australia), Creative Commons Attribution 4.0 International Licence. http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_69869.

Heyward, A., J. Colquhoun, E. Cripps, D. McCorry, M. Stowar, B. Radford, K. Miller, I. Miller, and C. Battershill. 2018. No evidence of damage to the soft tissue or skeletal integrity of mesophotic corals exposed to a 3D marine seismic survey. *Marine Pollution Bulletin* 129(1): 8-13. https://doi.org/10.1016/j.marpolbul.2018.01.057.

Houser, D.S. and M.J. Cross. 1999. *Marine Mammal Movement and Behavior (3MB): A Component of the Effects of Sound on the Marine Environment (ESME) Distributed Model*. Version 8.08, by BIOMIMETICA.

Houser, D.S. 2006. A method for modeling marine mammal movement and behavior for environmental impact assessment. *IEEE Journal of Oceanic Engineering* 31(1): 76-81. https://doi.org/10.1109/JOE.2006.872204.

Ireland, D.S., R. Rodrigues, D.W. Funk, W.R. Koski, and D.E. Hannay. 2009. *Marine mammal monitoring and mitigation during open water seismic exploration by Shell Offshore Inc. in the Chukchi and Beaufort Seas, July–October 2008: 90-Day Report*. Document Number P1049-1. 277 p.

Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. 2011. *Computational Ocean Acoustics*. 2nd edition. AIP Series in Modern Acourics and Signal Processing. AIP Press - Springer, New York. 794 p. https://doi.org/10.1007/978-1-4419-8678-8.

Landrø, M. 1992. Modeling of GI gun signatures. *Geophysical Prospecting* 40(7): 721–747. https://doi.org/10.1111/j.1365-2478.1992.tb00549.x.

Laws, R.M., L. Hatton, and M. Haartsen. 1990. Computer modelling of clustered airguns. *First Break* 8(9): 331–338. https://doi.org/10.3997/1365-2397.1990017.

Lucke, K., U. Siebert, P.A. Lepper, and M.-A. Blanchet. 2009. Temporary shift in masked hearing thresholds in a harbor porpoise (*Phocoena phocoena*) after exposure to seismic airgun stimuli. *Journal of the Acoustical Society of America* 125(6): 4060-4070. https://doi.org/10.1121/1.3117443.

Lurton, X. 2002. *An Introduction to Underwater Acoustics: Principles and Applications*. Springer, Chichester, UK. 347 p.

MacGillivray, A.O. and N.R. Chapman. 2012. Modeling underwater sound propagation from an airgun array using the parabolic equation method. *Canadian Acoustics* 40(1): 19-25. https://jcaa.caa-aca.ca/index.php/jcaa/article/view/2502/2251.

MacGillivray, A.O. 2018. Underwater noise from pile driving of conductor casing at a deep-water oil platform. *Journal of the Acoustical Society of America* 143(1): 450-459. https://doi.org/10.1121/1.5021554.

Malme, C.I., P.R. Miles, C.W. Clark, P.L. Tyack, and J.E. Bird. 1984. *Investigations of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Migrating Gray Whale Behavior. Phase II: January 1984 Migration*. Report Number 5586. Report by Bolt Beranek and Newman Inc. for the US Department of the Interior, Minerals Management Service, Cambridge, MA, USA. https://www.boem.gov/sites/default/files/boem-newsroom/Library/Publications/1983/rpt5586.pdf.

Martin, B., K. Bröker, M.-N.R. Matthews, J.T. MacDonnell, and L. Bailey. 2015. Comparison of measured and modeled air-gun array sound levels in Baffin Bay, West Greenland. *OceanNoise 2015*. 11-15 May 2015, Barcelona, Spain.

Martin, B., J.T. MacDonnell, and K. Bröker. 2017a. Cumulative sound exposure levels—Insights from seismic survey measurements. *Journal of the Acoustical Society of America* 141(5): 3603-3603. https://doi.org/10.1121/1.4987709.

Martin, S.B. and A.N. Popper. 2016. Short- and long-term monitoring of underwater sound levels in the Hudson River (New York, USA). *Journal of the Acoustical Society of America* 139(4): 1886-1897. https://doi.org/10.1121/1.4944876.

Martin, S.B., M.-N.R. Matthews, J.T. MacDonnell, and K. Bröker. 2017b. Characteristics of seismic survey pulses and the ambient soundscape in Baffin Bay and Melville Bay, West Greenland. *Journal of the Acoustical Society of America* 142(6): 3331-3346. https://doi.org/10.1121/1.5014049.

Matthews, M.-N.R. and A.O. MacGillivray. 2013. Comparing modeled and measured sound levels from a seismic survey in the Canadian Beaufort Sea. *Proceedings of Meetings on Acoustics* 19(1): 1-8. https://doi.org/10.1121/1.4800553.

Mattsson, A. and M. Jenkerson. 2008. Single Airgun and Cluster Measurement Project. *Joint Industry Programme (JIP) on Exploration and Production Sound and Marine Life Proramme Review*. 28-30 Oct 2008. International Association of Oil and Gas Producers, Houston, TX, USA.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, et al. 2000a. *Marine seismic surveys: Analysis and propagation of air-gun signals; and effects of air-gun exposure on humpback whales, sea turtles, fishes and squid*. Report Number R99-15. Prepared for Australian Petroleum Production Exploration Association by Centre for Maine Science and Technology, Western Australia. 198 p. https://cmst.curtin.edu.au/wp-content/uploads/sites/4/2016/05/McCauley-et-al-Seismic-effects-2000.pdf.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, et al. 2000b. Marine seismic surveys: A study of environmental implications. *Australian Petroleum Production Exploration Association (APPEA) Journal* 40(1): 692-708. https://doi.org/10.1071/AJ99048.

McCauley, R.D., R.D. Day, K.M. Swadling, Q.P. Fitzgibbon, R.A. Watson, and J.M. Semmens. 2017. Widely used marine seismic survey air gun operations negatively impact zooplankton. *Nature Ecology & Evolution* 1(7): 1-8. https://doi.org/10.1038/s41559-017-0195.

McCrodan, A., C.R. McPherson, and D.E. Hannay. 2011. *Sound Source Characterization (SSC) Measurements for Apache's 2011 Cook Inlet 2D Technology Test*. Version 3.0. Technical report by JASCO Applied Sciences for Fairweather LLC and Apache Corporation. 51 p.

McPherson, C.R. and G.A. Warner. 2012. *Sound Sources Characterization for the 2012 Simpson Lagoon OBC Seismic Survey 90-Day Report*. Document Number 00443, Version 2.0. Technical report by JASCO Applied Sciences for BP Exploration (Alaska) Inc.

McPherson, C.R., K. Lucke, B.J. Gaudet, S.B. Martin, and C.J. Whitt. 2018. *Pelican 3-D Seismic Survey Sound Source Characterisation*. Document Number 001583. Version 1.0. Technical report by JASCO Applied Sciences for RPS Energy Services Pty Ltd.

McPherson, C.R. and B. Martin. 2018. *Characterisation of Polarcus 2380 in^3 Airgun Array*. Document Number 001599, Version 1.0. Technical report by JASCO Applied Sciences for Polarcus Asia Pacific Pte Ltd.

Möller, L.M., C.R.M. Attard, K. Bilgmann, V. Andrews-Goff, I. Jonsen, D. Paton, and M.C. Double. 2020. Movements and behaviour of blue whales satellite tagged in an Australian upwelling system. *Scientific Reports* 10(1): 21165. https://doi.org/10.1038/s41598-020-78143-2.

Nedwell, J.R. and A.W. Turnpenny. 1998. The use of a generic frequency weighting scale in estimating environmental effect. *Workshop on Seismics and Marine Mammals*. 23–25 Jun 1998, London, UK.

Nedwell, J.R., A.W. Turnpenny, J. Lovell, S.J. Parvin, R. Workman, J.A.L. Spinks, and D. Howell. 2007. *A validation of the dB_{ht} as a measure of the behavioural and auditory effects of underwater noise*. Document Number 534R1231 Report prepared by Subacoustech Ltd. for Chevron Ltd, TotalFinaElf Exploration UK PLC, Department of Business, Enterprise and Regulatory Reform, Shell UK Exploration and Production Ltd, The Industry Technology Facilitator, Joint Nature Conservation Committee, and The UK Ministry of Defence. 74 p. https://tethys.pnnl.gov/sites/default/files/publications/Nedwell-et-al-2007.pdf.

O'Neill, C., D. Leary, and A. McCrodan. 2010. Sound Source Verification. (Chapter 3) *In* Blees, M.K., K.G. Hartin, D.S. Ireland, and D.E. Hannay (eds.). *Marine mammal monitoring and mitigation during open water seismic exploration by Statoil USA E&P Inc. in the Chukchi Sea, August-October 2010: 90-day report*. LGL Report P1119. Prepared by LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Applied Sciences Ltd. for Statoil USA E&P Inc., National Marine Fisheries Service (US), and US Fish and Wildlife Service. pp. 1-34.

Owen, K., C.S. Jenner, M.-N.M. Jenner, and R.D. Andrews. 2016. A week in the life of a pygmy blue whale: Migratory dive depth overlaps with large vessel drafts. *Animal Biotelemetry* 4: 17. https://doi.org/10.1186/s40317-016-0109-4.

Payne, J.F., C. Andrews, L. Fancey, D. White, and J. Christian. 2008. *Potential Effects of Seismic Energy on Fish and Shellfish: An Update since 2003*. Report Number 2008/060. Canadian Science Advisory Secretariat. 22 p.

Payne, R. and D. Webb. 1971. Orientation by means of long range acoustic signaling in baleen whales. *Annals of the New York Academy of Sciences* 188: 110-141. https://doi.org/10.1111/j.1749-6632.1971.tb13093.x.

Popper, A.N., A.D. Hawkins, R.R. Fay, D.A. Mann, S. Bartol, T.J. Carlson, S. Coombs, W.T. Ellison, R.L. Gentry, et al. 2014. *Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI*. ASA S3/SC1.4 TR-2014. SpringerBriefs in Oceanography. ASA Press and Springer. https://doi.org/10.1007/978-3-319-06659-2.

Porter, M.B. and Y.C. Liu. 1994. Finite-element ray tracing. *In*: Lee, D. and M.H. Schultz (eds.). *International Conference on Theoretical and Computational Acoustics*. Volume 2. World Scientific Publishing Co. pp. 947-956.

Racca, R., A.N. Rutenko, K. Bröker, and M.E. Austin. 2012a. A line in the water - design and enactment of a closed loop, model based sound level boundary estimation strategy for mitigation of behavioural impacts from a seismic survey. *11th European Conference on Underwater Acoustics*. Volume 34(3), Edinburgh, UK.

Racca, R., A.N. Rutenko, K. Bröker, and G. Gailey. 2012b. Model based sound level estimation and in-field adjustment for real-time mitigation of behavioural impacts from a seismic survey and post-event evaluation of sound exposure for individual whales. *In*: McMinn, T. (ed.). *Acoustics 2012*. Fremantle, Australia. http://www.acoustics.asn.au/conference_proceedings/AAS2012/papers/p92.pdf.

Racca, R., M.E. Austin, A.N. Rutenko, and K. Bröker. 2015. Monitoring the gray whale sound exposure mitigation zone and estimating acoustic transmission during a 4-D seismic survey, Sakhalin Island, Russia. *Endangered Species Research* 29(2): 131-146. https://doi.org/10.3354/esr00703.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, Jr., D. Kastak, D.R. Ketten, J.H. Miller, et al. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. *Aquatic Mammals* 33(4): 411-521. https://doi.org/10.1578/AM.33.4.2007.411.

Southall, B.L., D.P. Nowaceck, P.J.O. Miller, and P.L. Tyack. 2016. Experimental field studies to measure behavioral responses of cetaceans to sonar. *Endangered Species Research* 31: 293-315. https://doi.org/10.3354/esr00764.

Southall, B.L., J.J. Finneran, C. Reichmuth, P.E. Nachtigall, D.R. Ketten, A.E. Bowles, W.T. Ellison, D.P. Nowacek, and P.L. Tyack. 2019a. Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. *Aquatic Mammals* 45(2): 125-232. https://doi.org/10.1578/AM.45.2.2019.125.

Southall, B.L., J.J. Finneran, C.J. Reichmuth, P.E. Nachtigall, D.R. Ketten, A.E. Bowles, W.T. Ellison, D.P. Nowacek, and P.L. Tyack. 2019b. Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. *Aquatic Mammals* 45(2): 125-232. https://doi.org/10.1578/AM.45.2.2019.125.

Southall, B.L., D.P. Nowacek, A.E. Bowles, V. Senigaglia, L. Bejder, and P.L. Tyack. 2021. Marine Mammal Noise Exposure Criteria: Assessing the Severity of Marine Mammal Behavioral Responses to Human Noise. *Aquatic Mammals* 47(5): 421-464.

Teague, W.J., M.J. Carron, and P.J. Hogan. 1990. A comparison between the Generalized Digital Environmental Model and Levitus climatologies. *Journal of Geophysical Research* 95(C5): 7167-7183. https://doi.org/10.1029/JC095iC05p07167.

Warner, G.A., C. Erbe, and D.E. Hannay. 2010. Underwater Sound Measurements. (Chapter 3) *In* Reiser, C.M., D. Funk, R. Rodrigues, and D.E. Hannay (eds.). *Marine Mammal Monitoring and Mitigation during Open Water Shallow Hazards and Site Clearance Surveys by Shell Offshore Inc. in the Alaskan Chukchi Sea, July-October 2009: 90-Day Report*. LGL Report P1112-1. Report by LGL Alaska Research Associates Inc. and JASCO Applied Sciences for Shell Offshore Inc., National Marine Fisheries Service (US), and Fish and Wildlife Service (US). pp. 1-54.

Warner, G.A., M.E. Austin, and A.O. MacGillivray. 2017. Hydroacoustic measurements and modeling of pile driving operations in Ketchikan, Alaska [Abstract]. *Journal of the Acoustical Society of America* 141(5): 3992. https://doi.org/10.1121/1.4989141.

Whiteway, T. 2009. *Australian Bathymetry and Topography Grid, June 2009*. GeoScience Australia, Canberra. http://pid.geoscience.gov.au/dataset/ga/67703.

Wood, J.D., B.L. Southall, and D.J. Tollit. 2012. *PG&E offshore 3-D Seismic Survey Project Environmental Impact Report–Marine Mammal Technical Draft Report*. Report by SMRU Ltd. 121 p. https://www.coastal.ca.gov/energy/seismic/mm-technical-report-EIR.pdf.

Zhang, Z.Y. and C.T. Tindle. 1995. Improved equivalent fluid approximations for a low shear speed ocean bottom. *Journal of the Acoustical Society of America* 98(6): 3391-3396. https://doi.org/10.1121/1.413789.

Ziolkowski, A.M. 1970. A method for calculating the output pressure waveform from an air gun. *Geophysical Journal International* 21(2): 137-161. https://doi.org/10.1111/j.1365-246X.1970.tb01773.x.

Zykov, M.M. and J.T. MacDonnell. 2013. *Sound Source Characterizations for the Collaborative Baseline Survey Offshore Massachusetts Final Report: Side Scan Sonar, Sub-Bottom Profiler, and the R/V Small Research Vessel experimental*. Document Number 00413, Version 2.0. Technical report by JASCO Applied Sciences for Fugro GeoServices, Inc. and the (US) Bureau of Ocean Energy Management.

Appendix A. Acoustic Metrics

A.1. Pressure Related Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 μPa. Because the perceived loudness of sound, especially 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 $L_{p,pk}$; dB re 1 µPa), is the decibel level of the maximum instantaneous acoustic pressure in a stated frequency band attained by an acoustic pressure signal, $p(t)$:

$$L_{p,\mathrm{pk}} = 10\log_{10}\frac{\max|p^2(t)|}{p_0^2} = 20\log_{10}\frac{\max|p(t)|}{p_0} \qquad \text{(A-1)}$$

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 $L_{p,pk\text{-}pk}$; dB re 1 µPa) is the difference between the maximum and minimum instantaneous sound pressure, possibly filtered in a stated frequency band, attained by an impulsive sound, $p(t)$:

$$L_{p,\mathrm{pk\text{-}pk}} = 10\log_{10}\frac{[\max(p(t)) - \min(p(t))]^2}{p_0^2} \qquad \text{(A-2)}$$

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 ($L_{p,fast}$) 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 $L_{p,boxcar\ 125ms}$. 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 are referred to as 90% SPL ($L_{p,90\%}$).

The sound exposure level (SEL or L_E; dB re 1 μPa²·s) is the time-integral of the squared acoustic pressure over a duration (T):

$$L_E = 10\log_{10}\left(\int_T p^2(t)\,dt \Big/ T_0 p_0^2\right) \quad \text{(A-4)}$$

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:

$$L_{E,N} = 10\log_{10}\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}} \quad \text{(A-5)}$$

If applied, the frequency weighting of an acoustic event should be specified, as in the case of weighted SEL (e.g., $L_{E,LF,24h}$; see Appendix A.4) or auditory-weighted SPL ($L_{p,ht}$). The use of fast, slow, or impulse exponential-time-averaging or other time-related characteristics should also be specified.

A.1. 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:

$$v = -\int \nabla p(t)dt/\rho_0 \quad \text{(A-6)}$$

The particle acceleration (a) is the rate of change of the velocity with respect to time, and it can be obtained from equation A-6 as:

$$a = \frac{dv}{dt} = -\frac{\nabla p(t)}{\rho_0} \quad \text{(A-7)}$$

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:

$$|v| = \sqrt{v_x + v_y + v_z} \quad \text{(A-8)}$$

The magnitude of particle acceleration is calculated similarly from the particle acceleration in the *x*, *y*, and *z* directions.

A.2. Decidecade Band Analysis

The distribution of a sound's power with frequency is described by the sound's spectrum. The sound spectrum can be split into a series of adjacent frequency bands. Splitting a spectrum into 1 Hz wide bands, called passbands, yields the power spectral density of the sound. This splitting of the spectrum into passbands of a constant width of 1 Hz, however, does not represent how animals perceive sound.

Because animals perceive exponential increases in frequency rather than linear increases, analysing a sound spectrum with passbands that increase exponentially in size better approximates real-world scenarios. In underwater acoustics, a spectrum is commonly split into decidecade bands, which are one tenth of a decade wide. They are approximately one third of an octave (base 2) wide and are therefore often referred to as 1/3-octave-bands. Each octave represents a doubling in sound frequency. The centre frequency of the ith band, $f_c(i)$, is defined as:

$$f_c(i) = 10^{\frac{i}{10}}\ \text{kHz} \tag{A-9}$$

and the low (f_{lo}) and high (f_{hi}) frequency limits of the ith decade band are defined as:

$$f_{lo,i} = 10^{\frac{-1}{20}} f_c(i) \quad \text{and} \quad f_{hi,i} = 10^{\frac{1}{20}} f_c(i) \tag{A-10}$$

The decidecade bands become wider with increasing frequency, and on a logarithmic scale the bands appear equally spaced (Figure A-1). The acoustic modelling spans from band 7 (f_c (7) = 5 Hz) to band 44 (f_c(44) = 25 kHz).

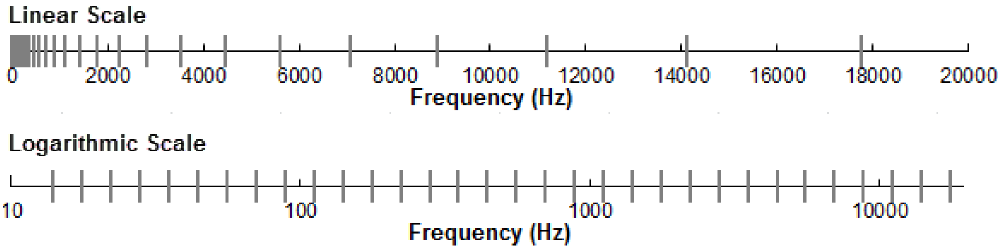


Figure A-1. Decidecade frequency bands (vertical lines) shown on a linear frequency scale and a logarithmic scale.

The sound pressure level in the ith band ($L_{p,i}$) is computed from the spectrum $S(f)$ between $f_{lo,i}$ and $f_{hi,i}$:

$$L_{p,i} = 10 \log_{10} \int_{f_{lo,i}}^{f_{hi,i}} S(f)\, df \tag{A-11}$$

Summing the sound pressure level of all the bands yields the broadband sound pressure level:

$$\text{Broadband SPL} = 10 \log_{10} \sum_i 10^{\frac{L_{p,i}}{10}} \tag{A-12}$$

Figure A-2 shows an example of how the decidecade band sound pressure levels compare to the sound pressure spectral density levels of an ambient noise signal. Because the decidecade bands are wider with increasing frequency, the decidecade band SPL is higher than the spectral levels at higher frequencies. Acoustic modelling of decidecade bands requires less computation time than 1 Hz bands and still resolves the frequency-dependence of the sound source and the propagation environment.

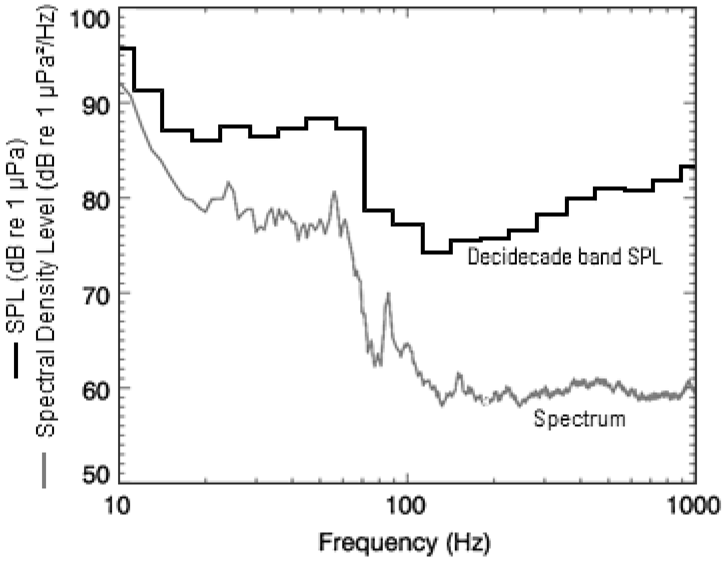


Figure A-2. Sound pressure spectral density levels and the corresponding decidecade band sound pressure levels of example ambient noise shown on a logarithmic frequency scale.

A.3. Marine Mammal Impact Criteria

It has been long recognised that marine mammals can be adversely affected by underwater anthropogenic noise. For example, Payne and Webb (1971) suggested that communication distances of fin whales are reduced by shipping sounds. Subsequently, similar concerns arose regarding effects of other underwater noise sources and the possibility that impulsive sources—primarily airguns used in seismic surveys—could cause auditory injury. This led to a series of workshops held in the late 1990s, conducted to address acoustic mitigation requirements for seismic surveys and other underwater noise sources (NMFS 1998, ONR 1998, Nedwell and Turnpenny 1998, HESS 1999, Ellison and Stein 1999). In the years since these early workshops, a variety of thresholds have been proposed for both injury and disturbance. The following sections summarize the recent development of thresholds; however, this field remains an active research topic.

A.3.1. Injury

In recognition of shortcomings of the SPL-only based injury criteria, in 2005 NMFS sponsored the Noise Criteria Group to review literature on marine mammal hearing to propose new noise exposure criteria. Some members of this expert group published a landmark paper (Southall et al. 2007) that suggested assessment methods similar to those applied for humans. The resulting recommendations introduced dual acoustic injury criteria for impulsive sounds that included peak pressure level thresholds and SEL_{24h} thresholds, where the subscripted 24h refers to the accumulation period for calculating SEL. The peak pressure level criterion is not frequency weighted whereas the SEL_{24h} is frequency weighted according to one of four marine mammal species hearing groups: low-, mid- and high-frequency cetaceans (LF, MF, and HF cetaceans, respectively) and Pinnipeds in Water (PINN). These weighting functions are referred to as M-weighting filters (analogous to the A-weighting filter for human; Appendix A.4). The SEL_{24h} thresholds were obtained by extrapolating measurements of onset levels of Temporary Threshold Shift (TTS) in belugas by the amount of TTS required to produce Permanent Threshold Shift (PTS) in chinchillas. The Southall et al. (2007) recommendations do not specify an exchange rate, which suggests that the thresholds are the same regardless of the duration of exposure (i.e., it implies a 3 dB exchange rate).

Wood et al. (2012) refined Southall et al.'s (2007) thresholds, suggesting lower injury values for LF and HF cetaceans while retaining the filter shapes. Their revised thresholds were based on TTS-onset levels in harbour porpoises from Lucke et al. (2009), which led to a revised impulsive sound PTS threshold for HF cetaceans of 179 dB re 1 µPa^2·s. Because there were no data available for baleen whales, Wood et al. (2012) based their recommendations for LF cetaceans on results obtained from MF cetacean studies. In particular they referenced Finneran and Schlundt (2010) research, which found mid-frequency cetaceans are more sensitive to non-impulsive sound exposure than Southall et al. (2007) assumed. Wood et al. (2012) thus recommended a more conservative TTS-onset level for LF cetaceans of 192 dB re 1 µPa^2·s.

As of present, 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). The latest criteria are from Southall et al. (2019b) which is applied in this report.

A.3.2. Behavioural response

Numerous studies on marine mammal behavioural responses to sound exposure have not resulted in consensus in the scientific community regarding the appropriate metric for assessing behavioural reactions. However, it is recognised that the context in which the sound is received affects the nature and extent of responses to a stimulus (Southall et al. 2007, Ellison and Frankel 2012, Southall et al. 2016).

For impulsive noise, NMFS currently uses step function thresholds of 160 dB re 1 µPa SPL (unweighted) to assess and regulate noise-induced behavioural impacts for marine mammals (NOAA 2018, NOAA 2019b). The threshold for impulsive sound is derived from the High-Energy Seismic Survey (HESS) panel (HESS 1999) report that, in turn, is based on the responses of migrating mysticete whales to airgun sounds (Malme et al. 1984). The HESS team recognised that behavioural responses to sound may occur at lower levels, but significant responses were only likely to occur above a SPL of 140 dB re 1 µPa. Southall et al. (2007) found varying responses for most marine mammals between a SPL of 140 and 180 dB re 1 µPa, consistent with the HESS (1999) report, but lack of convergence in the data prevented them from suggesting explicit step functions.

A.4. Marine Mammal Frequency Weighting

The potential for noise to affect animals depends on how well the animals can hear it. Noises are less likely to disturb or injure an animal if they are at frequencies that the animal cannot hear well. An exception occurs when the sound pressure is so high that it can physically injure an animal by non-auditory means (i.e., barotrauma). For sound levels below such extremes, the importance of sound components at particular frequencies can be scaled by frequency weighting relevant to an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

A.4.1. Marine Mammal Frequency Weighting Functions

In 2015, a US Navy technical report by Finneran (2015) recommended new auditory weighting functions. The overall shape of the auditory weighting functions is similar to human A-weighting functions, which follows the sensitivity of the human ear at low sound levels. The new frequency-weighting function is expressed as:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^2\right]^a\left[1+(f/f_{hi})^2\right]^b}\right)\right] \quad \text{(A-13)}$$

Finneran (2015) proposed five functional hearing groups for marine mammals in water: low-, mid- and high-frequency cetaceans (LF, MF, and HF cetaceans, respectively), 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 acoustic impacts on marine mammals (NMFS 2018), and in the latest guidance by Southall (2019b). The updates did not affect the content related to either the definitions of frequency-weighting functions or the threshold values. Table A-1 lists the frequency-weighting parameters for each hearing group. Figure A-3 shows the resulting frequency-weighting curves.

Table A-1. Parameters for the auditory weighting functions used in this project as recommended by Southall et al. (2019b).

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
High-frequency cetaceans (dolphins, plus toothed, beaked, and bottlenose whales)	1.6	2	8,800	110,000	1.20
Very-high-frequency cetaceans (true porpoises, *Kogia*, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* and *L. australis*)	1.8	2	12,000	140,000	1.36
Sirenians (Dugongs)	1.8	2	4,300	25,000	2.62

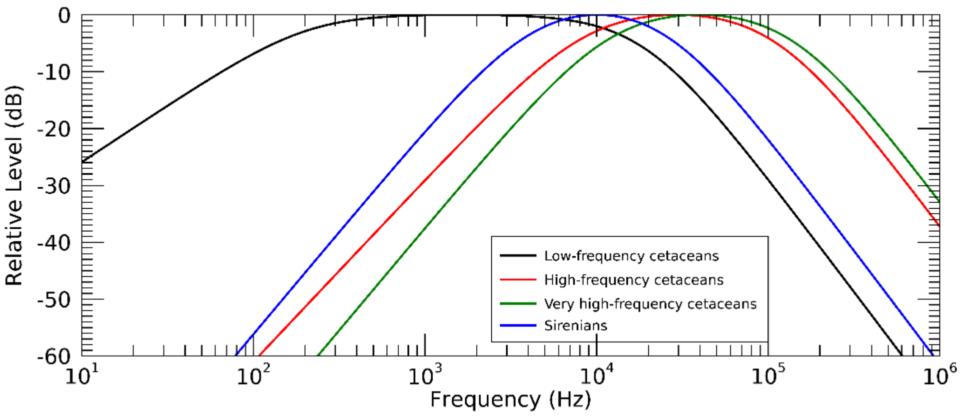


Figure A-3. Auditory weighting functions for functional marine mammal hearing groups used in this project as recommended by Southall et al. (2019b).

Appendix B. Acoustic Source Model

B.1. Airgun Array Source Model

The source levels and directivity of the seismic source were predicted with JASCO's Airgun Array Source Model (AASM). AASM includes low- and high-frequency modules for predicting different components of the seismic source spectrum. The low-frequency module is based on the physics of oscillation and radiation of airgun bubbles, as originally described by Ziolkowski (1970), that solves the set of parallel differential equations that govern bubble oscillations. Physical effects accounted for in the simulation include pressure interactions between airguns, port throttling, bubble damping, and generator-injector (GI) gun behaviour discussed by Dragoset (1984), Laws et al. (1990), and Landrø (1992). A global optimisation algorithm tunes free parameters in the model to a large library of airgun source signatures.

While airgun signatures are highly repeatable at the low frequencies, which are used for seismic imaging, their sound emissions have a large random component at higher frequencies that cannot be predicted using a deterministic model. Therefore, AASM uses a stochastic simulation to predict the high-frequency (800−25,000 Hz) sound emissions of individual airguns, using a data-driven multiple-regression model. The multiple-regression model is based on a statistical analysis of a large collection of high quality seismic source signature data recently obtained from the Joint Industry Program (JIP) on Sound and Marine Life (Mattsson and Jenkerson 2008). The stochastic model uses a Monte-Carlo simulation to simulate the random component of the high-frequency spectrum of each airgun in an array. The mean high-frequency spectra from the stochastic model augment the low-frequency signatures from the physical model, allowing AASM to predict airgun source levels at frequencies up to 25,000 Hz.

AASM produces a set of "notional" signatures for each array element based on:

- Array layout
- Volume, tow depth, and firing pressure of each airgun
- Interactions between different airguns in the array

These notional signatures are the pressure waveforms of the individual airguns at a standard reference distance of 1 m; they account for the interactions with the other airguns in the array. The signatures are summed with the appropriate phase delays to obtain the far-field source signature of the entire array in all directions. This far-field array signature is filtered into decidecade-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. Seismic Source

The layout of the 3000 in^3 seismic sources used for modelling in this study is provided in Figure B-1. Details of the airgun parameters are provided in Tables B-1.

For the modelled array, the layout is presented in a nominal cartesian coordinate system. In this coordinate system the direction of vessel travel determines the relative position of the array elements as plotted and tabulated. The layout used for acoustic modelling was produced by transforming the coordinates of client supplied layouts such that the resultant layouts correspond to a vessel travel direction along the positive X-axis and the array is centred on the X-Y origin. When used with an acoustic model the positive X-axis in this nominal coordinate system aligns with the vessel tow direction or survey line azimuth.

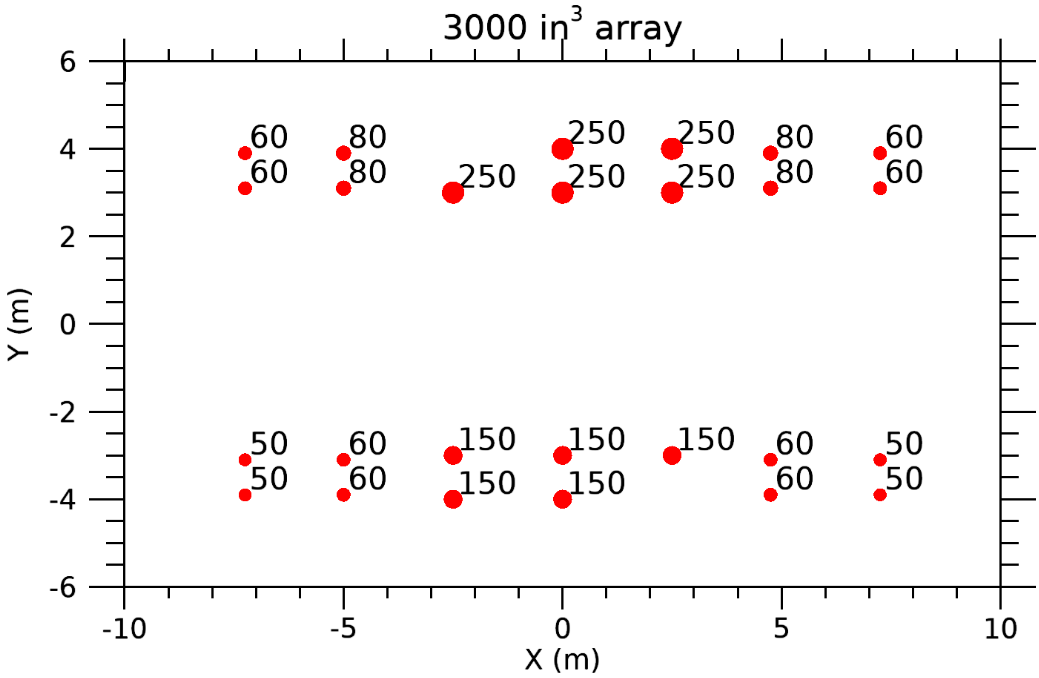


Figure B-1. Layout of the modelled 3000 in^3 seismic source where the plotted layout is such that the array is centred on the origin and vessel travel direction is in the positive x-direction. Tow depth is 8 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table B-1.

Table B-1. Layout of the modelled 3000 in³ seismic source. Tow depth was 8 m. Firing pressure for all guns was 2000 psi. Greyed out values indicate spares. Also see Figure B-1.

String	Gun	*x* (m)	*y* (m)	*z* (m)	Vol (in³)	String	Gun	*x* (m)	*y* (m)	*z* (m)	Vol (in³)
1	1	7.25	-3.9	8	50	2	1	7.25	3.1	8	60
	2	7.25	-3.1	8	50		2	7.25	3.9	8	60
	3	4.75	-3.9	8	60		3	4.75	3.1	8	80
	4	4.75	-3.1	8	60		4	4.75	3.9	8	80
	5	2.5	-4	8	150		5	2.5	3	8	250
	6	2.5	-3	8	150		6	2.5	4	8	250
	7	0	-4	8	150		7	0	3	8	250
	8	0	-3	8	150		8	0	4	8	250
	9	-2.5	-4	8	150		9	-2.5	3	8	250
	10	-2.5	-3	8	150		10	-2.5	4	8	250
	11	-5	-3.9	8	60		11	-5	3.1	8	80
	12	-5	-3.1	8	60		12	-5	3.9	8	80
	13	-7.25	-3.9	8	50		13	-7.25	3.1	8	60
	14	-7.25	-3.1	8	50		14	-7.25	3.9	8	60

B.3. Array Source Levels and Directivity

Figure B-2 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 3000 in³ seismic source (Appendix B.2). Horizontal decidecade-band source levels are shown as a function of band centre frequency and azimuth in Figures B-3.

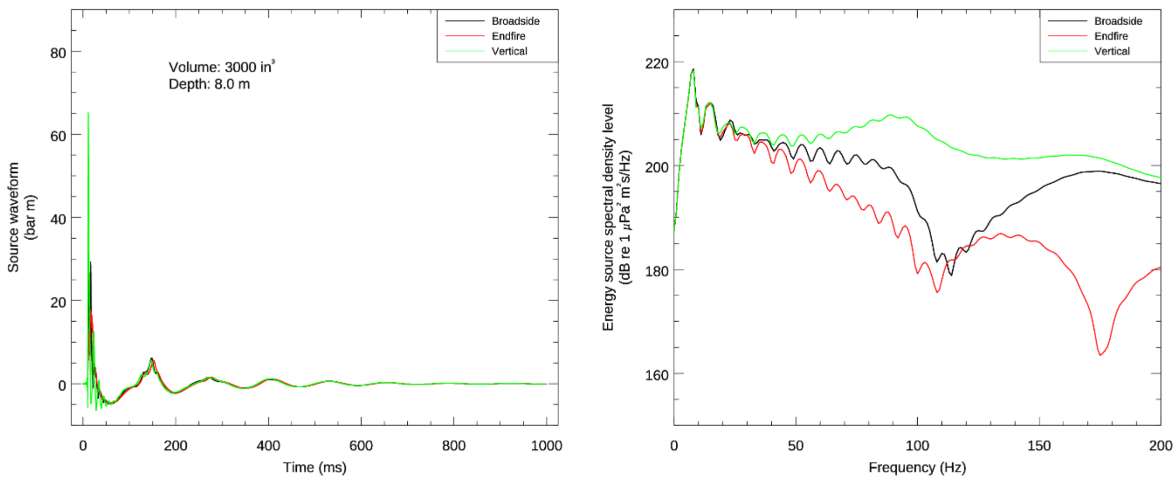


Figure B-2. Predicted source level details for the 3000 in³ seismic source with an 8 m towed depth. (Left) the overpressure signature and (right) the power spectrum for in-plane horizontal (broadside), perpendicular (endfire), and vertical directions (no surface ghost).

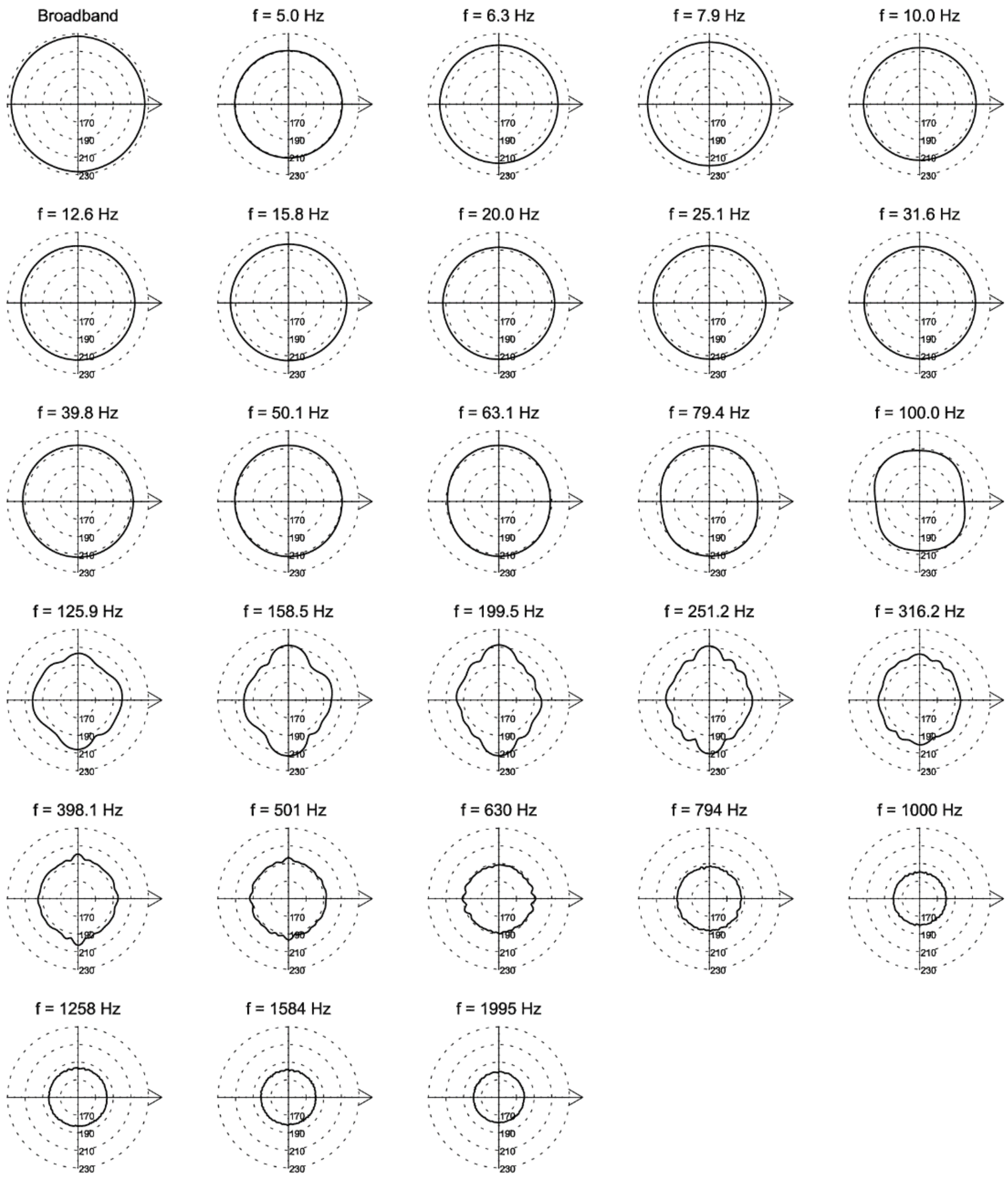


Figure B-3. Directionality of the predicted horizontal source levels for the 3000 in^3 seismic source, 5 Hz to 2 kHz. Source levels (in dB re 1 µPa^2·s m^2) are shown as a function of azimuth for the centre frequencies of the decidecade bands modelled; frequencies are shown above the plots. The perpendicular direction to the frame is to the right. Tow depth is 8 m (see Table B-1).

Appendix C. Sound Propagation Models

C.1. MONM-BELLHOP

Long-range sound fields were computed using JASCO's Marine Operations Noise Model (MONM). Compared to VSTACK, MONM less accurately predicts steep-angle propagation for environments with higher shear speed but is well suited for effective longer-range estimation. This model computes sound propagation at frequencies of 5 Hz to 1 kHz via a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the US 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 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).

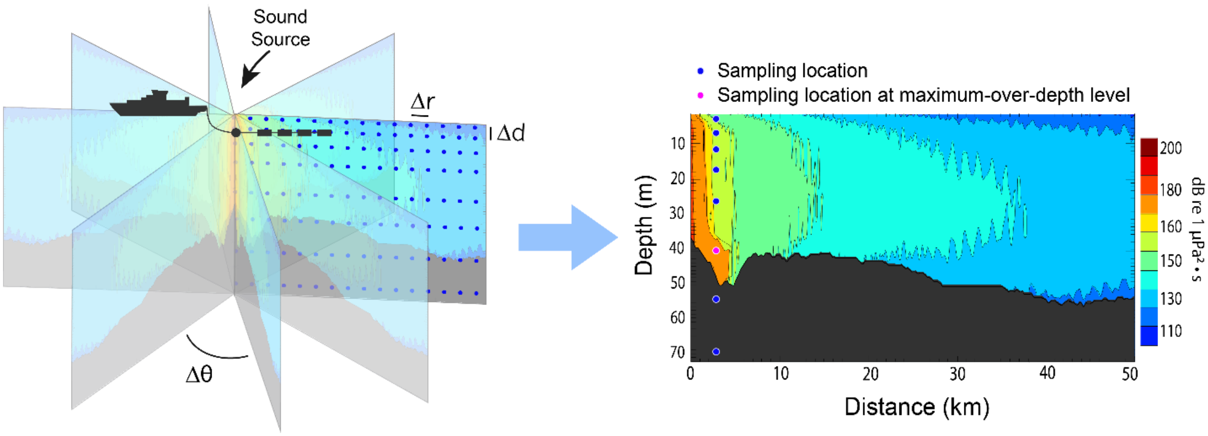


Figure C-1. The N×2-D and maximum-over-depth modelling approach used by MONM.

MONM treats frequency dependence by computing acoustic transmission loss at the centre frequencies of decidecade bands. Sufficiently many decidecade bands, starting at 5 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 decidecade 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 decidecade 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. The maximum received per-pulse SEL at many sampling depths are taken 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 contours around the source.

C.2. Full Waveform Range-dependent Acoustic Model: FWRAM

For impulsive sounds from the seismic source, time-domain representations of the pressure waves generated in the water are required to calculate SPL and PK. Furthermore, the seismic source must be represented as a distributed source to accurately characterise vertical directivity effects in the near-field zone. For this study, synthetic pressure waveforms were computed using FWRAM, which is a time-domain acoustic model based on the same wide-angle parabolic equation (PE) algorithm as MONM. FWRAM computes synthetic pressure waveforms versus range and depth for range-varying marine acoustic environments, and it takes the same environmental inputs as MONM (bathymetry, water sound speed profile, and seafloor geoacoustic profile). Unlike MONM, FWRAM computes pressure waveforms via Fourier synthesis of the modelled acoustic transfer function in closely spaced frequency bands. FWRAM employs the array starter method to accurately model sound propagation from a spatially distributed source (MacGillivray and Chapman 2012).

Besides providing direct calculations of the PK and SPL, the synthetic waveforms from FWRAM can also be used to convert the SEL values from MONM to SPL.

C.3. Wavenumber Integration Model

Sound pressure levels near the seismic source were modelled using JASCO's VSTACK wavenumber integration model. VSTACK computes synthetic pressure waveforms versus depth and range for arbitrarily layered, range-independent acoustic environments using the wavenumber integration approach to solve the exact (range-independent) acoustic wave equation. This model is valid over the full angular range of the wave equation and can fully account for the elasto-acoustic properties of the sub-bottom. Wavenumber integration methods are extensively used in the field of underwater acoustics and seismology where they are often referred to as reflectivity methods or discrete wavenumber methods. VSTACK computes sound propagation in arbitrarily stratified water and seabed layers by decomposing the outgoing field into a continuum of outward-propagating plane cylindrical waves. Seabed reflectivity in the model is dependent on the seabed layer properties: compressional and shear wave speeds, attenuation coefficients, and layer densities. The output of the model can be post-processed to yield estimates of the SEL, SPL, and PK.

VSTACK accurately predicts steep-angle propagation in the proximity of the source, but it is computationally slow at predicting sound pressures at large distances due to the need for smaller wavenumber steps with increasing distance. Additionally, VSTACK assumes range-invariant bathymetry with a horizontally stratified medium (i.e., a range-independent environment) which is azimuthally symmetric about the source. VSTACK is thus best suited to modelling the sound field near the source.

C.3.1. Particle Motion

VSTACK was also used to compute estimates of particle acceleration and velocity at three sites for the 3000 in^3 seismic source. Particle motion waveforms were modelled, and pulse metrics were computed from the time-domain traces. VSTACK uses the wavenumber integration approach to solve the exact acoustic wave equation for arbitrarily layered range-independent acoustic environments.

The VSTACK model setup for the particle velocity scenarios was identical to that for the peak pressure scenarios (Section 5.2.1.2) in terms of source treatment, frequency range and environmental model. The particle acceleration and velocity waveforms were computed to a maximum distance of 1000 m in the broadside and endfire directions from the centre of the airgun array for a receiver 5 cm above the seafloor.

As discussed above in Appendix A.1, particle velocity (v) is the physical speed of a particle in a material. It can be derived from the pressure gradient and Euler's linearised momentum equation where ρ_0 is the density of the medium. Since the wavenumber integration kernel is a product of analytic expressions in terms of range and depth, VSTACK computes particle velocity by computing the spatial gradient of the pressure field analytically in the frequency domain. Fourier synthesis is applied to compute time series synthetic pressure and/or velocity waveforms at depth and range receivers by convolving the source waveforms with the impulse response of the waveguide. Particle velocity metrics at each receiver location were calculated from the modelled particle motion along three perpendicular axes (horizontal and along the source-receiver path, horizontal and perpendicular to the source-receiver path, and vertical).

The particle velocity results were converted to acceleration by time differentiation. The peak particle acceleration and velocity were calculated from the maximum of the predicted acceleration and velocity magnitude, defined as "peak magnitude" and are presented as plots of peak value versus range.

Appendix D. Methods and Parameters

This section the environmental parameters used in the propagation models.

D.1. Estimating Range to Thresholds Levels

Sound level contours were calculated based on the underwater sound fields predicted by the propagation models, sampled by taking the maximum value over all modelled depths above the sea floor for each location in the modelled region. The predicted distances to specific levels were computed from these contours. Two distances relative to the source are reported for each sound level: 1) R_{max}, the maximum range to the given sound level over all azimuths, and 2) $R_{95\%}$, the range to the given sound level after the 5% farthest points were excluded (see examples in Figure D-1).

The $R_{95\%}$ is used because sound field footprints are often irregular in shape. In some cases, a sound level contour might have small protrusions or anomalous isolated fringes. This is demonstrated in the image in Figure D-1(a). In cases such as this, where relatively few points are excluded in any given direction, R_{max} can misrepresent the area of the region exposed to such effects, and $R_{95\%}$ is considered more representative. In strongly asymmetric cases such as shown in Figure D-1(b), on the other hand, $R_{95\%}$ neglects to account for significant protrusions in the footprint. In such cases R_{max} might better represent the region of effect in specific directions. Cases such as this are usually associated with bathymetric features affecting propagation. The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the non-uniformity of the acoustic environment.

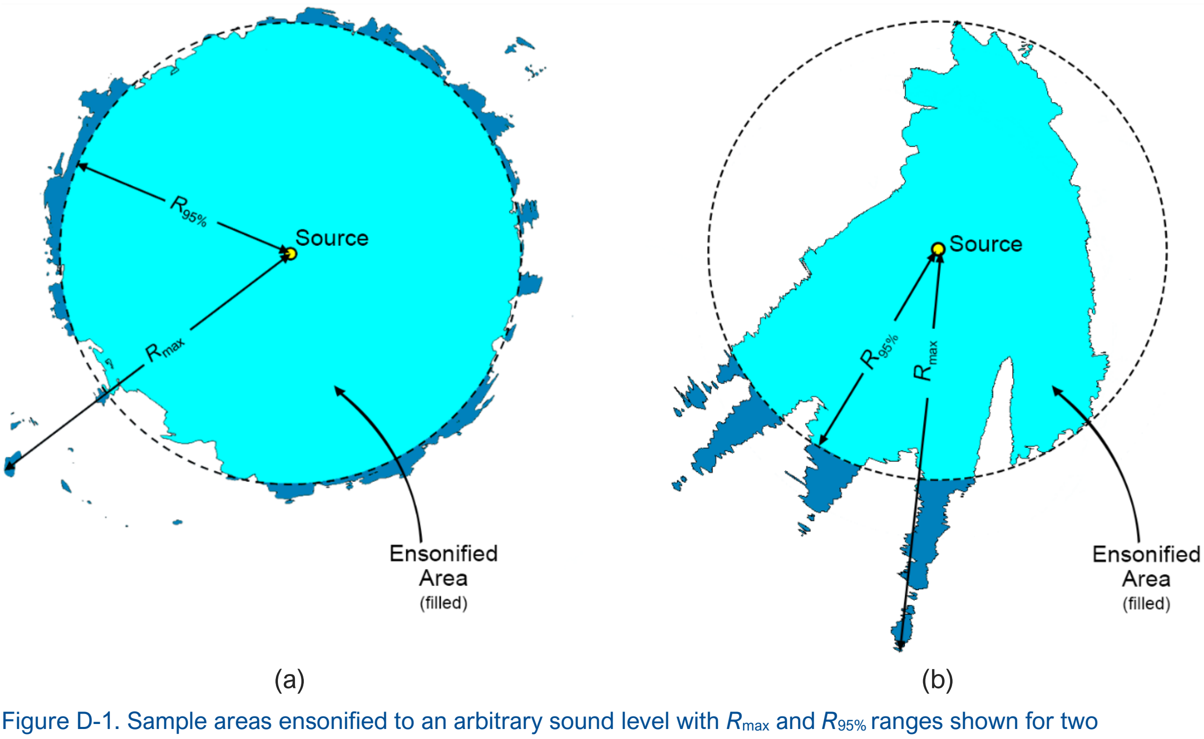


Figure D-1. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified areas bounded 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 applied to predicted per-pulse SEL results from MONM to model SPL values. Figures D-2 to D-3 show the conversion offsets for Sites 1, 7, 13, 16, 26, and 30 for the 3000 in^3 array; 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 considering the water depth and seabed geology at a given modelled site.

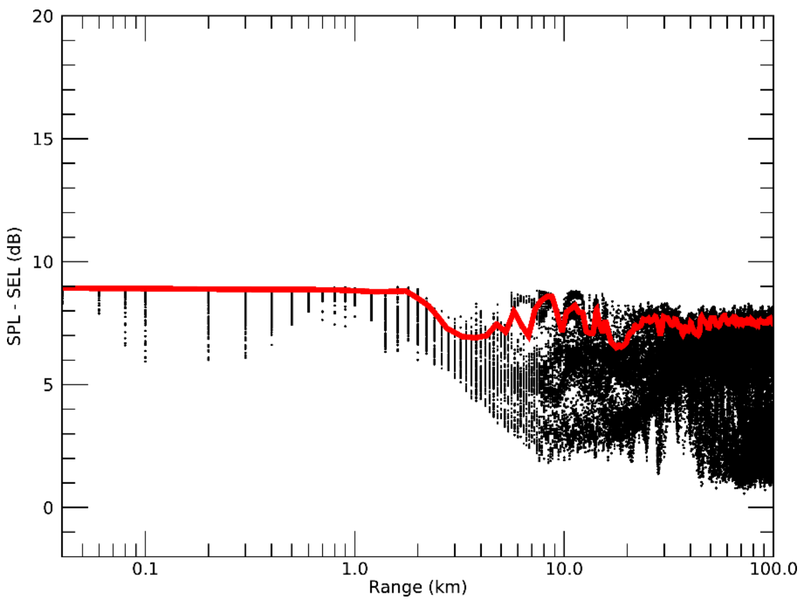


Figure D-2. *Site 1*: Range-and-depth-dependent conversion offsets for converting sound exposure level (SEL) to sound pressure level (SPL) for seismic pulses. Slices are shown for the 3000 in^3 seismic source. Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

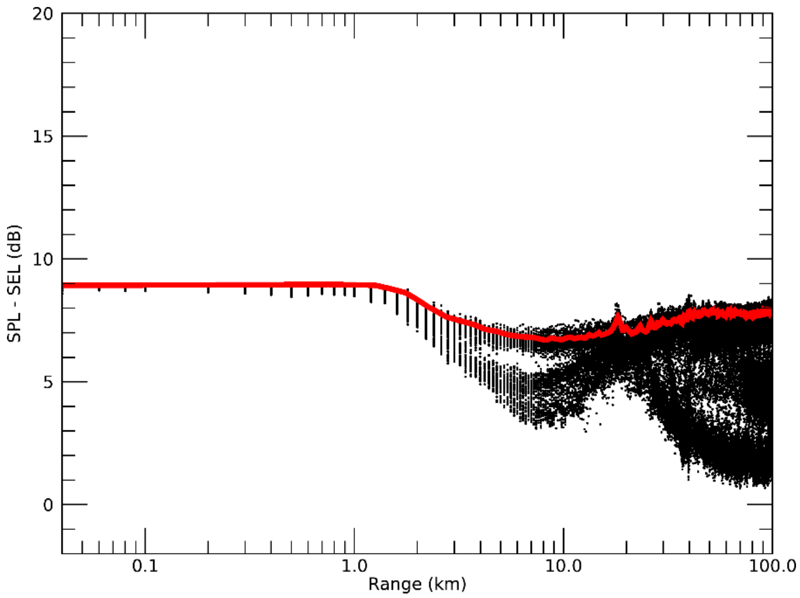


Figure D-3. *Site 7*: Range-and-depth-dependent conversion offsets for converting sound exposure level (SEL) to sound pressure level (SPL) for seismic pulses. Slices are shown for the 3000 in^3 seismic source. Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

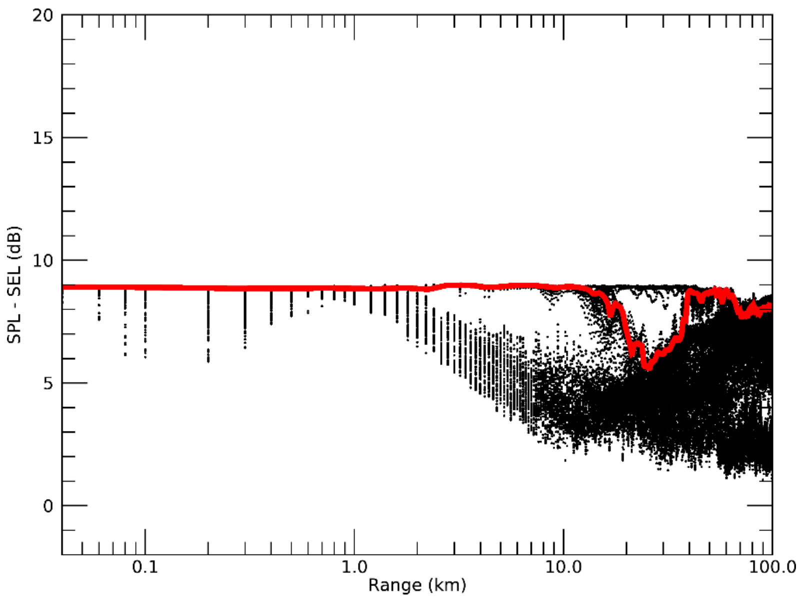


Figure D-4. *Site 8*: Range-and-depth-dependent conversion offsets for converting sound exposure level (SEL) to sound pressure level (SPL) for seismic pulses. Slices are shown for the 3000 in^3 seismic source. Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

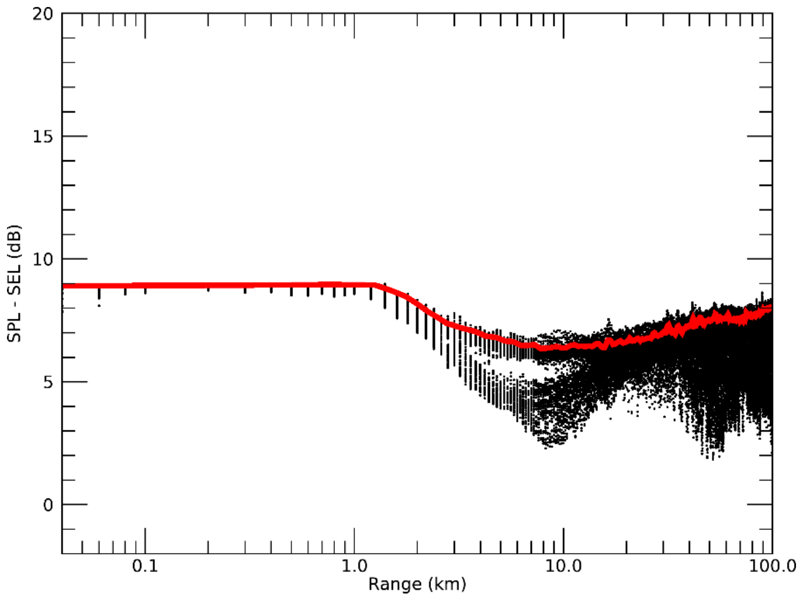


Figure D-5. *Site 11*: Range-and-depth-dependent conversion offsets for converting sound exposure level (SEL) to sound pressure level (SPL) for seismic pulses. Slices are shown for the 3000 in^3 seismic source. Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

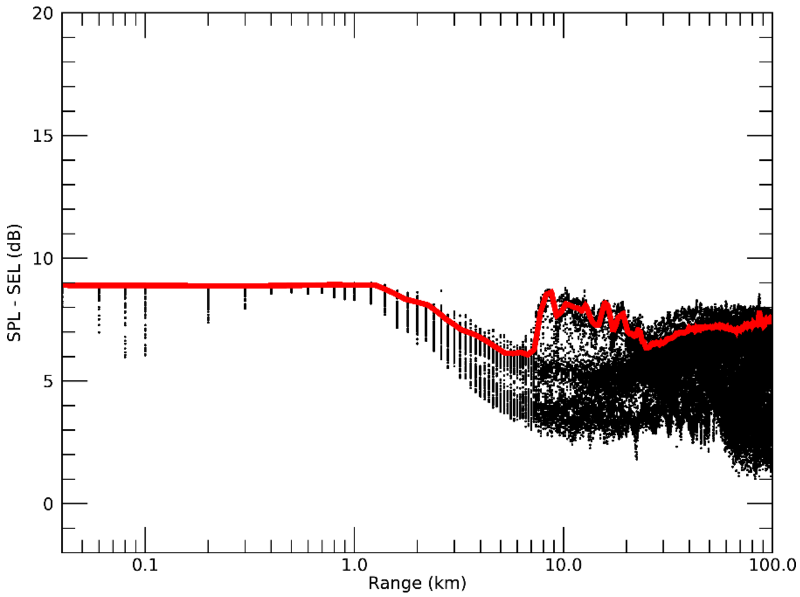


Figure D-6. *Site 14*: Range-and-depth-dependent conversion offsets for converting sound exposure level (SEL) to sound pressure level (SPL) for seismic pulses. Slices are shown for the 3000 in^3 seismic source. Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

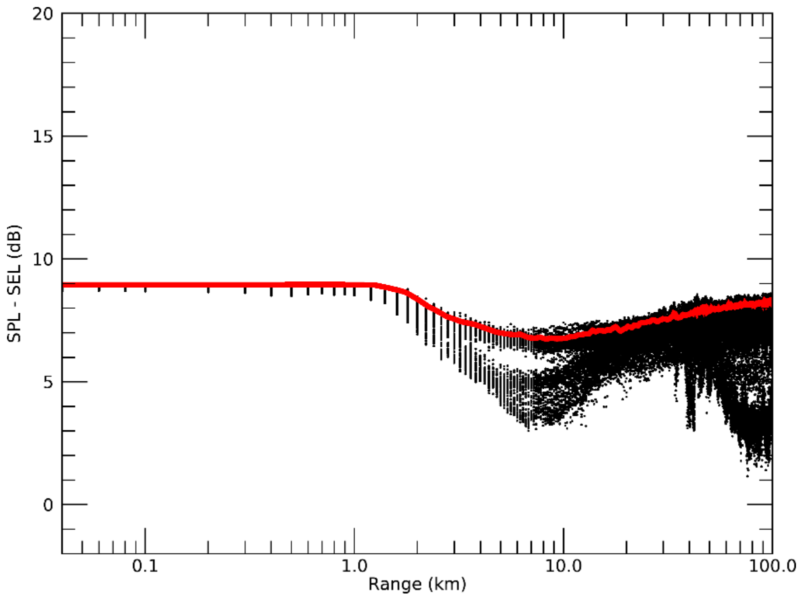


Figure D-7. *Site 22*: Range-and-depth-dependent conversion offsets for converting sound exposure level (SEL) to sound pressure level (SPL) for seismic pulses. Slices are shown for the 3000 in^3 seismic source. Black lines are the modelled differences between SEL and SPL across different radials and 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 Australian Bathymetry and Topography Grid, a 9 arc-second grid rendered for Australian waters (Whiteway 2009). Bathymetry data was extracted and re-gridded onto a Map Grid of Australia (MGA) coordinate projection (Zone 51) with a regular grid spacing of 250 × 250 m to generate the bathymetry in Figure D-8.

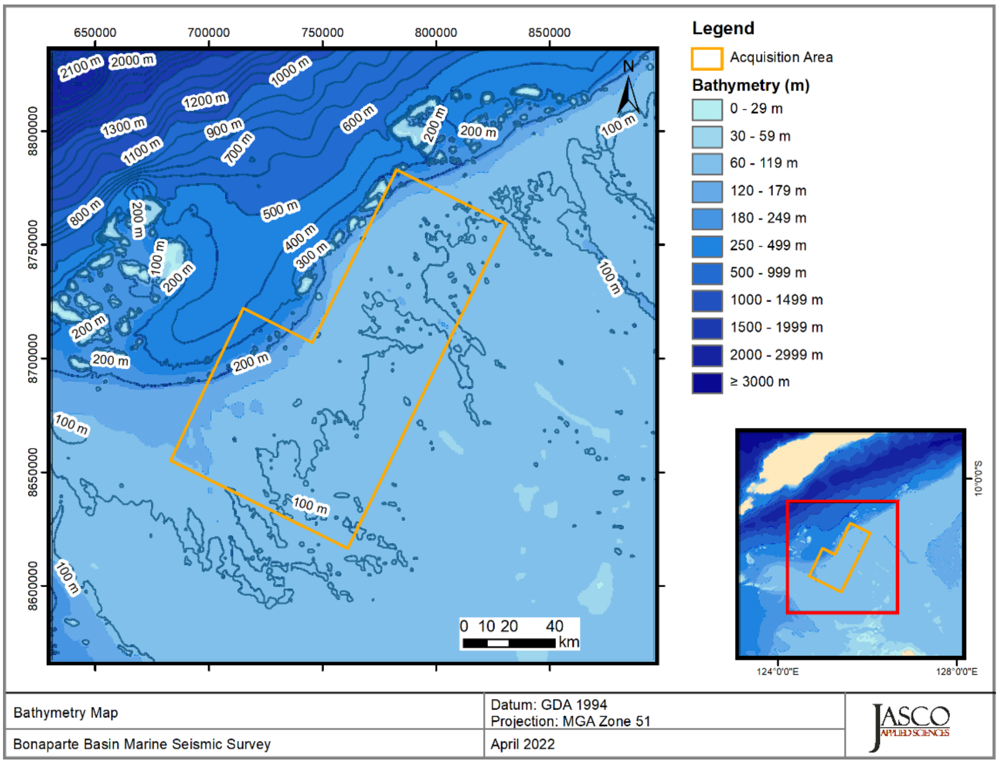


Figure D-8. Bathymetry map of the modelling area for the Bonaparte Basin Marine Seismic Survey.

D.3.2. Sound speed profile

The sound speed profiles for the modelled sites were derived from temperature and salinity profiles from the US 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 US Navy's Master Oceanographic Observational Data Set (MOODS). The climatology profiles include 78 fixed depth points to a maximum depth of 6800 m (where the ocean is that deep). The GDEM temperature-salinity profiles were converted to sound speed profiles according to Coppens (1981).

Mean monthly sound speed profiles were derived from the GDEM profiles within a 100 km box radius encompassing all modelled sites. The March sound speed profile is expected to be most favourable to longer-range sound propagation during the proposed survey time frame. As such, March was selected for sound propagation modelling to ensure precautionary estimates of distances to received sound level thresholds. Figure D-9 shows the resulting profile used as input to the sound propagation modelling.

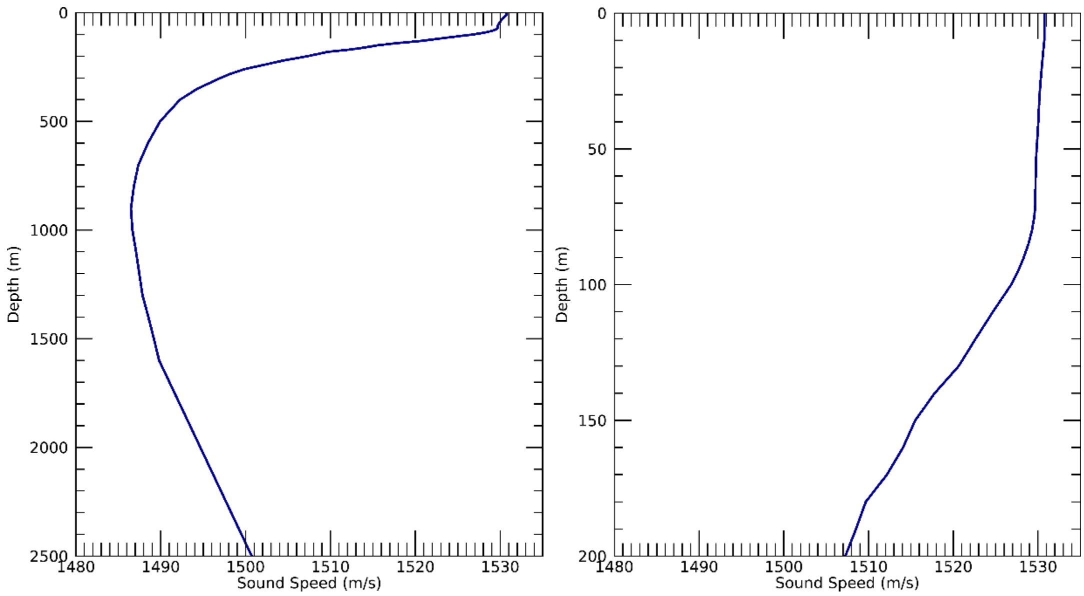


Figure D-9. The sound speed profile (March) used for the modelling showing the entire water column (left) and the top 200 m within the profile (right). Profiles are calculated from temperature and salinity profiles from GDEM V 3.0 (GDEM; Teague et al. 1990, Carnes 2009).

D.3.3. Geoacoustics

Geoacoustic parameters used for modelling at all sites were derived from sedimentary grain size measurements from the Australian Government's Marine Sediments (MARS) database (Heap 2009). On average, the surficial grain size indicates silty sand is present throughout the modelled area. Representative grain sizes were used in the grain-shearing model proposed by Buckingham (2005) to estimate the geoacoustic parameters required by the sound propagation models. Table D-1 lists the geoacoustic parameters used for modelling for all sites.

Table D-1. Geoacoustic profile for all modelling sites.

Depth below seafloor (m)	Predicted lithology	Density (g/cm^3)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–10	Sandy silt to increasing in compaction and lithification with depth	2.02	1633–1815	0.08–0.76	344	3.65
10–20			1815–1875	0.76–0.94		
20–40			1875–1953	0.94–1.16		
40–60			1953–2010	1.16–1.30		
60–80			2010–2057	1.30–1.40		
80–100			2057–2097	1.40–1.49		
100-200			2097–2248	1.49–1.77		
200-500			2248-2525	1.77-2.16		

D.4. Animal Movement and Exposure Modelling

Animal movement and exposure modelling considers the movement of both sound sources (if mobile) and animals over time. Acoustic source and propagation modelling are used to generate 3-D sound fields that vary as a function of distance to source, depth, and azimuth. Sound sources are modelled at representative sites and the resulting sound fields are assigned to source 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 to sound arising from the anthropogenic activities. Animats are programmed to behave like the species 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 JASCO's Marine Operations Noise Model (MONM) and Full Waveform Range-dependent Acoustic Model 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.

D.4.1. 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.

D.4.2. 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, a representative 24-hour period was simulated.

Ideally, a simulation area is large enough to encompass the entire range of a population so that any animal that could approach the source 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 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.

D.4.3. Seeding Density and Scaling

Seeding density refers to the spatial sample rate, in units of animats/km^2, used in the simulation. It is not related to the real-world animal density, but rather is a model parameter that controls the how samples are drawn from the model space. The minimum required seeding density for any given project depends on several factors such as bathymetry, source characteristics, and the behavioural profile of the animats, with the main constraint being computation time and resources. Seeding density is adjusted as needed based on model conditions specific to a project or project area.

In the present study, the exposure criteria for continuous 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 4 animat/km^2 over the entire simulation area. The modelling results are not related to real-world animal densities and the number of real-world animals potentially exposed was not calculated.

Appendix E. 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 B

Oil Spill Trajectory Modelling Report

OIL SPILL TRAJECTORY MODELLING ARISING FROM A VESSEL COLLISION IN THE BONAPARTE BASIN

Report prepared for Schlumberger Australia Pty Ltd:

Version	Date	Status	Approved by
RevA	01/03/2022	Draft for internal review	Zyngfogel
RevB	04/03/2022	Draft for client review	McComb
RevC	07/03/2022	Updated draft	Zyngfogel
Rev0	09/03/2022	Updated and approved for release	Zyngfogel

CALYPSO SCIENCE

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Schlumberger Australia Pty Ltd has commissioned an assessment of the oceanic dispersal and beaching potential in the unlikely event of a spill event resulting from vessel collision during Bonaparte MC3D survey. The operational area (OA) is in the Bonaparte Basin, located in Commonwealth waters adjacent to Western Australia (Figure 1.1).

In this study, a stochastic approach has been adopted to define the statistical probabilities related to oil trajectory, dispersion, diffusion, weathering, and beaching patterns. To achieve this, we simulated the occurrence of 100 realistic spill events from three locations within the OA, randomly distributed over the previous decade. The results from these simulations were collated and used to generate statistics and probabilities for an impact assessment.

This report is structured as follows. A description of the oil spill modelling methodology is provided in Section 2. In Section 3, we present the results of the modelling and provide an interpretation of the results. The findings are summarised in Section 4, and the references cited are listed in the final Section 5.

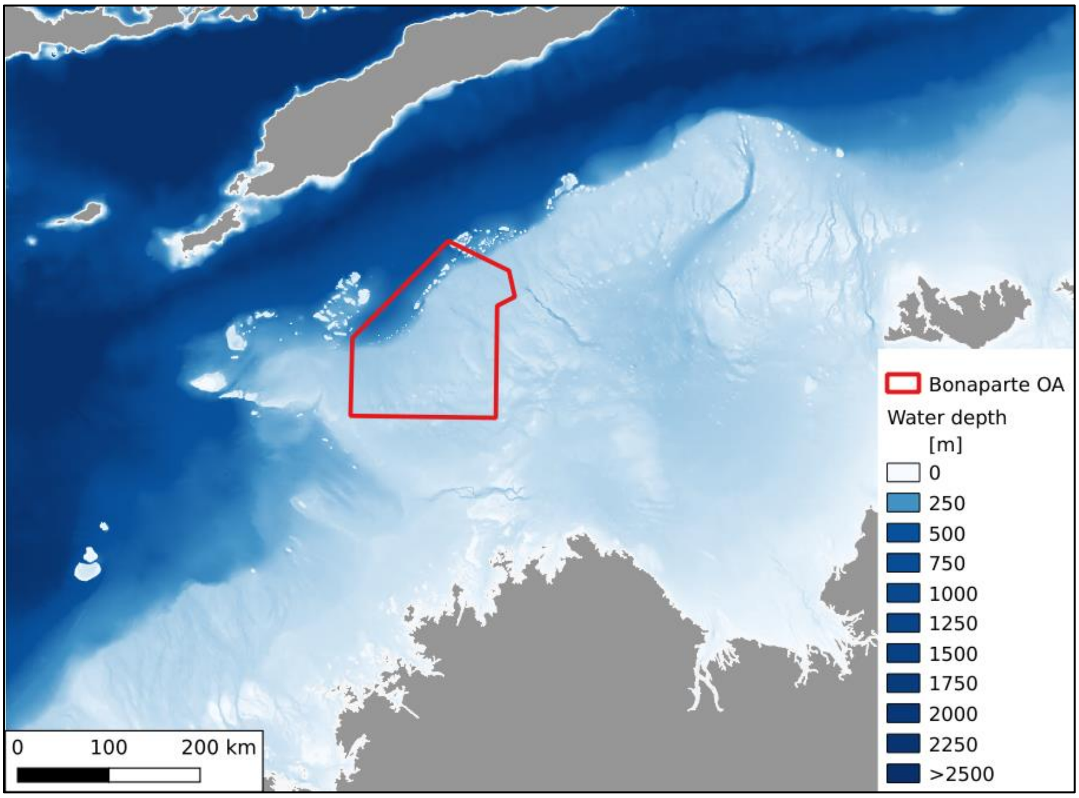


Figure 1.1 Location of the Bonaparte MC3D operational area (OA) in Western Australia.

2. METHODOLOGY

2.1. Spill scenario

The spill scenario under this assessment has the following attributes:

- Release of marine gas oil (MGO).
- Release at three locations within the OA.
- Continuous release of 1000 m^3 over six hours at sea level.

For this scenario, a total of 100 spill events were simulated at each of the three locations at random times over a contemporary decade (2010-2019).

2.2. Spill location

For the purpose of this simulation exercise, three hypothetical spill locations were chosen within the OA (Fig. 2.1, Table 2.1). To guide the site selection, AIS vessel traffic data from 2019 was plotted over the OA; highlighting the regions with highest traffic. On the basis of AIS density and geographic spread, three hypothetical spill locations (A, B, and C) were selected - allowing for maximum distance between the spill locations in order to capture the effect of variation in environmental factors on the spill outcomes.

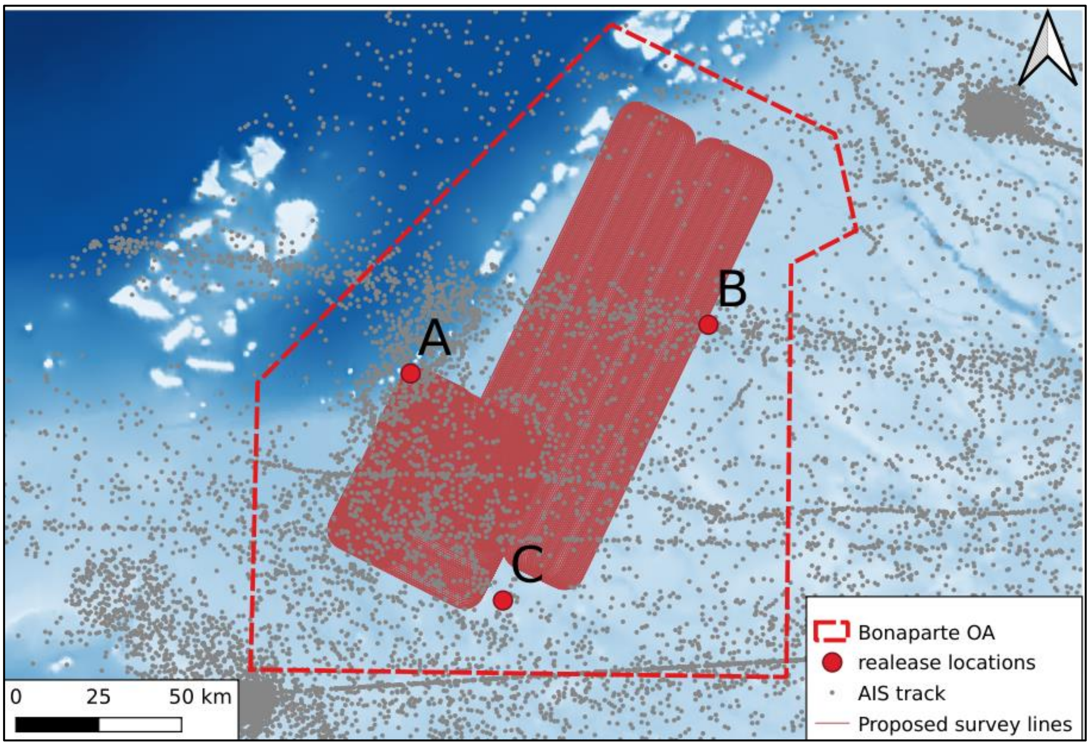


Figure 2.1 Position of the three locations chosen within the Bonaparte OA.

Table 2.1 Coordinates of the three spill locations used in this study.

Site	Longitude	Latitude
A	124° 59' 42.0" E	11° 45 57.6" S
B	125° 49' 22.8" E	11° 37 58.8" S
C	125° 15' 7.2" E	12° 23 2.4" S

2.3. Spill product

The fuel for the survey vessel will either be marine diesel oil (MDO) or marine gas oil (MGO), with the latter having greater environmental persistence following a spill. Accordingly, the more conservative approach has been adopted for this study, with MGO being selected as the spill product. Marine Gas Oil (MGO) has specific and well documented characteristics which influence its persistence in the marine environment after a spill event (see Hellstrom et al, 2017):

- Density of 852 kg/m^3 and a kinematic viscosity of 3 cP at 15°C.
- Total wax content of 0.8% by mass with no significant emulsifying properties.
- Low pour point for both fresh oil and 250°C+ residue (<-36 °C)
- Low viscosity for both fresh oil and 250°C+ residue (< 20 mPa·s at 2 °C)
- Intermediate evaporative loss (30.6 vol. % at 250 °C),
- Relatively high natural dispersion in breaking wave conditions and poor natural dispersion in non-breaking wave (swell) conditions

2.4. Oceanographic and atmospheric conditions

The following environmental datasets were used in the oil spill modelling:

- Surface (10 m elevation) wind fields were prescribed from the ERA5 reanaylsis product, provided by the European Centre for Medium Range Weather Forecasting (ECMWF, 2019). ERA5 combines vast amounts of specifically curated historical observations with state-of-the-art 4D-Var data assimilation to produce a hindcast of unprecedented quality. These gridded data have a spatial resolution of 31 km spatial and temporal resolution of 1 hourly.

- The wave conditions were defined from a validated global WW3 wave hindcast supplied by Oceanum Ltd. This product is a 3-hourly dataset at 0.5-degree resolution, using the ERA5 wind field as boundary condition.

- Residual velocities and water column properties were defined from the global 1/12-degree reanalysis products released by the EU-funded Copernicus Project.

- Tidal velocities were sourced from a downscaled spectral solution from the OTIS (Oregon State University Tidal Inversion Software) assimilated barotropic model.

Rose plots for the seasonal and annual conditions for winds and surface currents are presented in Figures 2.2 and 2.3.

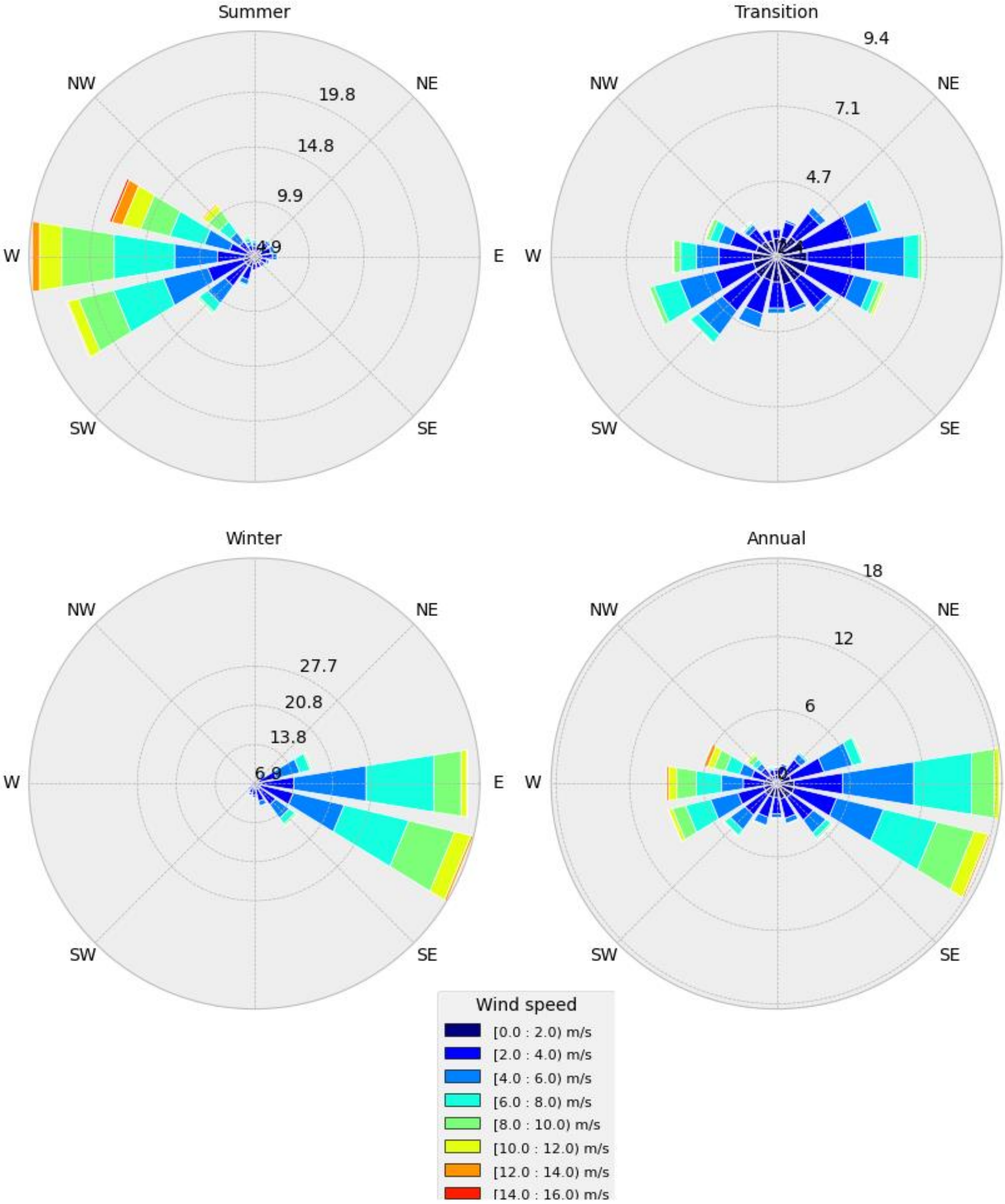


Figure 2.2 Annual and seasonal wind roses at the center of the OA, from hindcast data 2008-2017. Note the wind directional convention is 'coming from'.

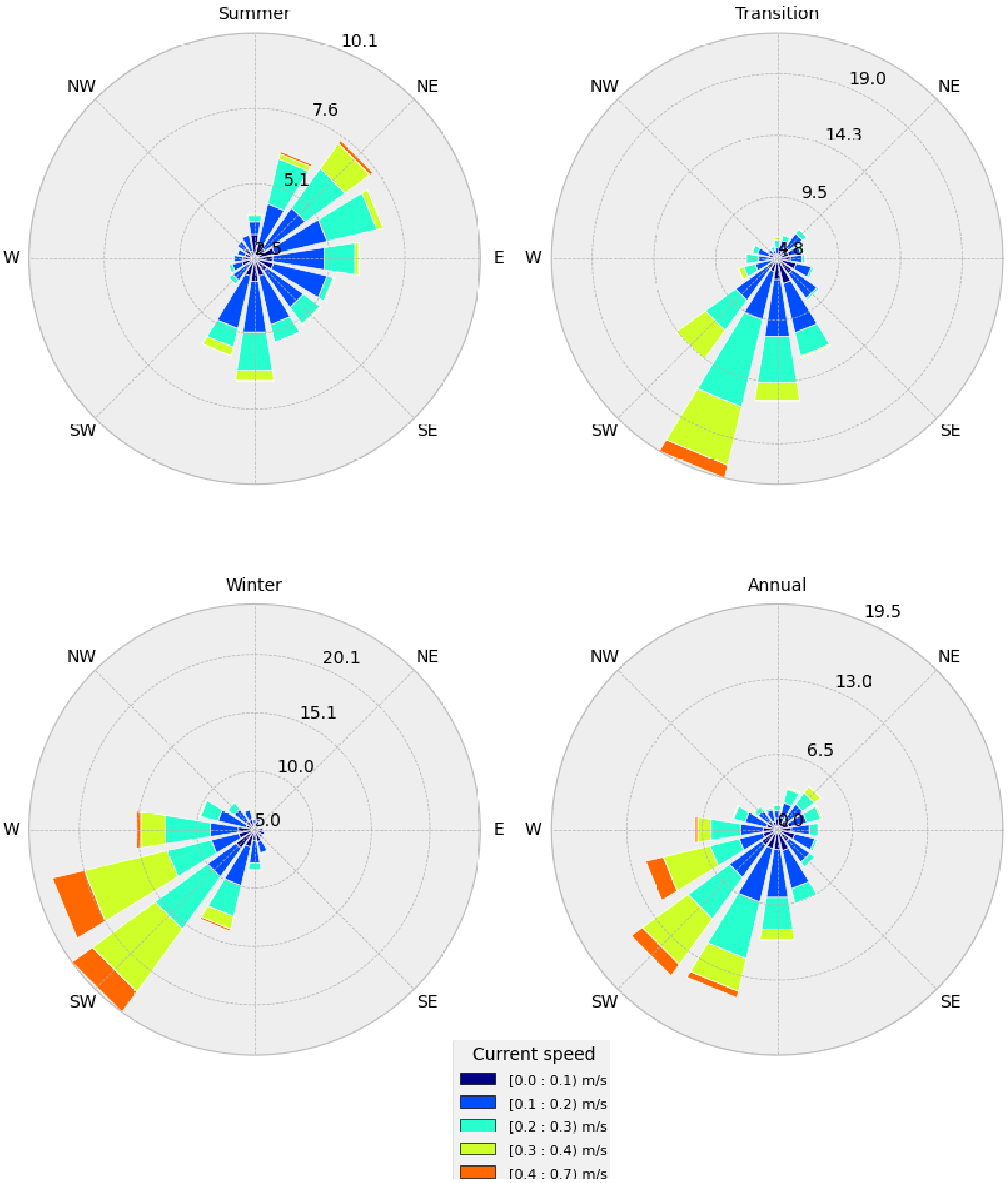


Figure 2.3 Annual and seasonal current roses for the sea surface (tidal and non-tidal) at the center of the OA, from hindcast data 2008-2017. Note the current directional convention is 'going to'.

2.5. Oil spill modelling framework

The OpenOil simulation framework was used to model the weathering dispersal, and trajectory of the spill. This module is part of the OpenDrift project[1] which is an open-source code base with considerable community input and ongoing peer review. Full technical details of the model are reported by Dagestad *et al*. (2018), and the key model settings used in the present study are provided in Table 2.2

Note, this OpenOil version has been modified to include dissolution process. As a result, the evaporation and dissolution process are based on the pseudo-component approach. This method is used in oil spill models such as OSCAR, and SIMAP (Keramea *et al*., 2021).

Table 2.2 OpenOil model settings.

Parameter	**Value applied**
Windage	2%
Horizontal diffusion	1.0 m^2/s
Stokes drift	from wave model
Vertical diffusion coefficient	Variable based on Large *et al*. 1994
Model time step	900 s
Particles per spill	7200
Duration of each spills	6 hours
Duration of each simulation	90 days
Droplet size distribution	Li et al. (2017)
Entrainment rate	Li et al. (2017)
Oil density	852 kg/m^3 at 13 degC
Oil dynamic viscosity	3 cP at 15 degC
Shoreline	Sticky, no re-float

2.6. Processing of results

Each model simulation was post-processed to derive oil concentrations and statistical representations. For each timestep of every run, a bi-directional weighted histogram was calculated using the particles in the surface layer or particles that had beached. Concentrations were calculated from 10 x 10 km cells, with the histogram of values was normalized by the area of the cell to derive results in g/m^2 or ppb. For the beached concentrations, each histogram of values was divided by the length of coast and an assumed beach width of 100 m to define the results in g/m^2.

[1] https://github.com/OpenDrift/opendrift

From the histogram timeseries, the following statistics were calculated (see footnote[2]):

- Maximum extent in which the surface concentration lies above a certain threshold for a minimum duration of 1 hour. Calculated for each run at low, moderate, and high thresholds of 1, 10 and 50 g/m^2, respectively.

- Maximum extent in which entrained hydrocarbon concentration persists beyond a certain threshold for at least an hour. Calculated for each run at depths of 0 to 10 m and 10 to 20 m for low and moderate thresholds of 10 and 100 ppb, respectively.

- Maximum extent in which dissolved hydrocarbon concentration persists beyond a certain threshold for at least an hour. Calculated for each run at depths of 0 to 10 m for low, moderate, and high thresholds concentrations of 10, 50 and 400 ppb, respectively

- Beaching risk – defined as the probability for each 10 x 10 km cell of shoreline to accumulate MGO at low, moderate, and high thresholds concentrations of 10 g, 100 g, 1000 g per m^2, respectively.

- Total oil on the beach - for each run the mass of oil entering a 10 x 10 km cell is summed and presented as the maximum.

[2] These exposure values are based on the NOPSEMA Environment Bulletin (April 2019).

3. RESULTS

3.1. Stochastic simulation

The set of 100 randomly selected spills over an historical decade provides a robust dataset to define the statistics of spill trajectory, beaching along the shore, and expected mass budgets of any spilled MGO.

The characteristics of MGO is that oil will quickly disperse under wave action but tends to persist as a surface slick during calm weather. On the sea surface, strong winds will increase the rate of evaporation, while the wave conditions associated with these winds also act to mix and disperse the oil into the upper layers of the ocean. Consequently, the day-to-day weather conditions strongly influence the mass budget of MGO throughout the simulations.

3.1.1. Results for annual conditions

For the annual conditions, Figure 3.1 to Figure 3.4 present mapped statistics derived from all 100 simulations and demonstrate the extent of the Environment that May Be Affected (EMBA). The EMBA exhibits a South-West / North-East axis with an extension toward the Joseph Bonaparte Gulf. Some 79% of the runs exceed 1 g/m^2 on the surface and 100% of the runs exceed the 10-ppb threshold in the water column (Table 3.1). However, no concentration was found to exceed the highest thresholds (see footnote[2] above). In Table 3.2, the maximum concentrations of spilled MGO over 1 to 60 days are presented, with statistics provided for the surface, entrained, and beached fractions.

Beaching is defined as any particles reaching the coastline (defined as the mean high water spring level), and a sticky shoreline has been imposed in the model so there is no re-floating by tide. In Figure 3.5, we show the locations where beaching occurred with a concentration exceeding 10 g/m^2. The results from 100 simulations indicate the highest chance of beaching occurs around Ashmore Reef, Cartier Island, the Joseph Bonaparte Gulf and North Kimberley coast. Beaching quantities are presented as g per m^2 (Figure 3.5, right plots).

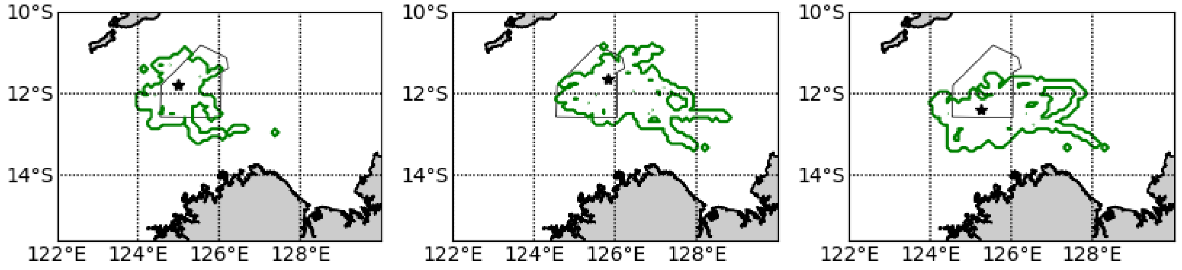


Figure 3.1 Annual zone of maximum surface exposure above 1 g/m^2 (green) for spills from locations A (left), B (middle) and C (right).

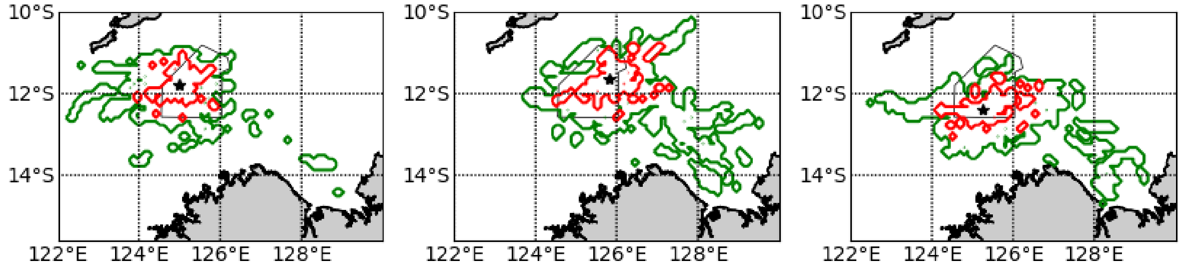


Figure 3.2 Annual zone of maximum entrained MGO (0 to 10 m) above 10 g/m^2 (green) and 100 g/m^2 (red) for spills from locations A (left), B (middle) and C (right).

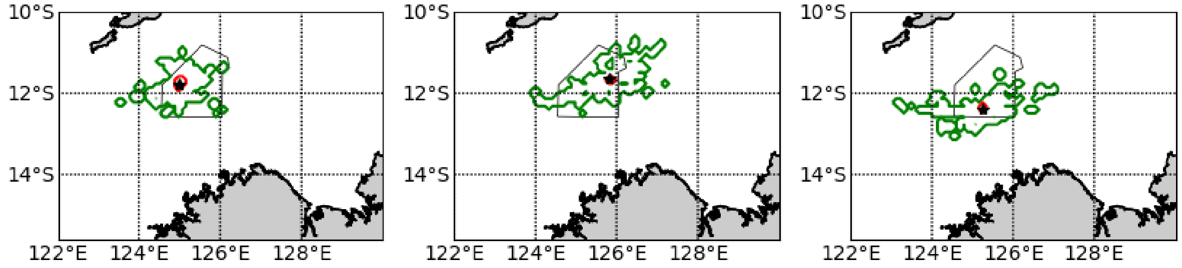


Figure 3.3 Annual zone of maximum entrained MGO (10 to 20 m) above 10 g/m^2 (green) and 100 g/m^2 (red) for spills from locations A (left), B (middle) and C (right).

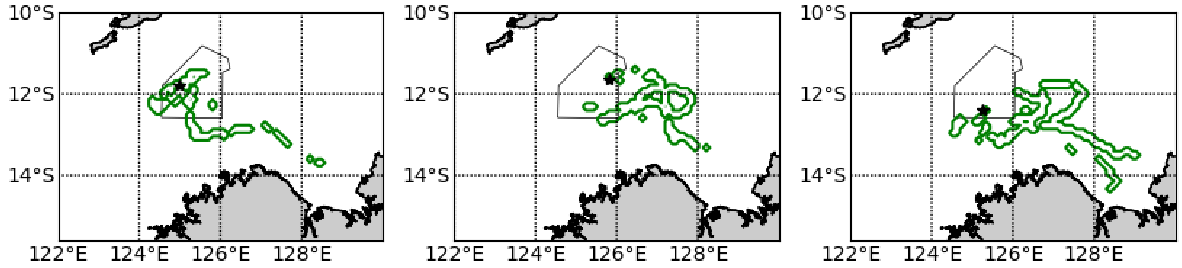


Figure 3.4 Annual zone of maximum dissolved (0 to 10 m) exposure above 10 g/m^2 (green) for spills from location A (left), B (middle) and C (right).

Table 3.1 Annual probability (in %) of MGO reaching each defined threshold. The low and moderate surface thresholds for surface MGO are 1 and 10 g/m^{2,} respectively. The low and moderate concentration thresholds for entrained MGO is 10 and 100 ppb, respectively. The low and moderate concentration thresholds for dissolved MGO are 10 and 50 ppb, respectively.

	Release location A		**Release location B**		**Release location C**	
	Low	**Moderate**	**Low**	**Moderate**	**Low**	**Moderate**
Surface	77	0	79	0	78	0
Entrained 0-10 m	100	99	100	95	100	97
Entrained 10-20 m	77	15	79	8	80	6
Dissolved	9	0	12	0	10	0
Beached	6	0	7	0	9	0

Table 3.2 Annual maximum concentration of MGO after 1, 2, 7, 15, 30, 40 and 60 days.

	Release	**1 day**	**2 days**	**7 days**	**15 days**	**30 days**	**40 days**	**60 days**
Surface [g.m^2]	**A**	6.96	6.29	5.19	2.47	2.26	1.07	0.14
	B	6.96	6.20	4.82	3.28	1.56	0.52	0.03
	C	7.00	6.36	4.97	2.95	1.84	1.45	0.06
Entrained 0 to 10 m [ppb]	**A**	559.97	425.48	247.57	59.36	39.61	25.31	2.29
	B	501.82	365.20	255.71	74.44	57.98	10.60	0.38
	C	545.75	413.84	211.45	45.78	43.24	20.89	1.11
Entrained 10 to 20 m [ppb]	**A**	100.42	86.31	43.38	16.80	1.29	0.48	0.21
	B	101.81	66.91	47.07	9.84	3.09	0.59	0.07
	C	87.05	68.60	30.39	11.91	2.40	0.52	0.17
Dissolved 0 to 10 m [ppb]	**A**	1.71	3.86	8.64	10.09	12.95	9.46	3.70
	B	1.73	3.90	7.87	9.03	14.78	7.09	8.16
	C	2.06	3.77	7.92	9.04	12.86	15.19	2.80
Beached [g.m^2]	**A**	0.00	0.00	0.00	0.00	23.93	24.90	24.91
	B	0.00	0.00	0.00	0.00	1.90	47.28	52.72
	C	0.00	0.00	0.00	0.00	48.79	48.79	75.15

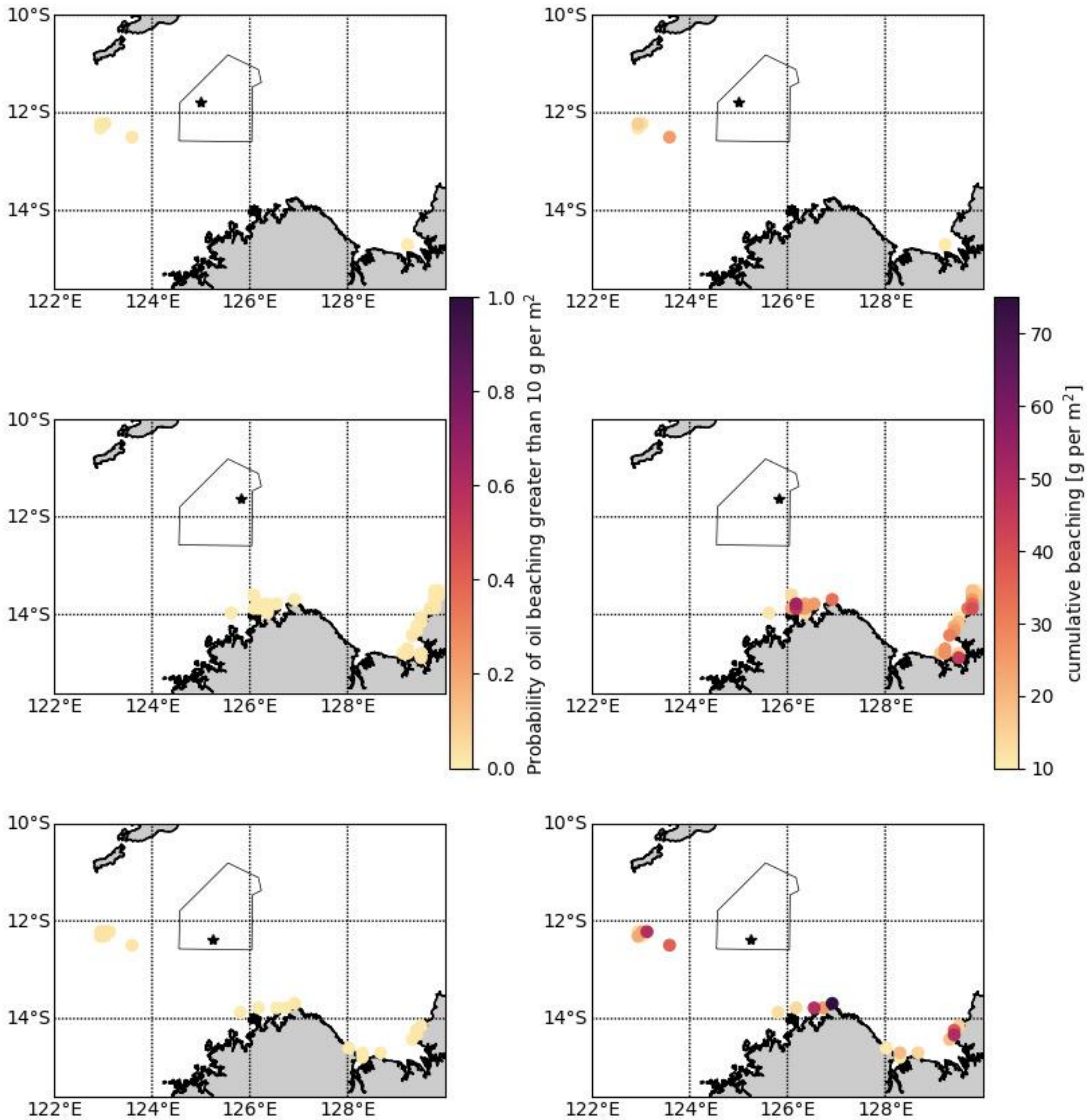


Figure 3.5 Annual probability of MGO to beach (left) and maximum beached MGO concentrations for spills from locations A (top), B (middle) and C (bottom). Note, a probability of 1 represents a 100 % chance of MGO beaching above 10 g/m^2.

The annual maximum probability that each threshold is exceeded from each release location (A, B, C) is provided in Tables 3.3 – 3.5. Here, potential sensitive receptors within the EMBA have been provided by SLR Consulting Limited. The locations and areas listed in these tables are denoted in Appendix One.

Table 3.3 Annual maximum probability (in %) of potential sensitive receptors reaching specific concentration thresholds due to a spill at location A.

	Release location A						
	Surface	Entrained 0-10m		Entrained 10-20m		Dissolved	Beached
Potential Sensitive Receptor	**1 g.m²**	**10 ppb**	**100 ppb**	**10 ppb**	**100 ppb**	**10 ppb**	**10 g.m²**
Heywood Shoal	0	1	0	0	0	0	0
Eugene McDermott Shoal	0	0	0	0	0	0	0
Vulcan Shoal	1	0	0	0	0	0	0
Barracouta Shoal	0	5	0	0	0	0	0
Woodbine Bank	0	2	0	0	0	0	0
Hibernia Reef	0	1	0	0	0	0	0
Fantome Shoal	10	18	5	7	0	0	0
Sahul Bank	76	97	88	67	15	7	0
Margaret Harries Bank	0	0	0	0	0	0	0
Gale Bank	1	2	0	0	0	1	0
Van Cloon Shoal	0	0	0	0	0	0	0
Flat Top Bank	0	0	0	0	0	0	0
Penguin Shoal	1	1	0	0	0	1	0
Bassett-Smith Shoal	0	0	0	0	0	0	0
Holothuria Bank	1	0	0	0	0	1	0
Long Reef	0	0	0	0	0	0	0
Johnson Bank	0	2	0	0	0	0	0

Kimberley AMP (Multiple Use Zone VI)	1	2	0	0	0	0	0
Cartier Island AMP (Sanctuary Zone Ia)	0	1	0	0	0	0	2
Ashmore Reef AMP (Recreational Use Zone IV)	0	0	0	0	0	0	0
Ashmore Reef AMP (Sanctuary Zone Ia)	0	1	0	0	0	0	3
Oceanic Shoals AMP (Multiple Use Zone VI)	1	6	0	2	0	1	0
Joseph Bonaparte Gulf AMP (Special Purpose Zone VI)	0	0	0	0	0	0	0
Joseph Bonaparte Gulf AMP (Multiple Use Zone VI)	0	1	0	0	0	0	0
Pinnacles of the Bonaparte Basin KEF	0	0	0	0	0	0	0
Carbonate bank and terrace system of the Sahul Shelf KEF	16	31	13	15	0	4	0
Ashmore Reef, Cartier Island and surrounding Commonwealth waters KEF	0	3	0	1	0	0	5
Continental Slope Demersal Fish Communities KEF	0	5	0	0	0	0	3
Ancient coastline at 125 m depth contour KEF	0	2	0	0	0	0	0
Dolphin BIAs	0	0	0	0	0	0	0
Pygmy Blue Whale BIA	44	55	37	35	1	1	3
Seabird BIAs	3	15	1	2	0	1	5
Marine Reptile BIAs	1	9	0	1	0	1	6
Dugong BIAs	0	0	0	0	0	0	0
Whale Shark BIA	46	71	48	44	4	7	0
North Kimberley Marine Park	0	0	0	0	0	0	0
Joseph Bonaparte Gulf SE Coastline	0	0	0	0	0	0	1

Table 3.4 Annual maximum probability (in %) of potential sensitive receptors reaching specific concentration thresholds due to a spill at location B.

	Release location B						
	Surface	Entrained 0-10m		Entrained 10-20m		Dissolved	Beached
Potential Sensitive Receptor	**1 $g.m^2$**	**10 ppb**	**100 ppb**	**10 ppb**	**100 ppb**	**10 ppb**	**10 $g.m^2$**
Heywood Shoal	0	0	0	0	0	0	0
Eugene McDermott Shoal	0	1	0	0	0	0	0
Vulcan Shoal	0	0	0	0	0	0	0
Barracouta Shoal	0	0	0	0	0	0	0
Woodbine Bank	0	0	0	0	0	0	0
Hibernia Reef	0	0	0	0	0	0	0
Fantome Shoal	0	2	0	0	0	0	0
Sahul Bank	7	15	4	8	0	0	0
Margaret Harries Bank	0	2	0	0	0	0	0
Gale Bank	2	6	2	0	0	2	0
Van Cloon Shoal	0	0	0	0	0	0	0
Flat Top Bank	0	1	0	0	0	0	0
Penguin Shoal	0	0	0	0	0	0	0
Bassett-Smith Shoal	0	0	0	0	0	0	0
Holothuria Bank	0	0	0	0	0	0	1
Long Reef	0	0	0	0	0	0	0
Johnson Bank	0	0	0	0	0	0	0

Kimberley AMP (Multiple Use Zone VI)	0	2	0	0	0	0	0
Cartier Island AMP (Sanctuary Zone Ia)	0	0	0	0	0	0	0
Ashmore Reef AMP (Recreational Use Zone IV)	0	0	0	0	0	0	0
Ashmore Reef AMP (Sanctuary Zone Ia)	0	0	0	0	0	0	0
Oceanic Shoals AMP (Multiple Use Zone VI)	37	58	39	35	0	10	0
Joseph Bonaparte Gulf AMP (Special Purpose Zone VI)	0	1	0	0	0	0	0
Joseph Bonaparte Gulf AMP (Multiple Use Zone VI)	0	2	0	0	0	0	0
Pinnacles of the Bonaparte Basin KEF	5	8	2	1	0	4	0
Carbonate bank and terrace system of the Sahul Shelf KEF	79	100	89	74	8	12	0
Ashmore Reef and Cartier Island and surrounding Commonwealth waters KEF	0	0	0	0	0	0	0
Continental Slope Demersal Fish Communities KEF	0	0	0	0	0	0	0
Ancient coastline at 125 m depth contour KEF	0	0	0	0	0	0	0
Dolphin BIAs	0	0	0	0	0	0	1
Pygmy Blue Whale BIA	3	9	2	6	0	0	0
Seabird BIAs	2	11	0	2	0	1	1
Marine Reptile BIAs	37	55	32	29	0	8	2
Dugong BIAs	0	0	0	0	0	0	0
Whale Shark BIA	77	91	77	69	8	4	0
North Kimberley Marine Park	0	1	0	0	0	0	1
Joseph Bonaparte Gulf SE Coastline	0	0	0	0	0	0	6

Table 3.5 Annual maximum probability (in %) of potential sensitive receptors reaching specific concentration thresholds due to a spill at location C.

	Release location C						
	Surface	Entrained 0-10m		Entrained 10-20m		Dissolved	Beached
Potential Sensitive Receptor	**1 g.m^2**	**10 ppb**	**100 ppb**	**10 ppb**	**100 ppb**	**10 ppb**	**10 g.m^2**
Heywood Shoal	0	0	0	0	0	0	0
Eugene McDermott Shoal	2	3	1	1	0	1	0
Vulcan Shoal	0	3	0	3	0	0	0
Barracouta Shoal	1	4	2	2	0	0	0
Woodbine Bank	0	3	0	1	0	0	0
Hibernia Reef	0	0	0	0	0	0	0
Fantome Shoal	0	3	0	0	0	0	0
Sahul Bank	0	4	0	0	0	0	0
Margaret Harries Bank	0	0	0	0	0	0	0
Gale Bank	8	9	1	0	0	2	0
Van Cloon Shoal	4	5	0	0	0	2	0
Flat Top Bank	0	0	0	0	0	0	0
Penguin Shoal	2	1	0	0	0	1	0
Bassett-Smith Shoal	1	2	0	0	0	1	0
Holothuria Bank	0	1	0	0	0	0	1
Long Reef	0	0	0	0	0	0	0
Johnson Bank	0	3	0	2	0	0	0

Kimberley AMP (Multiple Use Zone VI)	2	4	0	0	0	1	0
Cartier Island AMP (Sanctuary Zone Ia)	0	3	0	0	0	0	2
Ashmore Reef AMP (Recreational Use Zone IV)	0	2	0	0	0	0	0
Ashmore Reef AMP (Sanctuary Zone Ia)	0	2	0	2	0	0	3
Oceanic Shoals AMP (Multiple Use Zone VI)	17	25	8	9	0	6	0
Joseph Bonaparte Gulf AMP (Special Purpose Zone VI)	0	1	0	0	0	0	0
Joseph Bonaparte Gulf AMP (Multiple Use Zone VI)	0	3	0	0	0	1	0
Pinnacles of the Bonaparte Basin KEF	2	5	0	2	0	2	0
Carbonate bank and terrace system of the Sahul Shelf KEF	78	99	91	73	6	9	0
Ashmore Reef and Cartier Island and surrounding Commonwealth waters KEF	0	4	0	2	0	0	4
Continental Slope Demersal Fish Communities KEF	0	4	0	2	0	0	4
Ancient coastline at 125 m depth contour KEF	1	2	0	0	0	0	0
Dolphin BIAs	0	2	0	0	0	0	2
Pygmy Blue Whale BIA	0	8	0	3	0	0	3
Seabird BIAs	12	26	3	5	0	4	7
Marine Reptile BIAs	14	27	5	9	0	6	5
Dugong BIAs	0	2	0	2	0	0	0
Whale Shark BIA	78	99	93	76	6	4	0
North Kimberley Marine Park	0	2	0	0	0	0	3
Joseph Bonaparte Gulf SE Coastline	0	0	0	0	0	0	2

3.1.2. Results for the summer conditions

Spill scenarios which started during summer months (December, January and February) were sub-selected from the database of 100 simulations.

The lowest surface threshold of 1 g per m^2 was reached by up to 72% of the runs. MGO concentrations of 10 ppb were found between 0 and 20 m depths in at least 96% of the runs (Table 3.6). The plume followed the summer wind pattern and spread towards the North-East (Figure 3.6 to Figure 3.9). The maximum surface concentration was 8 g/m^2, and the 1 g/m^2 threshold was exceeded for up to 24 days after the start of the spill, extending up to 168 km from the release site. The maximum entrained concentration within 0 to 10 m depth was 702 ppb and the 10-ppb threshold was exceeded over the first 32 days.

There were no beaching events with exposures exceeding 10 g/m^2.

Table 3.6 Summer probability (in %) of MGO reaching defined thresholds. The low and moderate surface thresholds for surface MGO are 1 and 10 g/m^2, respectively. The low and moderate concentration thresholds for entrained MGO is 10 and 100 ppb, respectively. The low and moderate concentration thresholds for dissolved MGO are 10 and 50 ppb, respectively.

	Release location A		**Release location B**		**Release location C**	
Threshold	**Low**	**Moderate**	**Low**	**Moderate**	**Low**	**Moderate**
Surface	64	0	72	0	72	0
Entrained 0-10 m	100	100	100	96	100	100
Entrained 10-20 m	96	8	100	8	100	4
Dissolved	4	0	8	0	8	0

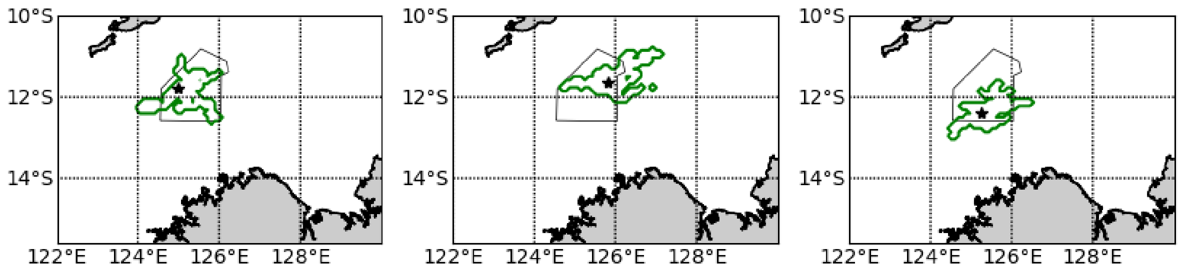


Figure 3.6 Zone of maximum surface exposure above 1 g/m^2 (green) during summer for spills from location A (left), B (middle) and C (right).

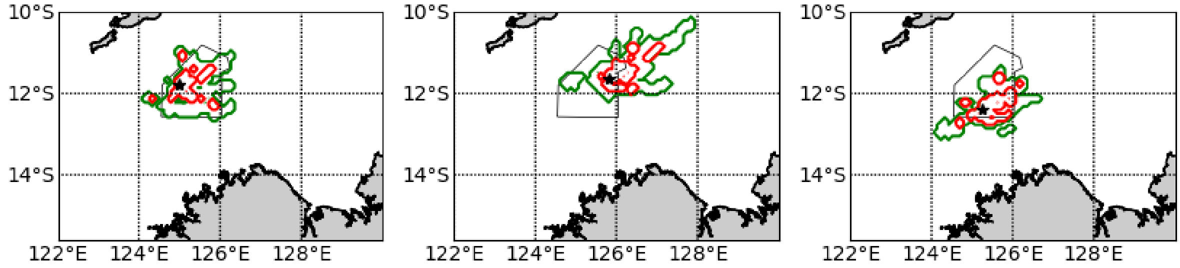


Figure 3.7 Zone of maximum entrained (0 to 10 m) exposure above 10 g/m^2 (green) and 100 g/m^2 (red) during summer for spills from location A (left), B (middle) and C (right).

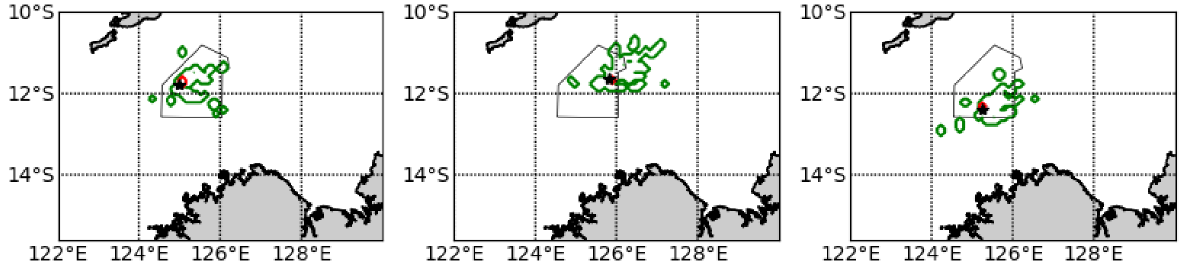


Figure 3.8 Zone of maximum entrained (10 to 20 m) exposure above 10 g/m^2 (green) and 100 g/m^2 (red) during summer for spills from location A (left), B (middle) and C (right).

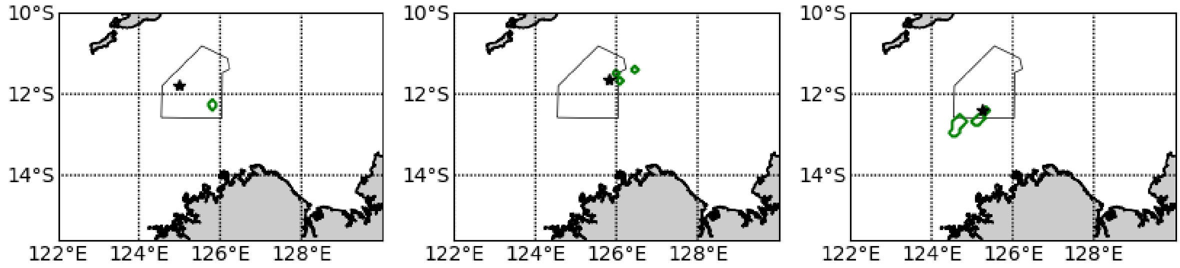


Figure 3.9 Zone of maximum dissolved (0 to 10 m) exposure above 10 g/m^2 (green) during summer for spills from location A (left), B (middle) and C (right).

Table 3.7 Summer maximum concentration of MGO after 1, 2, 7, 15,30, 40 and greater than 60 days.

	Location	1 day	2 days	7 days	15 days	30 days	40 days	>60 days
Surface [g.m^2]	**A**	6.82	6.15	4.71	1.69	0.29	0.00	0.04
	B	6.85	5.87	4.70	1.58	0.72	0.00	0.03
	C	6.99	6.19	4.83	2.38	0.84	0.00	0.01
Entrained 0 to 10 m [ppb]	**A**	500.70	278.76	247.57	59.36	4.64	0.01	0.00
	B	425.93	345.67	255.71	74.44	6.24	0.13	0.01
	C	384.44	257.52	211.45	45.78	17.84	0.00	0.00
Entrained 10 to 20 m [ppb]	**A**	96.35	45.30	43.38	6.26	0.63	0.00	0.00
	B	96.90	62.56	47.07	7.58	1.12	0.06	0.00
	C	83.25	52.08	26.67	3.08	0.78	0.00	0.00
Dissolved 0 to 10 m [ppb]	**A**	1.33	3.86	7.27	7.49	3.75	1.45	1.51
	B	1.18	3.90	7.87	7.66	5.10	2.66	1.72
	C	1.31	3.77	6.98	9.04	8.29	4.19	2.46
Beached [g.m^2]	**A**	0.00	0.00	0.00	0.00	0.00	0.03	3.06
	B	0.00	0.00	0.00	0.00	0.00	0.08	1.63
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.96

3.1.3. Results for the transitional conditions

Spill scenarios which started during the transition months (March, September, October and November) were sub-selected from the database of 100 simulations.

The lowest surface threshold of 1 g per m^2 was reached in all the runs (Table 3.8) and MGO concentrations of 10 ppb were found between 0 and 20 m depths in at least 31 % of the runs. During the transitional months, the plume is more influenced by ocean currents than wind, and the spread is therefore oriented towards the South-East (Figure 3.10 to Figure 3.13). The maximum surface concentration was 8 g/m^2, and the 1 g/m^2 threshold persisted for 43 days and extended up to 350 km from the release site. The maximum entrained concentration in 0 to 10 m water depths was 663 ppb and the 10-ppb threshold was exceeded over the first 50 days.

The highest shoreline loading was 75.15 g/m^2. Beaching is most likely to occur in the Kimberley area, Joseph Bonaparte Gulf (7%) and Ashmore area (3%). The minimum time between the spill start and beaching is 16 days.

Table 3.8 Probability (in %) of MGO reaching each defined threshold during the transitional months. The low and moderate surface thresholds for surface MGO are 1 and 10 g/m^2, respectively. The low and moderate concentration thresholds for entrained MGO is 10 and 100 ppb, respectively. The low and moderate concentration thresholds for dissolved MGO are 10 and 50 ppb, respectively.

	Release location A		**Release location B**		**Release location C**	
Threshold	**Low**	**Moderate**	**Low**	**Moderate**	**Low**	**Moderate**
Surface	100	0	100	0	97	0
Entrained 0-10 m	100	97	100	90	100	90
Entrained 10-20 m	31	10	38	3.45	38	3
Dissolved	24	0	34	0	24	0
Beached	17	0	21	0	17	0

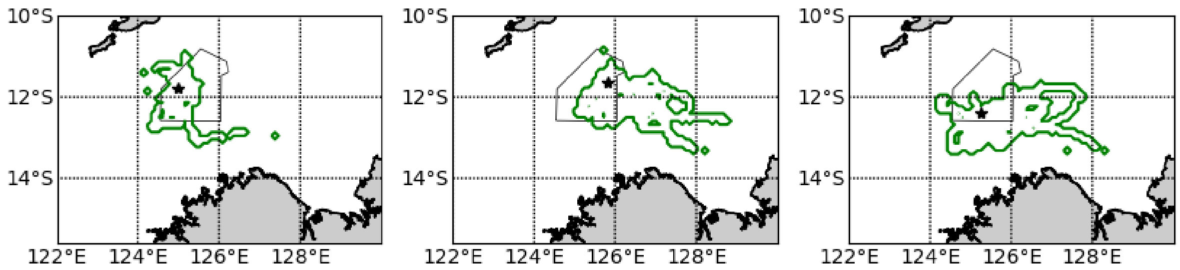


Figure 3.10 Zone of maximum surface exposure above 1 g/m² (green) during the transitional months for spills from location A (left), B (middle) and C (right).

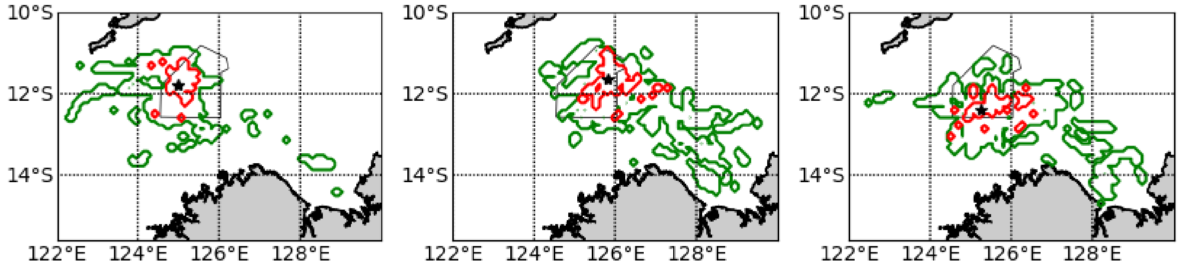


Figure 3.11 Zone of maximum entrained (0 to 10 m) exposure above 10 g/m² (green) and 100 g/m² (red) during the transitional months for spills from location A (left), B (middle) and C (right).

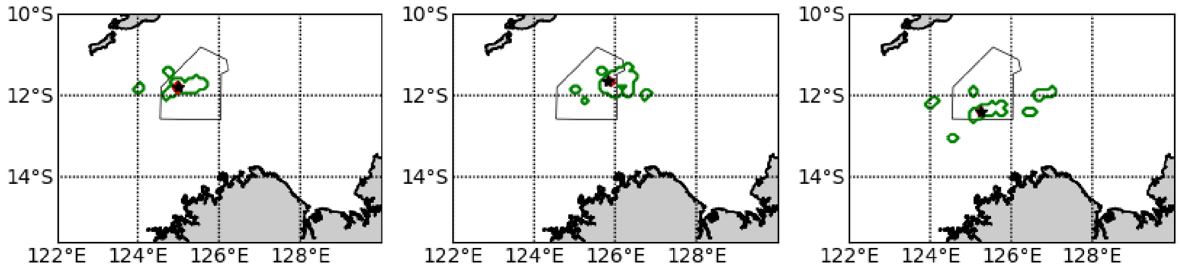


Figure 3.12 Zone of maximum entrained (10 to 20 m) exposure above 10 g/m² (green) and 100 g/m² (red) during the transitional months for spills from location A (left), B (middle) and C (right).

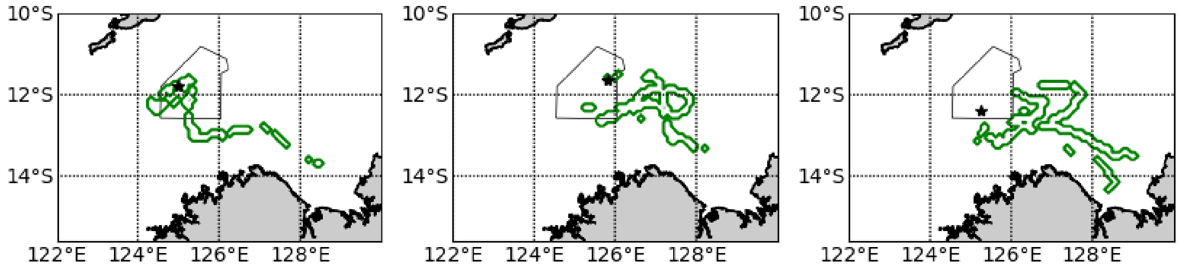


Figure 3.13 Zone of maximum dissolved (0 to 10 m) exposure above 10 g/m² (green) during the transitional months for spills from location A (left), B (middle) and C (right).

Table 3.9 Maximum concentration of MGO after 1, 2, 7, 15, 30, 40 and greater than 60 days during the transitional months.

	Location	1 day	2 days	7 days	15 days	30 days	40 days	>60 days
Surface [g/m^2]	**A**	6.93	6.29	4.61	2.47	2.26	1.07	0.00
	B	6.94	6.20	4.46	2.89	1.56	0.52	0.01
	C	7.00	6.33	4.97	2.95	1.84	1.45	0.02
Entrained 0 to 10 m [ppb]	**A**	540.66	425.48	153.18	47.40	39.61	5.62	0.13
	B	501.82	333.20	107.50	43.23	57.98	7.74	0.20
	C	545.75	413.84	96.61	40.13	43.24	12.69	0.62
Entrained 10 to 20 m [ppb]	**A**	92.53	63.76	8.53	8.22	1.22	0.48	0.03
	B	89.62	55.74	6.71	4.24	3.09	0.59	0.05
	C	71.50	47.60	5.61	4.68	2.40	0.50	0.12
Dissolved 0 to 10m [ppb]	**A**	1.48	3.76	8.64	10.09	12.95	9.46	2.34
	B	1.57	3.88	5.94	9.03	14.78	7.09	2.41
	C	2.06	3.68	7.92	8.93	12.86	15.19	2.80
Beached [g/m^2]	**A**	0.00	0.00	0.00	0.00	9.88	9.95	16.46
	B	0.00	0.00	0.00	0.00	0.50	47.28	52.72
	C	0.00	0.00	0.00	0.00	15.71	15.71	75.15

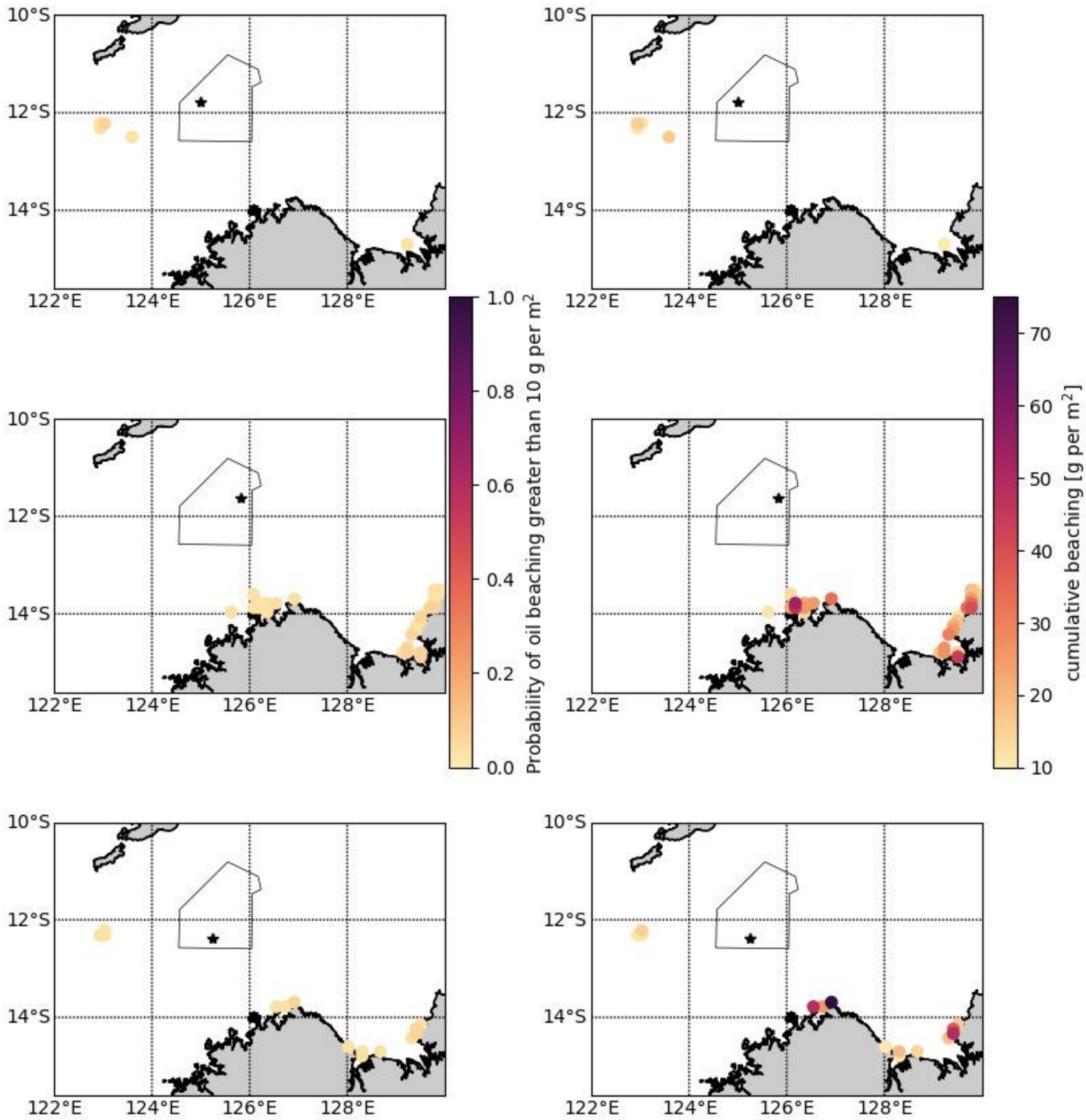


Figure 3.14 Probability for oil beaching (left) and maximum beached MGO concentration during the transitional months for spills from location A (top), B (middle) and C (bottom). Note, a probability of 1 represents 100% chance of oil beaching above 10 g/m^2.

3.1.4. Results for the winter conditions

Spill scenarios which started during winter months (April, May, June, July and August) were sub-selected from the database of 100 simulations.

The lowest surface threshold of 1 g per m^2 was reached in 69% of the runs (Table 3.10) and MGO concentrations of 10 ppb were found between 0 and 20 m depths in at least 93 % of the runs The plume follows the winter wind pattern and spread towards the South-West (Figure 3.15 to Figure 3.18). The maximum surface concentration was 8 g/m^2, and the 1 g/m^2 threshold persisted for up to 22 days and extended some 180 km from the release site. The maximum entrained concentration in 0 to 10 m water depth was 677 ppb and the 10-ppb threshold was exceeded over the first 27 days.

The highest shoreline loading was 48.79 g/m^2. Beaching is most likely to occur in and around Ashmore Reef and on Cartier Island (6% probability) and North Kimberley coast (2%). The minimum time between spill start and beaching is 16 days.

Table 3.10 Winter probability (in %) of MGO reaching each defined threshold. The low and moderate surface thresholds for surface MGO are 1 and 10 g/m^2, respectively. The low and moderate concentration thresholds for entrained MGO is 10 and 100 ppb, respectively. The low and moderate concentration thresholds for dissolved MGO are 10 and 50 ppb, respectively.

	Release location A		**Release location B**		**Release location C**	
Threshold	**Low**	**Moderate**	**Low**	**Moderate**	**Low**	**Moderate**
Surface	70	0	70	0	70	0
Entrained 0-10 m	100	100	100	98	100	100
Entrained 10-20 m	96	22	93	11	96	9
Dissolved	2	0	0	0	2	0
Beached	2	0	2	0	9	0

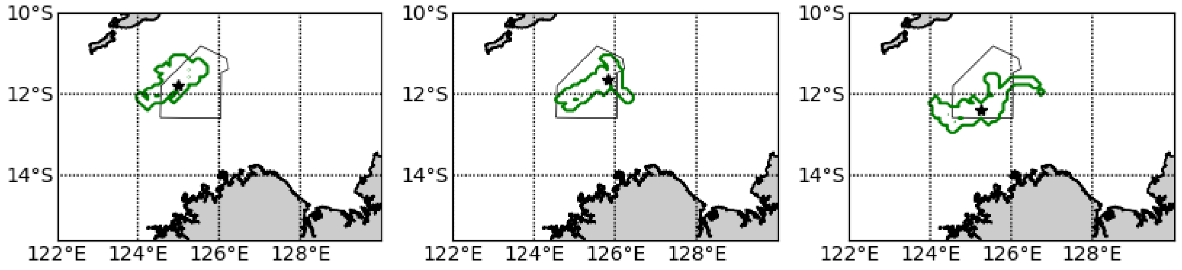


Figure 3.15 Winter zone of maximum surface exposure above 1 g/m^2 (green) for spills from location A (left), B (middle) and C (right).

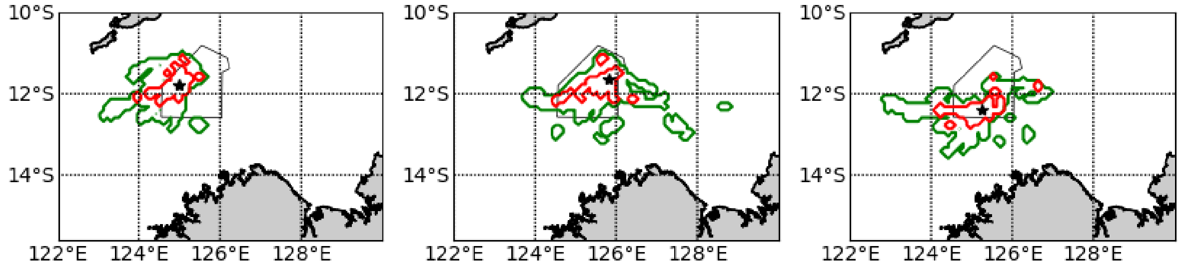


Figure 3.16 Winter zone of maximum entrained (0 to 10 m) exposure above 10 g/m^2 (green) and 100 g/m^2 (red) for spills from location A (left), B (middle) and C (right).

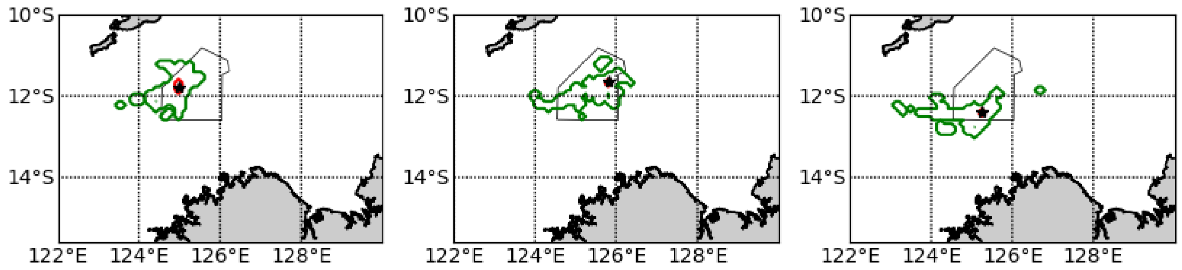


Figure 3.17 Winter zone of maximum entrained (10 to 20m) exposure above 10 g/m^2 (green) and 100 g/m^2 (red) for spills from location A (left), B (middle) and C (right).

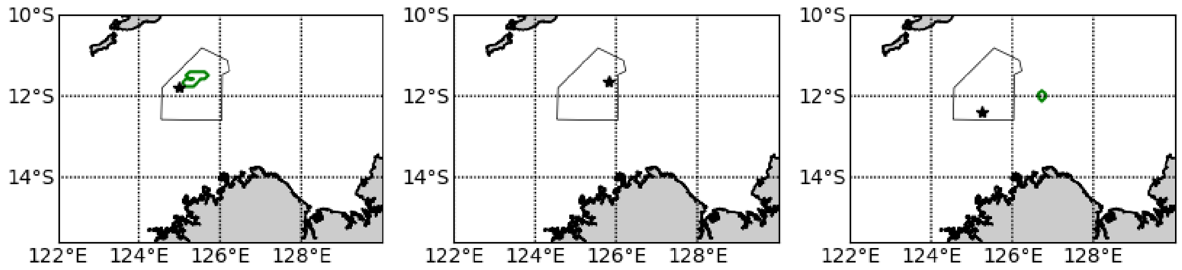


Figure 3.18 Winter zone of maximum dissolved (0 to 10m) exposure above 10 g/m^2 (green) for spills from location A (left), B (middle) and C (right).

Table 3.11 Winter maximum concentration of MGO after 1,2,7,15,30,40 and greater than 60 days.

	Location	1 day	2 days	7 days	15 days	30 days	40 days	>60 days
Surface [g.m^2]	**A**	6.96	6.20	5.19	2.00	0.49	0.37	0.14
	B	6.96	6.10	4.82	3.28	0.55	0.21	0.03
	C	6.57	6.36	4.93	2.71	0.62	0.19	0.06
Entrained 0 to 10m [ppb]	**A**	559.97	404.95	75.64	49.06	5.71	25.31	2.29
	B	499.14	365.20	50.60	36.29	5.38	10.60	0.38
	C	500.53	327.86	56.55	32.31	7.09	20.89	1.11
Entrained 10 to 20 m [ppb]	**A**	100.42	86.31	19.44	16.80	1.29	0.33	0.21
	B	101.81	66.91	17.84	9.84	2.94	0.32	0.07
	C	87.05	68.60	30.39	11.91	0.87	0.52	0.17
Dissolved 0 to 10 m [ppb]	**A**	1.71	3.07	6.54	7.90	5.01	4.24	3.70
	B	1.73	2.98	6.31	8.05	4.84	4.75	8.16
	C	1.57	3.39	6.22	6.59	5.89	3.66	2.17
Beached [g/m^2]	**A**	0.00	0.00	0.00	0.00	23.93	24.90	24.91
	B	0.00	0.00	0.00	0.00	1.90	3.37	14.63
	C	0.00	0.00	0.00	0.00	48.79	48.79	48.79

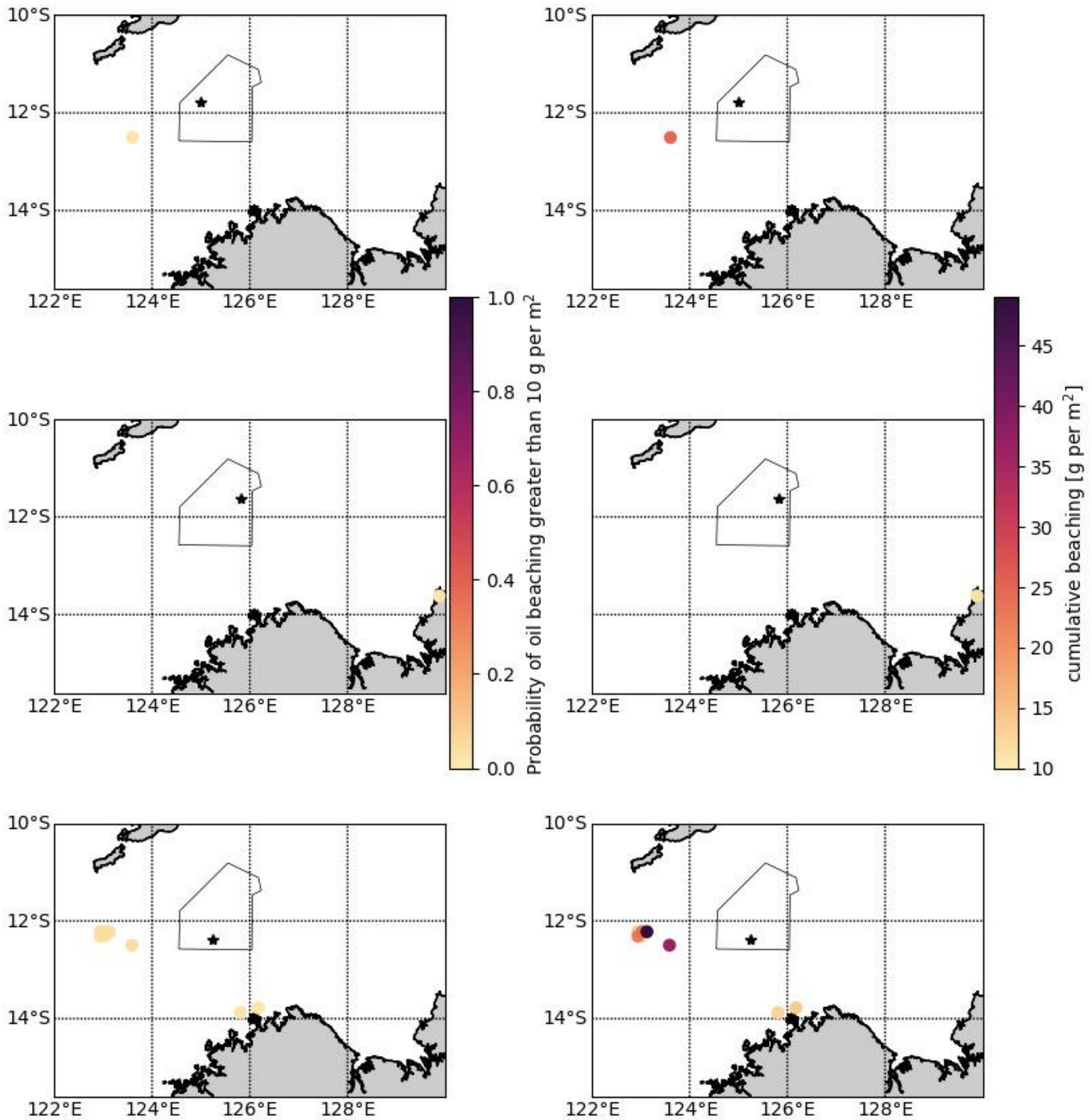


Figure 3.19 Winter probability for oil beaching (left) and maximum beached MGO concentration for spills from location A (top), B (middle) and C (bottom). Note, a probability of 1 represents 100 % chance of oil beaching above 10 g/m^2.

3.2. Worst-case beaching simulation

The worst-case beaching outcome identified from the 100 random simulations occurred from a spill that started on 22nd October 2012, which gave rise to a shoreline loading of up to 75 g/m^2 of MGO on the coast. Due to the calm weather at this time of the year, there is less dispersal of the oil and the transport vectors align toward the Kimberley coast. In total, some 13% of the spilled volume was beached. The trajectory is shown on Figure 3.20, which displays the maximum surface, entrained and dissolved concentration from the 90-day simulation.

Localised concentrations of up to 75 g/m^2 were observed in the simulation, while the average was 2.7 g/m^2. In total, some 115 tonnes (i.e., 136 m^3) of MGO were beached. The fate and mass budget for the event is provided as a time series graph in Figure 3.22.

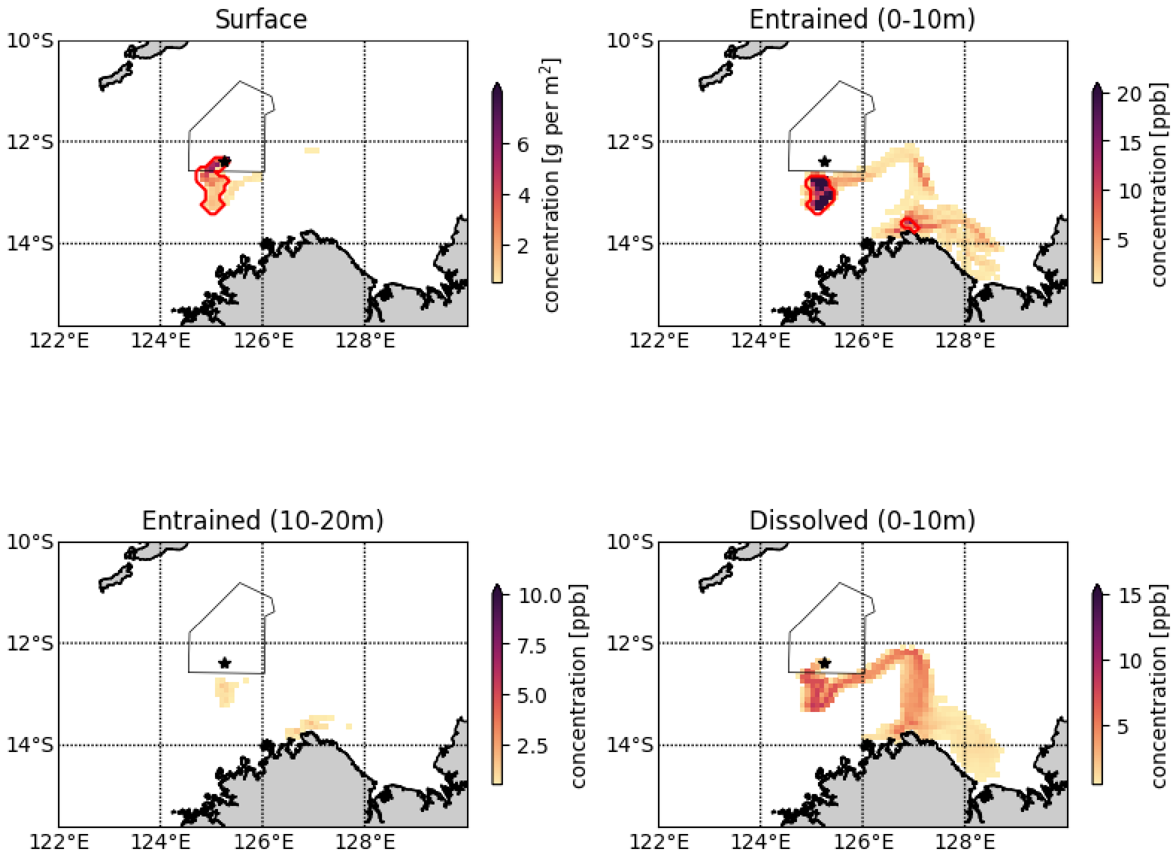


Figure 3.20 The maximum surface, entrained and dissolved concentration during the worst-case scenario simulated beaching event. The red contour illustrates the lowest threshold for each concentration.

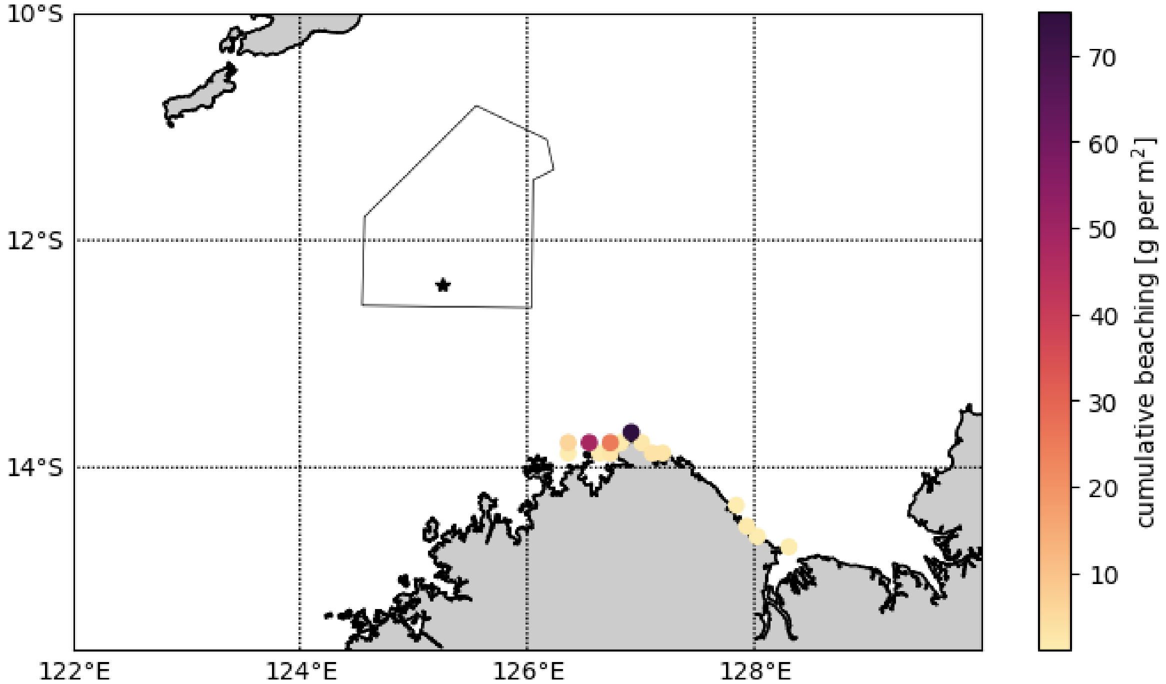
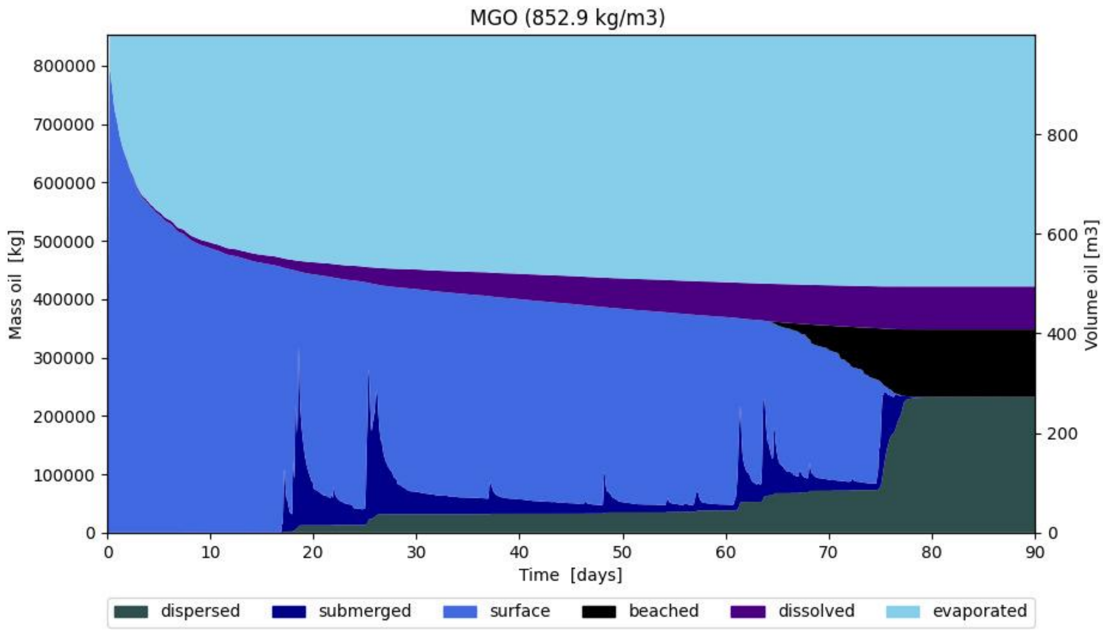


Figure 3.21 Total concentration of MGO (in g/m²) beached during the worst-case scenario.



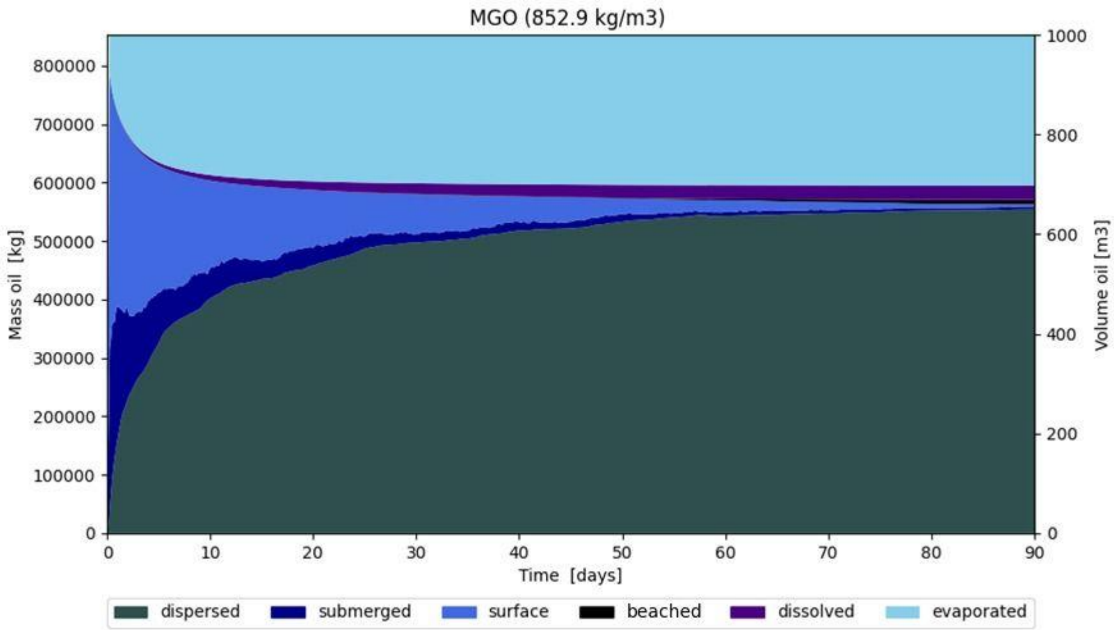


Figure 3.22 Timeseries representing the fate and mass budget of the October 2012 spill event from location C (top) and the average from all the simulations (bottom).

4. SUMMARY

A stochastic approach was undertaken to define the statistical probabilities related to oil trajectory, dispersion, weathering, and beaching patterns arising from a spill due to a vessel collision during Bonaparte MC3D survey in the Bonaparte Basin. A numerical particle model was used to simulate oil spills for 100 randomly selected dates over a decade. Historical hindcasts of the wave, wind, and ocean current conditions were used to drive the numerical model.

The simulated spill scenario was a surface release of 1,000 m^3 of MGO over a 6-hour period. Each spill was tracked by the model for 90 days, and the results used to form a database of 100 events which were analysed to derive statistics on the fate and mass budgets, plus the probability of occurrence for specific impacts.

The results show that the fate of spilled MGO in the Bonaparte Basin is highly dependent on the wind and wave climate. During the transitional months (March, September, October and November) winds and waves are relatively calm and the fuel persists on sea surface for a long period of time than other seasons. There is less dispersion within the water column and more surface trajectory toward Joseph Bonaparte Gulf. During the winter months (April, May, June, July and August) the plume tends to spread toward the South-West (i.e., Ashmore reef and Cartier Island), whereas during the summer months (December, January, February) the plume trajectory is predominantly directed toward the North-East.

On average, around 1.7% of the spilled volume can be expected to beach during an event at location B and less than 1% at locations A and C. The worst-case outcome from the simulations resulted in 13% of the spilled volume beaching on the North Kimberley Coast. Overall, on an annual basis, the location with the highest chance of oil beaching is Joseph Bonaparte Gulf (6%), followed by the Ashmore Reef and Cartier Island area (5%) and North Kimberley coast (3%). The minimum times for the beaching concentration to reach 10 g/m^2 is 40 days for the Kimberley coast and 18 days for Ashmore Reef.

5. REFERENCES

Dagestad K.F, Röhrs J., Breivik O., and Ådlandsvik B. 2018. “OpenDrift v1.0: A Generic Framework for Trajectory Modelling.” *Geoscientfic Model Development* 11: 1405– 1420.

ECMWF. 2019. “ERA5: Fifth Generation of ECMWF Atmospheric Reanalyses of the Global Climate.” https://cds.climate.copernicus.eu/cdsapp#!/home.

Ferry, N., L. Parent, G. Garric, C. Bricaud, C. E. Testut, O. Le Galloudec, J. M. Lellouche, M. Drevillon, E. Greiner, and B. Barnier. 2012. “GLORYS2V1 Global Ocean Reanalysis of the Altimetric Era (1992–2009) at Meso Scale.” *Mercator Ocean–Quaterly Newsletter* 44.

Hellstrom et al, 2017, Memo report no OC2017-A123, Version 1, SINTEF.

Johansen M. R., Reed M., and Bodsberg N. R. 2015. “Natural Dispersion Revisited.” Marine Pollution Bulletin 93 (1–2): 20–26.

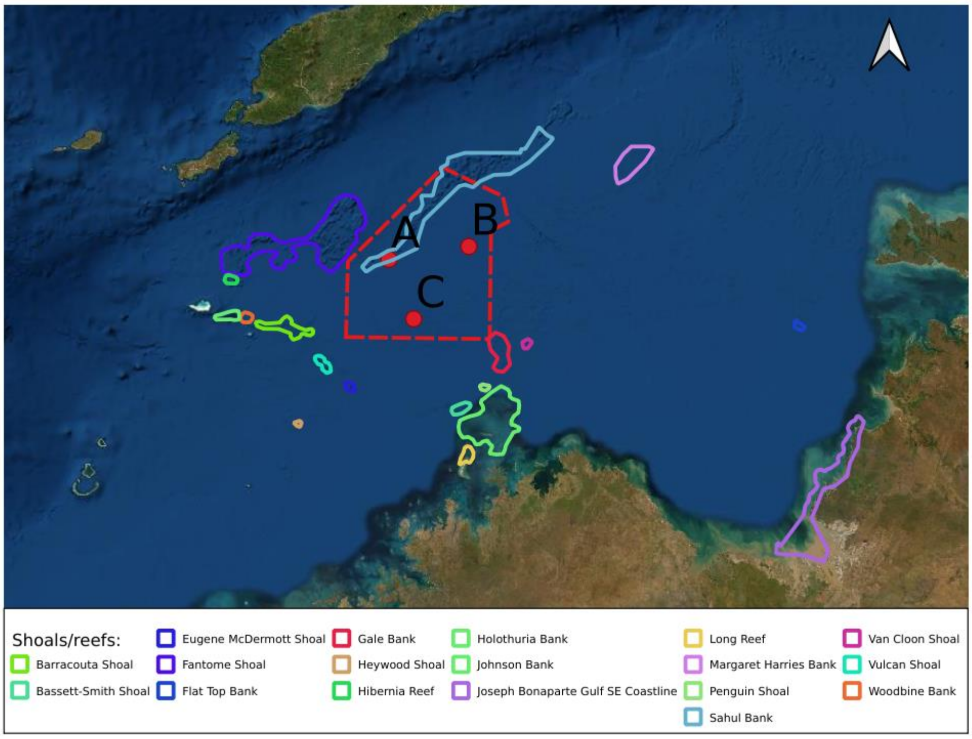
Keramea, Panagiota, Katerina Spanoudaki, George Zodiatis, Georgios Gikas, and Georgios Sylaios. 2021. "Oil Spill Modeling: A Critical Review on Current Trends, Perspectives, and Challenges" Journal of Marine Science and Engineering 9, no. 2: 181. https://doi.org/10.3390/jmse9020181

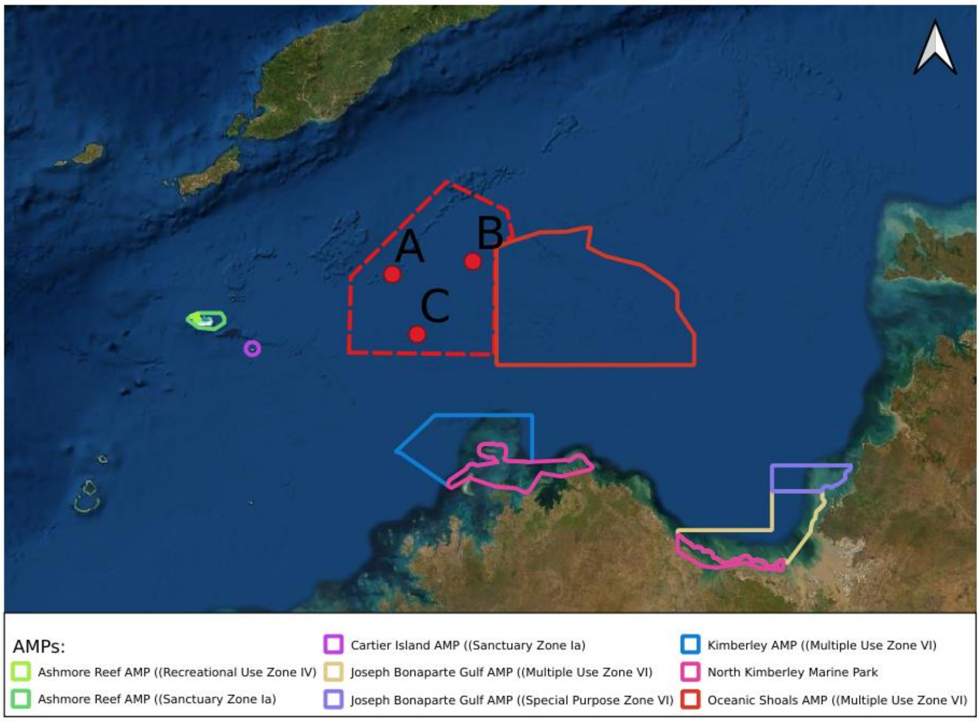
Large, W.G., McWilliams, J.C. and Doney, S.C., 1994. Oceanic vertical mixing: A review and a model with a nonlocal boundary layer parameterization. Reviews of geophysics, 32(4), pp.363-403.

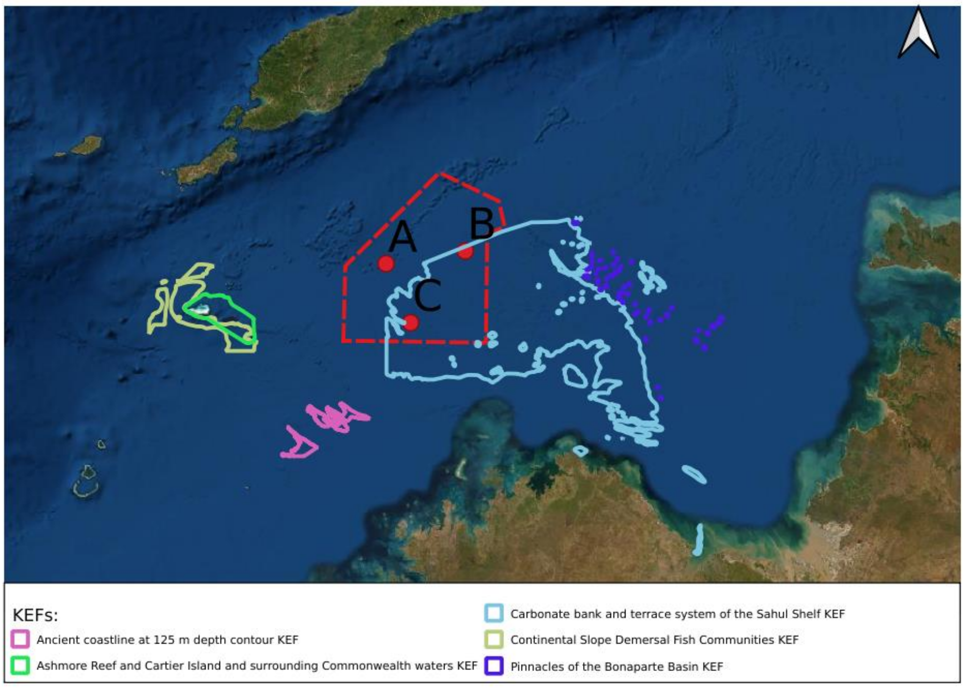
Li Z., Spaulding M.L., and French-McCay, D. 2017. “An Algorithm for Modeling Entrainment and Naturally and Chemically Dispersed Oil Droplet Size Distribution under Surface Breaking Wave Conditions.” Marine Pollution Bulletin, no. 119: 145–52.

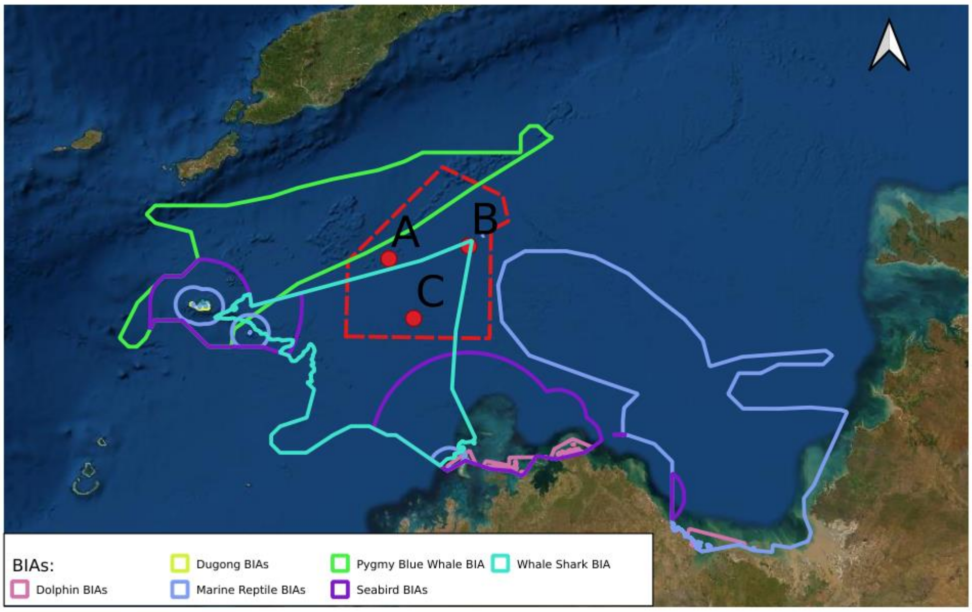
The National Offshore Petroleum Safety and Environmental Management Authority, 2019. Bulletin #1 Oil Spill Modelling, April 2019. Available at https://www.nopsema.gov.au/assets/Bulletins/A652993.pdf

APPENDIX ONE






A
B
C
KEFs:
Ancient coastline at 125 m depth contour KEF
Ashmore Reef and Cartier Island and surrounding Commonwealth waters KEF
Carbonate bank and terrace system of the Sahul Shelf KEF
Continental Slope Demersal Fish Communities KEF
Pinnacles of the Bonaparte Basin KEF


A
B
C
BIAs:
Dolphin BIAs
Dugong BIAs
Marine Reptile BIAs
Pygmy Blue Whale BIA
Seabird BIAs
Whale Shark BIA

APPENDIX C

Protected Matters Search Tool Results

Australian Government
Department of Agriculture, Water and the Environment

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 03-Mar-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	1
Wetlands of International Importance (Ramsar	2
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	3
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	48
Listed Migratory Species:	72

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

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 Lands:	4
Commonwealth Heritage Places:	1
Listed Marine Species:	120
Whales and Other Cetaceans:	27
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	8
Habitat Critical to the Survival of Marine Turtles:	2

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	7
Regional Forest Agreements:	None
Nationally Important Wetlands:	2
EPBC Act Referrals:	110
Key Ecological Features (Marine):	7
Biologically Important Areas:	45
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

National Heritage Places [Resource Information]

Name	State	Legal Status
Natural		
The West Kimberley	WA	Listed place

Wetlands of International Importance (Ramsar Wetlands) [Resource Information]

Ramsar Site Name	Proximity
Ashmore reef national nature reserve	Within Ramsar site
Ord river floodplain	Within 10km of Ramsar site

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea
Extended Continental Shelf
Extended Continental Shelf

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris tenuirostris Great Knot [862]	Critically Endangered	Species or species habitat likely to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Species or species habitat likely to occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat likely to occur within area
Erythrura gouldiae Gouldian Finch [413]	Endangered	Species or species habitat likely to occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat likely to occur within area
Falcunculus frontatus whitei Crested Shrike-tit (northern), Northern Shrike-tit [26013]	Vulnerable	Species or species habitat likely to occur within area
Geophaps smithii blaauwi Partridge Pigeon (western) [66501]	Vulnerable	Species or species habitat likely to occur within area
Limosa lapponica baueri Nunivak Bar-tailed Godwit, Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat may occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Critically Endangered	Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Tyto novaehollandiae kimberli Masked Owl (northern) [26048]	Vulnerable	Species or species habitat likely to occur within area
FISH		
Thunnus maccoyii Southern Bluefin Tuna [69402]	Conservation Dependent	Breeding known to occur within area
MAMMAL		
Antechinus bellus Fawn Antechinus [344]	Vulnerable	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 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
Conilurus penicillatus Brush-tailed Rabbit-rat, Brush-tailed Tree-rat, Pakooma [132]	Vulnerable	Species or species habitat may occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Mesembriomys gouldii gouldii		
Black-footed Tree-rat (Kimberley and mainland Northern Territory), Djintamoonga, Manbul [87618]	Endangered	Species or species habitat may occur within area
Petrogale concinna canescens		
Nabarlek (Top End) [87606]	Endangered	Species or species habitat may occur within area
Petrogale concinna monastria		
Nabarlek (Kimberley) [87607]	Endangered	Species or species habitat known to occur within area
Phascogale pirata		
Northern Brush-tailed Phascogale [82954]	Vulnerable	Species or species habitat likely to occur within area
Saccolaimus saccolaimus nudicluniatus		
Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat likely to occur within area
Trichosurus vulpecula arnhemensis		
Northern Brushtail Possum [83091]	Vulnerable	Species or species habitat likely to occur within area
Xeromys myoides		
Water Mouse, False Water Rat, Yirrkoo [66]	Vulnerable	Species or species habitat likely to occur within area
REPTILE		
Acanthophis hawkei		
Plains Death Adder [83821]	Vulnerable	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 foliosquama		
Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat may occur within area
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
SHARK		
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki Northern River Shark, New Guinea River Shark [82454]	Endangered	Species or species habitat known to occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat likely 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

Scientific Name	Threatened Category	Presence Text
Sphyrna lewini Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat known to occur within area

Listed Migratory Species

[Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Breeding known to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding known to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Sternula albifrons Little Tern [82849]		Foraging, feeding or related behaviour known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat 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
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat may occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Dugong dugon Dugong [28]		Breeding 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
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Megaptera novaeangliae Humpback Whale [38]		Species or species habitat known to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat likely 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 sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Foraging, feeding or related behaviour known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area

Migratory Terrestrial Species

Scientific Name	Threatened Category	Presence Text
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat may occur within area
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat likely to occur within area
Migratory Wetlands Species		
Acrocephalus orientalis Oriental Reed-Warbler [59570]		Species or species habitat known to occur within area
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Species or species habitat likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris alba Sanderling [875]		Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
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 may occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Species or species habitat likely to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Species or species habitat likely to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius phaeopus Whimbrel [849]		Species or species habitat likely to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Pluvialis squatarola Grey Plover [865]		Species or species habitat likely to occur within area
Thalasseus bergii Greater 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 Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Defence	
Defence - MT GOODWIN RADAR SITE [70063]	NT
Unknown	
Commonwealth Land - [52276]	ACI
Commonwealth Land - [52278]	ACI
Commonwealth Land - [52277]	ACI

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Ashmore Reef National Nature Reserve	EXT	Listed place

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Acrocephalus orientalis		
Oriental Reed-Warbler [59570]		Species or species habitat known to occur within area overfly marine area
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous minutus		
Black Noddy [824]		Breeding known to occur within area
Anous stolidus		
Common Noddy [825]		Breeding known to occur within area
Anous tenuirostris melanops		
Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Anseranas semipalmata		
Magpie Goose [978]		Species or species habitat may occur within area overfly marine area
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area
Ardenna pacifica as Puffinus pacificus		
Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Arenaria interpres		
Ruddy Turnstone [872]		Species or species habitat likely to occur within area
Bubulcus ibis as Ardea ibis		
Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris alba		
Sanderling [875]		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 overfly marine area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area
Calidris melanotos		
Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area
Calidris tenuirostris		
Great Knot [862]	Critically Endangered	Species or species habitat likely to occur within area overfly marine area
Calonectris leucomelas		
Streaked Shearwater [1077]		Species or species habitat known to occur within area
Cecropis daurica as Hirundo daurica		
Red-rumped Swallow [80610]		Species or species habitat may occur within area overfly marine area
Chalcites osculans as Chrysococcyx osculans		
Black-eared Cuckoo [83425]		Species or species habitat likely to occur within area overfly marine area
Charadrius leschenaultii		
Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus		
Lesser Sand Plover, Mongolian Plover [879]	Endangered	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area overfly marine area
Chroicocephalus novaehollandiae as Larus novaehollandiae Silver Gull [82326]		Breeding known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area overfly marine area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area overfly marine area
Hydroprogne caspia as Sterna caspia Caspian Tern [808]		Breeding known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area overfly marine area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Species or species habitat likely to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Merops ornatus		
Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area
Motacilla cinerea		
Grey Wagtail [642]		Species or species habitat known to occur within area overfly marine area
Motacilla flava		
Yellow Wagtail [644]		Species or species habitat known to occur within area overfly marine area
Numenius madagascariensis		
Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius phaeopus		
Whimbrel [849]		Species or species habitat likely to occur within area
Onychoprion anaethetus as Sterna anaethetus		
Bridled Tern [82845]		Breeding 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 known to occur within area
Phaethon rubricauda		
Red-tailed Tropicbird [994]		Breeding known to occur within area
Pluvialis squatarola		
Grey Plover [865]		Species or species habitat likely to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Rhipidura rufifrons		
Rufous Fantail [592]		Species or species habitat likely to occur within area overfly marine area
Rostratula australis as Rostratula benghalensis (sensu lato)		
Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area overfly marine area
Sterna dougallii		
Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons as Sterna albifrons		
Little Tern [82849]		Foraging, feeding or related behaviour known to occur within area
Sula dactylatra		
Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster		
Brown Booby [1022]		Breeding known to occur within area
Sula sula		
Red-footed Booby [1023]		Breeding known to occur within area
Thalasseus bengalensis as Sterna bengalensis		
Lesser Crested Tern [66546]		Breeding known to occur within area
Thalasseus bergii as Sterna bergii		
Greater Crested Tern [83000]		Breeding known to occur within area
Tringa nebularia		
Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area overfly marine area
Fish		
Bhanotia fasciolata		
Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys haematopterus Reef-top Pipefish [66201]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Festucalex cinctus Girdled Pipefish [66214]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys cyanospilos Blue-speckled Pipefish, Blue-spotted Pipefish [66228]		Species or species habitat may occur within area
Hippichthys parvicarinatus Short-keel Pipefish, Short-keeled Pipefish [66230]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Trachyrhamphus longirostris		
Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammal		
Dugong dugon		
Dugong [28]		Breeding known to occur within area
Reptile		
Acalyptophis peronii		
Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis		
Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii		
Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii		
Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus foliosquama		
Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat may occur within area
Aipysurus fuscus		
Dusky Seasnake [1119]		Species or species habitat known to occur within area
Aipysurus laevis		
Olive Seasnake [1120]		Species or species habitat may occur within 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

Scientific Name	Threatened Category	Presence Text
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Chitulia inornata as Hydrophis inornatus Plain Seasnake [87379]		Species or species habitat may occur within area
Chitulia ornata as Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [87377]		Species or species habitat may occur within area
Crocodylus johnstoni Freshwater Crocodile, Johnston's Crocodile, Johnstone's Crocodile [1773]		Species or species habitat may occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Enhydrina schistosa Beaked Seasnake [1126]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis atriceps Black-headed Seasnake [1101]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis macdowelli as Hydrophis mcdowelli Small-headed Seasnake [75601]		Species or species habitat may occur within area
Lapemis curtus as Lapemis hardwickii Spine-bellied Seasnake [83554]		Species or species habitat may occur within area
Leioselasma coggeri as Hydrophis coggeri Black-headed Sea Snake, Slender-necked Seasnake [87373]		Species or species habitat may occur within area
Leioselasma pacifica as Hydrophis pacificus Large-headed Seasnake, Pacific Seasnake [87378]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Parahydrophis mertoni Northern Mangrove Seasnake [1090]		Species or species habitat may occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans [Resource Information]

Current Scientific Name	Status	Type of Presence

Current Scientific Name	Status	Type of Presence
Mammal		
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 Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Megaptera novaeangliae Humpback Whale [38]		Species or species habitat known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Orcaella heinsohni as Orcaella brevirostris Australian Snubfin Dolphin [81322]		Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
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 sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Foraging, feeding or related behaviour known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
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 known to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Park Name	Zone & IUCN Categories
Joseph Bonaparte Gulf	Multiple Use Zone (IUCN VI)
Kimberley	Multiple Use Zone (IUCN VI)
Oceanic Shoals	Multiple Use Zone (IUCN VI)
Ashmore Reef	Recreational Use Zone (IUCN IV)
Ashmore Reef	Sanctuary Zone (IUCN Ia)
Cartier Island	Sanctuary Zone (IUCN Ia)
Joseph Bonaparte Gulf	Special Purpose Zone (IUCN VI)
Oceanic Shoals	Special Purpose Zone (Trawl) (IUCN VI)

Habitat Critical to the Survival of Marine Turtles

Scientific Name	Behaviour	Presence
Aug - Sep		
Natator depressus Flatback Turtle [59257]	Nesting	Known to occur

Scientific Name	Behaviour	Presence
Dec - Jan		
Chelonia mydas		
Green Turtle [1765]	Nesting	Known to occur

Extra Information

State and Territory Reserves [Resource Information]

Protected Area Name	Reserve Type	State
Balanggarra	Indigenous Protected Area	WA
Keep River	Proposed National Parks Act park or park addition	NT
Marri-Jabin (Thamurrurr - Stage 1)	Indigenous Protected Area	NT
Niiwalarra Islands	National Park	WA
North Kimberley	Marine Park	WA
Pelican Island	Nature Reserve	WA
Uunguu	Indigenous Protected Area	WA

Nationally Important Wetlands [Resource Information]

Wetland Name	State
Ashmore Reef	EXT
Moyle Floodplain and Hyland Bay System	NT

EPBC Act Referrals [Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
275 km gas pipeline from Wadeye to existing Darwin gas pipeline	2006/2930	Controlled Action	Post-Approval
Audacious Oil Field Standalone Development	2001/407	Controlled Action	Completed
Australia-ASEAN Power Link	2020/8818	Controlled Action	Proposed Decision
Blacktip Project - Wharf Construction	2007/3293	Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Bonaparte Liquified Natural Gas Project	2011/6141	Controlled Action	Post-Approval
Decommissioning of Buffalo Oil Field	2003/984	Controlled Action	Post-Approval
Decommissioning of Challis Oilfield	2003/942	Controlled Action	Post-Approval
Development of Blacktip Gas Field	2003/1180	Controlled Action	Post-Approval
Development of Browse Basin Gas Fields (Upstream)	2008/4111	Controlled Action	Completed
Ichthys Gas Field, Offshore and onshore processing facilities and subsea pipeline	2008/4208	Controlled Action	Post-Approval
Montara 4, 5, and 6 Oil Production Wells, and Montara 3 Gas Re-Injection Well	2002/755	Controlled Action	Post-Approval
Prelude Floating Liquefied Natural Gas Facility and Gas Field Development	2008/4146	Controlled Action	Post-Approval
Project Sea Dragon stage 1 prawn aquaculture project, NT	2015/7527	Controlled Action	Post-Approval
PTTEP AA Floating LNG Facility	2011/6025	Controlled Action	Completed
Trans-territory Gas Pipeline	2003/1186	Controlled Action	Completed
Not controlled action			
2D seismic survey, exploration permit NT/P67	2004/1587	Not Controlled Action	Completed
2D Seismic Survey in Permit Areas WA-318-P & WA-319-P, near Cape Londonderry	2004/1687	Not Controlled Action	Completed
Adele Trend TQ3D Seismic Survey	2001/252	Not Controlled Action	Completed
AEC International Hydrocarbon Well Puffin 6	2000/36	Not Controlled Action	Completed
Audacious-3 oil drilling well	2003/1042	Not Controlled Action	Completed
Backpacker-1 Offshore Hydrocarbon Exploration Well	2001/300	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Buffalo In-Fill Production Wells	2001/475	Not Controlled Action	Completed
Controlled Source Electromagnetic 2D Survey	2009/4980	Not Controlled Action	Completed
Controlled Source Electromagnetic Survey	2010/5434	Not Controlled Action	Completed
Coot-1 hydrocarbon exploration well, Permit Area AC/L2 or AC/L3	2001/296	Not Controlled Action	Completed
Crux-A and Crux-B appraisal wells, Petroleum Permit Area AC/P23	2006/2748	Not Controlled Action	Completed
Crux gas-liquids development in permit AC/P23	2006/3154	Not Controlled Action	Completed
Drilling of 12 Hydrocarbon Exploration Wells, Permit Area WA-371-P	2006/3005	Not Controlled Action	Completed
Drilling of exploration well Audacious-1 in AC/P17	2000/5	Not Controlled Action	Completed
Drilling of Marina-1 Exploration Well	2007/3586	Not Controlled Action	Completed
Echuca Shoals-2 Exploration of Appraisal Well	2006/3020	Not Controlled Action	Completed
Exploration Drilling in AC/P17, AC/P18 and AC/P24	2001/359	Not Controlled Action	Completed
Exploration Well AC/P23	2001/234	Not Controlled Action	Completed
Marine Survey for the Australia-ASEAN Power Link AAPL	2020/8714	Not Controlled Action	Completed
Montara-3 Offshore Hydrocarbon Exploration Well Permit Area AC/RL3	2001/489	Not Controlled Action	Completed
Nexus Drilling Program NT-P66	2007/3745	Not Controlled Action	Completed
P30 Hydrocarbon Exploration Well	2001/293	Not Controlled Action	Completed
Project Highclere Geophysical Survey	2021/9023	Not Controlled Action	Completed
Puffin Oil wells 7, 8 & 9 development	2005/2336	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Saucepan 1 Exploration Well ACP23	2000/2	Not Controlled Action	Completed
Skua and Swift Oilfields	2006/3195	Not Controlled Action	Completed
Strumbo-1 Gas Exploration Well Permit Area WA-288-P	2002/884	Not Controlled Action	Completed
Thresher-1 Well	2000/84	Not Controlled Action	Completed
Not controlled action (particular manner)			
2 (3D) Marine Seismic Surveys	2009/4994	Not Controlled Action (Particular Manner)	Completed
2D and 3D Seismic Survey	2011/6197	Not Controlled Action (Particular Manner)	Post-Approval
2D and 3D Seismic Survey WA-405-P	2009/5104	Not Controlled Action (Particular Manner)	Post-Approval
2D and 3D Seismic Survey WA-405-P	2008/4133	Not Controlled Action (Particular Manner)	Post-Approval
2D Marine Seismic Survey	2009/4728	Not Controlled Action (Particular Manner)	Post-Approval
2D marine seismic survey of Braveheart,Kurrajong,Sunshine and Crocodile	2006/2917	Not Controlled Action (Particular Manner)	Post-Approval
2D marine seismic survey within permit area WA-318-P	2007/3879	Not Controlled Action (Particular Manner)	Post-Approval
2D or 3D Marine Seismic Survey in Petroleum Permit Area AC/P35	2009/4864	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic Marine Survey	2001/363	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
2D Seismic survey	2009/5076	Not Controlled Action (Particular Manner)	Post-Approval
2D seismic survey in permit areas WA-274P and WA-281P	2004/1521	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic Survey in WA Permit Area TP/22 and Commonwealth Permit Area WA-280-P	2005/2100	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey	2009/4681	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey	2008/4437	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey, Permit AC/P 23	2005/2364	Not Controlled Action (Particular Manner)	Post-Approval
3D Seismic Survey, petroleum exploration permit AC/P33	2006/2918	Not Controlled Action (Particular Manner)	Post-Approval
3D seismic survey of AC/P4, AC/P17 and AC/P24	2006/2857	Not Controlled Action (Particular Manner)	Post-Approval
3D Seismic Survey WA-406-P Bonaparte Basin	2007/3904	Not Controlled Action (Particular Manner)	Post-Approval
AC/P37 3D Seismic Survey Ashmore Cartier	2007/3774	Not Controlled Action (Particular Manner)	Post-Approval
Auralandia 3D marine seismic survey	2011/5961	Not Controlled Action (Particular Manner)	Post-Approval
Blacktip Gas Project Yelcherr Beach Wharf Construction	2007/3537	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Bonaparte 2D & 3D marine seismic survey	2011/5962	Not Controlled Action (Particular Manner)	Post-Approval
Bonaparte Seismic and Bathymetric Survey	2012/6295	Not Controlled Action (Particular Manner)	Post-Approval
Braveheart 2D Infill Marine Seismic Survey 100km offshore	2008/4442	Not Controlled Action (Particular Manner)	Post-Approval
Braveheart 2D Marine Seismic Survey	2005/2322	Not Controlled Action (Particular Manner)	Post-Approval
Canis 3D Marine Seismic Survey	2008/4492	Not Controlled Action (Particular Manner)	Post-Approval
Cartier East and Cartier West 3D Marine Seismic Surveys	2009/5230	Not Controlled Action (Particular Manner)	Post-Approval
Caswell MC3D Marine Seismic Survey	2012/6594	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Northwest Shelf 2D Seismic Survey	2007/3260	Not Controlled Action (Particular Manner)	Post-Approval
Dillon South-1 Exploration Well Drilling - AC/P4, Territory of Ashmore/Cartier	2013/6849	Not Controlled Action (Particular Manner)	Post-Approval
Drilling of Audacious-5 appraisal well	2008/4327	Not Controlled Action (Particular Manner)	Post-Approval
Drilling of Exploration & Appraisal Wells Braveheart-1 & Cornea-3	2009/5160	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Drilling of two appraisal wells	2011/5840	Not Controlled Action (Particular Manner)	Post-Approval
Exploration Drilling Campaign, Browse Basin, WA-341-P, AC-P36 and WA-343-P	2013/6898	Not Controlled Action (Particular Manner)	Post-Approval
Exploration Drilling in Permit Areas WA-402-P & WA-403-P	2010/5297	Not Controlled Action (Particular Manner)	Post-Approval
Fishburn2D Marine Seismic Survey	2012/6659	Not Controlled Action (Particular Manner)	Post-Approval
Floyd 3D and Chisel 3D Seismic Surveys	2011/6220	Not Controlled Action (Particular Manner)	Post-Approval
Gold 2D Marine Seismic Survey Permit Areas WA375P and WA376P	2009/4698	Not Controlled Action (Particular Manner)	Post-Approval
Kingtree & Ironstone-1 Exploration Wells	2011/5935	Not Controlled Action (Particular Manner)	Post-Approval
Malita West 3D Seismic Survey WA-402-P and WA-403-P	2007/3936	Not Controlled Action (Particular Manner)	Post-Approval
Marine Environmental Survey 2012	2012/6310	Not Controlled Action (Particular Manner)	Post-Approval
Nova 3D Seismic Survey	2013/6825	Not Controlled Action (Particular Manner)	Post-Approval
NT/P77 3D Marine Seismic Survey	2009/4683	Not Controlled Action (Particular Manner)	Post-Approval
NT/P80 2010 2D Marine Seismic Survey	2010/5487	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Octantis 3D Marine Seismic Survey, Permit Area AC/P41 off northern Western Australia	2007/3369	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Fibre Optic Cable Network Construction & Operation, Port Hedland WA to Darwin NT	2014/7223	Not Controlled Action (Particular Manner)	Post-Approval
Petrel MC2D Marine Seismic Survey	2010/5368	Not Controlled Action (Particular Manner)	Post-Approval
Removal of Potential Unexploded Ordnance within NAXA	2012/6503	Not Controlled Action (Particular Manner)	Post-Approval
Sandalford 3D Seismic Survey	2012/6261	Not Controlled Action (Particular Manner)	Post-Approval
Santos Petrel-7 Offshore Appraisal Drilling Programme (Bonaparte Basin)	2011/5934	Not Controlled Action (Particular Manner)	Post-Approval
Schild Phase 11 MC3D Marine Seismic Survey, Browse Basin	2013/6894	Not Controlled Action (Particular Manner)	Post-Approval
Searcher bathymetry & geochemical seismic survey, Brawse Basin,Timor Sea,WA	2013/6980	Not Controlled Action (Particular Manner)	Post-Approval
Sonar and Acoustic Trials	2001/345	Not Controlled Action (Particular Manner)	Post-Approval
Songa Venus Drilling and Testing Operations	2009/5122	Not Controlled Action (Particular Manner)	Post-Approval
Songa Venus Drilling Programme, Bonaparte Basin	2009/4990	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Sunshine Infill 2D and Mimosa 2D Marine Seismic Surveys	2009/4699	Not Controlled Action (Particular Manner)	Post-Approval
Thoar 3D Marine Seismic Survey	2010/5668	Not Controlled Action (Particular Manner)	Post-Approval
Tiffany 3D Seismic Survey	2010/5339	Not Controlled Action (Particular Manner)	Post-Approval
Tow West Atlas wreck from present location to boundary of EEZ	2010/5652	Not Controlled Action (Particular Manner)	Post-Approval
Ursa 3D Marine Seismic Survey	2008/4634	Not Controlled Action (Particular Manner)	Post-Approval
Vampire 2D Non Exclusive Seismic Survey, WA	2010/5543	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Zeppelin 3D Seismic Survey	2011/6148	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
2D Marine Seismic Survey	2008/4623	Referral Decision	Completed
Nova 3D Seismic Survey, WA 442-NT/P81, Joseph Bonaparte Gulf	2013/6820	Referral Decision	Completed
Puffin South-West Development of Oil Reserves	2007/3834	Referral Decision	Completed
Seismic Data Acquisition, Browse Basin	2010/5475	Referral Decision	Completed

Key Ecological Features [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
Ashmore Reef and Cartier Island and surrounding Commonwealth waters	North-west
Carbonate bank and terrace system of the Sahul Shelf	North-west
Carbonate bank and terrace system of the Van Diemen Rise	North
Continental Slope Demersal Fish Communities	North-west
Pinnacles of the Bonaparte Basin	North-west
Pinnacles of the Bonaparte Basin	North

Biologically Important Areas

Scientific Name	Behaviour	Presence
Dolphins		
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Breeding	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Calving	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Foraging (high density prey)	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Resting	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging	Likely to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging (high density prey)	Known to occur

Scientific Name	Behaviour	Presence
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Significant habitat	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Significant habitat - unknown behaviour	Likely to occur
Dugong		
Dugong dugon Dugong [28]	Breeding	Known to occur
Dugong dugon Dugong [28]	Calving	Known to occur
Dugong dugon Dugong [28]	Foraging	Known to occur
Dugong dugon Dugong [28]	Foraging (high density seagrass beds)	Known to occur
Dugong dugon Dugong [28]	Nursing	Known to occur
Marine Turtles		
Caretta caretta Loggerhead Turtle [1763]	Foraging	Known to occur
Chelonia mydas Green Turtle [1765]	Foraging	Known to occur
Chelonia mydas Green Turtle [1765]	Foraging	Likely to occur
Chelonia mydas Green Turtle [1765]	Internesting buffer	Likely to occur
Chelonia mydas Green Turtle [1765]	Internesting buffer	Known to occur
Chelonia mydas Green Turtle [1765]	Mating	Likely to occur

Scientific Name	Behaviour	Presence
Chelonia mydas Green Turtle [1765]	Nesting	Likely to occur
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Foraging	Likely to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting buffer	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting buffer	Likely to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Nesting	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Nesting	Likely to occur
Lepidochelys olivacea Olive Ridley Turtle [1767]	Foraging	Known to occur
Natator depressus Flatback Turtle [59257]	Foraging	Known to occur
Natator depressus Flatback Turtle [59257]	Internesting	Likely to occur
Natator depressus Flatback Turtle [59257]	Internesting buffer	Known to occur
Natator depressus Flatback Turtle [59257]	Nesting	Known to occur
Seabirds		
Ardenna pacifica Wedge-tailed Shearwater [84292]	Breeding	Known to occur
Fregata ariel Lesser Frigatebird [1012]	Breeding	Known to occur
Fregata minor Greater Frigatebird [1013]	Breeding	Known to occur

Scientific Name	Behaviour	Presence
Phaethon lepturus White-tailed Tropicbird [1014]	Breeding	Known to occur
Sterna dougallii Roseate Tern [817]	Breeding	Known to occur
Sternula albifrons sinensis Little Tern [82850]	Breeding	Known to occur
Sternula albifrons sinensis Little Tern [82850]	Resting	Known to occur
Sula leucogaster Brown Booby [1022]	Breeding	Known to occur
Sula sula Red-footed Booby [1023]	Breeding	Known to occur
Thalasseus bengalensis Lesser Crested Tern [66546]	Breeding	Known to occur
Sharks		
Rhincodon typus Whale Shark [66680]	Foraging	Known to occur
Whales		
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and 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

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a 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 detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

Department of Agriculture Water and the Environment
GPO Box 858
Canberra City ACT 2601 Australia
+61 2 6274 1111

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. Please see the caveat for interpretation of information provided here.

Report created: 04-Mar-2022

Summary

Matters of National Environment 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 (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	22
Listed Migratory Species:	35

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

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 Lands:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	65
Whales and Other Cetaceans:	23
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	1
Habitat Critical to the Survival of Marine Turtles:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	None
Regional Forest Agreements:	None
Nationally Important Wetlands:	None
EPBC Act Referrals:	40
Key Ecological Features (Marine):	1
Biologically Important Areas:	5
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

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 a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea
Extended Continental Shelf

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat 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
FISH		
Thunnus maccoyii Southern Bluefin Tuna [69402]	Conservation Dependent	Species or species habitat likely to occur within area
MAMMAL		

Scientific Name	Threatened Category	Presence Text
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
REPTILE		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	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
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
SHARK		
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki		
Northern River Shark, New Guinea River Shark [82454]	Endangered	Species or species habitat may occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may 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
Sphyrna lewini		
Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat likely to occur within area

Listed Migratory Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
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

Scientific Name	Threatened Category	Presence Text
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat likely to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat may occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat may occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	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

Scientific Name	Threatened Category	Presence Text
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 likely to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Megaptera novaeangliae Humpback Whale [38]		Species or species habitat likely to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat likely to occur within area
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat likely 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

Scientific Name	Threatened Category	Presence Text
Physeter macrocephalus		
Sperm Whale [59]		Species or species habitat may occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may 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
Tursiops aduncus (Arafura/Timor Sea populations)		
Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris 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

Other Matters Protected by the EPBC Act

Listed Marine Species		[Resource Information]
Scientific Name	Threatened Category	Presence Text
Bird		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	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 overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine 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

Scientific Name	Threatened Category	Presence Text
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
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat likely to occur within area
Fish		
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Reptile		

Scientific Name	Threatened Category	Presence Text
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	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
Chitulia ornata as Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [87377]		Species or species habitat may occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area

Scientific Name	Threatened Category	Presence Text
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Enhydrina schistosa Beaked Seasnake [1126]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Hydrophis atriceps Black-headed Seasnake [1101]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Lapemis curtus as Lapemis hardwickii Spine-bellied Seasnake [83554]		Species or species habitat may occur within area
Leioselasma coggeri as Hydrophis coggeri Black-headed Sea Snake, Slender-necked Seasnake [87373]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	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

Scientific Name	Threatened Category	Presence Text
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans [Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	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 Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Species or species habitat likely to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Tursiops aduncus (Arafura/Timor Sea populations)		
Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area
Tursiops truncatus s. str.		
Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris		
Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Park Name	Zone & IUCN Categories
Oceanic Shoals	Multiple Use Zone (IUCN VI)

Extra Information

EPBC Act Referrals [Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Audacious Oil Field Standalone Development	2001/407	Controlled Action	Completed
Australia-ASEAN Power Link	2020/8818	Controlled Action	Proposed Decision
Decommissioning of Challis Oilfield	2003/942	Controlled Action	Post-Approval
Ichthys Gas Field, Offshore and onshore processing facilities and subsea pipeline	2008/4208	Controlled Action	Post-Approval
Montara 4, 5, and 6 Oil Production Wells, and Montara 3 Gas Re-Injection Well	2002/755	Controlled Action	Post-Approval
PTTEP AA Floating LNG Facility	2011/6025	Controlled Action	Completed
Not controlled action			
Audacious-3 oil drilling well	2003/1042	Not Controlled Action	Completed
Controlled Source Electromagnetic 2D Survey	2009/4980	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Controlled Source Electromagnetic Survey	2010/5434	Not Controlled Action	Completed
Coot-1 hydrocarbon exploration well, Permit Area AC/L2 or AC/L3	2001/296	Not Controlled Action	Completed
Drilling of exploration well Audacious-1 in AC/P17	2000/5	Not Controlled Action	Completed
Exploration Drilling in AC/P17, AC/P18 and AC/P24	2001/359	Not Controlled Action	Completed
Marine Survey for the Australia-ASEAN Power Link AAPL	2020/8714	Not Controlled Action	Completed
Montara-3 Offshore Hydrocarbon Exploration Well Permit Area AC/RL3	2001/489	Not Controlled Action	Completed
Not controlled action (particular manner)			
2 (3D) Marine Seismic Surveys	2009/4994	Not Controlled Action (Particular Manner)	Completed
2D and 3D Seismic Survey	2011/6197	Not Controlled Action (Particular Manner)	Post-Approval
2D Marine Seismic Survey	2009/4728	Not Controlled Action (Particular Manner)	Post-Approval
2D or 3D Marine Seismic Survey in Petroleum Permit Area AC/P35	2009/4864	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic Marine Survey	2001/363	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic survey	2009/5076	Not Controlled Action (Particular Manner)	Post-Approval
3D Seismic Survey, petroleum exploration permit AC/P33	2006/2918	Not Controlled Action (Particular Manner)	Post-Approval
3D seismic survey of AC/P4, AC/P17 and AC/P24	2006/2857	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
3D Seismic Survey WA-406-P Bonaparte Basin	2007/3904	Not Controlled Action (Particular Manner)	Post-Approval
Auralandia 3D marine seismic survey	2011/5961	Not Controlled Action (Particular Manner)	Post-Approval
Bonaparte 2D & 3D marine seismic survey	2011/5962	Not Controlled Action (Particular Manner)	Post-Approval
Cartier East and Cartier West 3D Marine Seismic Surveys	2009/5230	Not Controlled Action (Particular Manner)	Post-Approval
Dillon South-1 Exploration Well Drilling - AC/P4, Territory of Ashmore/Cartier	2013/6849	Not Controlled Action (Particular Manner)	Post-Approval
Drilling of Audacious-5 appraisal well	2008/4327	Not Controlled Action (Particular Manner)	Post-Approval
Drilling of two appraisal wells	2011/5840	Not Controlled Action (Particular Manner)	Post-Approval
Kingtree & Ironstone-1 Exploration Wells	2011/5935	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Fibre Optic Cable Network Construction & Operation, Port Hedland WA to Darwin NT	2014/7223	Not Controlled Action (Particular Manner)	Post-Approval
Sandalford 3D Seismic Survey	2012/6261	Not Controlled Action (Particular Manner)	Post-Approval
Songa Venus Drilling and Testing Operations	2009/5122	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Thoar 3D Marine Seismic Survey	2010/5668	Not Controlled Action (Particular Manner)	Post-Approval
Tow West Atlas wreck from present location to boundary of EEZ	2010/5652	Not Controlled Action (Particular Manner)	Post-Approval
Ursa 3D Marine Seismic Survey	2008/4634	Not Controlled Action (Particular Manner)	Post-Approval
Vampire 2D Non Exclusive Seismic Survey, WA	2010/5543	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Zeppelin 3D Seismic Survey	2011/6148	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
2D Marine Seismic Survey	2008/4623	Referral Decision	Completed

Key Ecological Features [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Carbonate bank and terrace system of the Sahul Shelf	North-west

Biologically Important Areas

Scientific Name	Behaviour	Presence
Marine Turtles		
Natator depressus		
Flatback Turtle [59257]	Foraging	Known to occur
Seabirds		
Fregata ariel		
Lesser Frigatebird [1012]	Breeding	Known to occur

Scientific Name	Behaviour	Presence
Sharks		
Rhincodon typus Whale Shark [66680]	Foraging	Known to occur
Whales		
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and 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

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a 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 detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

Department of Agriculture Water and the Environment
GPO Box 858
Canberra City ACT 2601 Australia
+61 2 6274 1111

APPENDIX D

Seabirds Potentially Occurring in OA

EPBC Act List of Threatened Seabirds Potentially Occurring within the OA and/or Wider EMBA

Common Name(s) Scientific Name	Protection Status	Distribution, Habitat and Life Stages	Presence within the OA and EMBA
THREATENED – 17 observed within EMBA and 4 within OA			
Bar-tailed Godwit (Northern Siberian) *Limosa lapponica menzbieri*	CE	• The bar-tailed godwit has been recorded in the coastal areas of all Australian states. The bar-tailed godwit is found mainly in coastal habitats such as large intertidal sandflats, estuaries, inlets, coastal lagoons and bays. • At the subspecies level, *Limosa lapponica baueri* is listed as Vulnerable and *Limosa lapponica menzbieri* is listed as Critically Endangered under the BCA (DoEE, 2022).	Species KNOWN to occur within EMBA Given the preferred coastal habitat, the species is unlikely to be present in the OA. Higher population densities may be encountered in the coastal waters of the EMBA.
Far Eastern Curlew *Numenius madagascariensis*	CE M	• This species does not breed in Australia, rather in the Northern Hemisphere during summer, between May and June. They start to depart early March and begin to arrive back in late July. • During the non-breeding season in Australia, the eastern curlew is most commonly associated with sheltered coastal habitats (DoEE, 2022).	Species KNOWN to occur within EMBA Species MAY occur within OA Given the distribution of this coastal wetland bird species, the survey is likely to encounter low numbers of this species in the OA. Higher population densities may be encountered in the coastal waters of the EMBA.
Great Knot *Calidris tenuirostris*	CE M	• The Great Knot breeds in northeast Siberia and far northeast Russia and migrates along the East Asia-Australiasian Flyway to overwinter in the southern hemisphere. • The species occurs almost exclusively along the coast during migration and the non-breeding season. It prefers sheltered coastal habitats. (DEPWS, 2022a).	Species LIKELY to occur within EMBA Given the preferred coastal habitat, the species is unlikely to be present in the OA. Higher population densities may be encountered in the coastal waters of the EMBA.

Common Name(s) Scientific Name	Protection Status	Distribution, Habitat and Life Stages	Presence within the OA and EMBA
Curlew Sandpiper *Calidris ferruginea*	CE M	• Within Australia, curlew sandpipers occur around the coasts while also being widespread inland, though in smaller numbers (DoEE, 2022). • The curlew sandpiper does not breed in Australia, the breeding areas are mainly restricted to the Arctic. • The species move into certain areas in Australia during northward migration in April, and migrate out of Australia during May. They start returning to the area in August and throughout September (Chatto, 2003).	Species KNOWN to occur within EMBA Species MAY occur within OA Given the preferred coastal habitat, the species is unlikely to be present in the OA. Higher population densities may be encountered in the coastal waters of the EMBA.
Gouldian Finch *Erythrura gouldiae*	E	• The Gouldian Finch is mostly distributed within the NT and the Kimberley. • Gouldian Finches occupy two different regions of the terrestrial landscape on an annual cycle. Between February and October, they breed and occupy wooded hills with hollow-bearing gum trees. • In the wet season, Gouldian Finches move from the hills into lowland drainages, mainly inland but can also be found near the coast (DEPWS, 2022b).	Species LIKELY to occur within EMBA Given the preferred terrestrial habitat, the species is unlikely to be present in the OA. The species may be encountered in low numbers in the coastal waters of the EMBA.
Abbott's Booby *Papasula abbotti*	E	• Abbott's Booby breeds only on Christmas Island in the eastern Indian Ocean. The at-sea distribution of Abbott's Booby is poorly known. • During the breeding season, the species is thought to forage over oceanic waters northeast of Christmas Island to Indonesia. However, during the chick-rearing period, Abbott's Booby parents forage mostly within 100 km of Christmas Island. • The only record from the NT of Abbott's Booby is an exhausted individual that was found in a suburban to Darwin in January 2017. (DEPWS, 2022c)	Species MAY occur within EMBA Given the preferred habitat on and around the Christmas Island habitat, the species is unlikely to be present in the OA. Considering there is only one record in coastal waters of the northwestern Australia, the species is unlikely to be present within the EMBA.

Common Name(s) Scientific Name	Protection Status	Distribution, Habitat and Life Stages	Presence within the OA and EMBA
Australian Painted Snipe *Rostratula australis*	E	• The Australian painted snipe has been recorded at wetlands in all states of Australia, however the species has been recorded less frequently at a smaller number of more scattered locations farther west in South Australia, the NT and WA. • The species generally inhabits shallow terrestrial freshwater wetlands, including lakes, swamps and claypans. • The species mostly breed every two years and breed in response to wetland conditions rather than during a particular season (DoEE, 2022).	Species LIKELY to occur within EMBA Given the preferred coastal habitat, the species is unlikely to be present in the OA. Higher population densities may be encountered in the coastal waters of the EMBA.
Lesser Sand Plover *Charadrius mongolus*	E M	• The Lesser Sand Plover breeds during the northern summer in central Asia and eastern Russia and migrate along the East Asian-Australasian flyway to overwinter in East Asia, South-East Asia, New Guinea, and Australia. • The species occur almost exclusively along the coast, where they forage on sheltered intertidal mudflats and sandflats, sandy beaches, estuaries and mangroves. (DEPWS, 2022d).	Species LIKELY to occur within EMBA Given the preferred coastal habitat, the species is unlikely to be present in the OA. Higher population densities may be encountered in the coastal waters of the EMBA.
Red Knot *Calidris canutus*	E M	• The red knot is common in all the main suitable habitats around the coast of Australia, very large numbers are regularly recorded in northern Australia. • In Australasia, the red knot mainly inhabits intertidal mudflats, sandflats and sandy beaches of sheltered coasts coral reefs. • The red knot is migratory, breeding in the high Artic and moving south to non-breeding between 58° N and 50 °S. • Peak numbers of this species in the NWMR and NMR are usually between September and October. (DoEE, 2022).	Species KNOWN to occur within EMBA Species MAY occur within OA Red knots are recorded in large numbers along the coastal strip from Fog Bay to Peron Island North. Given the range and distribution of this species, the survey is likely to encounter low numbers of this species in the OA. Higher population densities may be encountered in the nearshore waters of the EMBA.

Common Name(s) Scientific Name	Protection Status	Distribution, Habitat and Life Stages	Presence within the OA and EMBA
Grey Falcon *Falco hypoleucos*	V	• The Grey Falcon is found throughout much of the arid and semi-arid zones of Australia, and has been recorded in all Australian mainland states and territories. • Grey Falcons live in areas of sparsely timbered lowland plains, The species occurs in low densities and usually only one or two individuals are seen. • Grey Falcons use nests built by other bird species and nesting has been recorded from June to November. (DEPWS, 2022e).	Species LIKELY to occur within EMBA. Given the preferred terrestrial habitat, the species is unlikely to be present in the OA. The species may be encountered in low numbers in the coastal waters of the EMBA.
Australian Lesser Noddy *Anous tenuirostris melanops*	V	• The Australian lesser noddy is endemic to Australia and nests on the Houtman Abrolhos Islands and, possibly, Ashmore Reef. The species remain near breeding islands throughout the year (DoEE, 2022). • The species usually occupies coral-limestone islands and occasionally occurs on shingle or sandy beaches. • The breeding season is protracted, extending from August to April; however this can vary year to year (Higgins and Davies, 1996). • The Australian lesser noddy may forage out at sea or in seas close to breeding islands and fringing reefs (Johnstone and Storr, 1998).	Breeding KNOWN to occur within EMBA Species MAY occur within OA Given the preferred habitat, the species is unlikely to be present in the OA. Higher population densities may be encountered in the EMBA.
Bar-tailed Godwit, (Western Alaskan) *Limosa lapponica baueri*	V	• Bar-tailed godwit breeds during the norther summer in west Alaska and northeast Siberia and overwinters mostly in northern and eastern Australia and New Zealand. • Bar-tailed Godwits have been reported along almost the entire coastline in NT and WA, including all major islands. The species is one of the more frequently recorded and abundant shorebird species. • Godwits usually congregate in flocks, rarely far from the coast. They forage on intertidal mudflats or in shallow water (DEPWS, 2022f).	Species MAY occur within EMBA Given the preferred habitat, the species is unlikely to be present in the OA. Higher population densities may be encountered in the EMBA.

Common Name(s) Scientific Name	Protection Status	Distribution, Habitat and Life Stages	Presence within the OA and EMBA
Partridge Pigeon (western) *Geophaps smithii blaauwi*	V	• Two subspecies are recognised, western and eastern Partridge pigeon. The Partridge Pigeon occurs across the Top of the NT and Kimberley. • The species occur principally in lowland eucalypt open forests and woodlands. The species nests and forages on the ground. • Partridge Pigeons are largely sedentary, although they may make local-scale movements (up to 5-10 km) in response to seasonal variations in water and food availability (DoEE, 2022).	Species LIKELY to occur within EMBA Given the preferred terrestrial habitat, the species is unlikely to be present in the OA. The species may be encountered in low numbers by the coastal waters of the EMBA.
Red Goshawk *Erythrotriorchis radiatus*	V	• The red goshawk occurs across much of northern Australia, from near Broome in the southwest Kimberley to southeastern Queensland. • The red goshawk hunts mainly for medium-sized birds. Territory size is typically very large (up to 200 km^2). • The preferred habitat is tall open eucalypt forest and riparian areas. (DEPWS, 2022g.	Species LIKELY to occur within EMBA Given the preferred terrestrial habitat, the species is unlikely to be present in the OA. The species may be encountered in low numbers by the coastal waters of the EMBA.
Masked Owl (northern) *Tyto novaehollandiae kimberli*	V	• The Masked Owl is distributed widely across northern Australia, from the Kimberley region, across the NT to Cape York Peninsula and far-north Queensland. • The Masked Owl occurs mainly in tall open eucalypt forests and breed in large tree hollows, which usually form in large rainforest trees (DEPWS, 2022h).	Species LIKELY to occur within EMBA Given the preferred terrestrial habitat, the species is unlikely to be present in the OA. The species may be encountered in low numbers by the coastal waters of the EMBA.
Crested Shrike-tit (northern) *Falcunculus frontatus whitei*	V	• The Crested Shrike-tit is distributed in the Kimberley region and Top End. Although large areas of the distribution remain poorly surveyed. • The Crested Shrike-tit typically occurs in open woodlands dominated by Eucalyptus and forage in the canopy of trees. • The subspecies is monogamous, resident and territorial. Breeding occurs over the wet season, between October and March (DEPWS, 2022i).	Species LIKELY to occur within EMBA Given the preferred terrestrial habitat, the species is unlikely to be present in the OA. The species may be encountered in low numbers by the coastal waters of the EMBA.

Common Name(s) Scientific Name	Protection Status	Distribution, Habitat and Life Stages	Presence within the OA and EMBA
Greater Sand Plover *Charadrius leschenaultii*	V M	• The Greater Sand Plover breeds during the northern summer in eastern and central Asia. Only this subspecies migrates to Australia along the East Asian-Australasian flyway. • The Greater Sand Plover occurs along most coastlines in Australia, but is more common in the north. • These non-breeding birds occur almost exclusively along the coast, favouring sheltered beaches, tidal lagoons, rocky islands and coral reefs (DEPWS, 2022j).	Species KNOWN to occur within EMBA Given the preferred costal habitat, the species is unlikely to be present in the OA. Higher population densities may be encountered in the EMBA.

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

EPBC Act List of Migratory Seabirds Potentially Occurring within the OA and/or Wider EMBA in addition to Species connected to BIAs in the region

Common Name(s) Scientific Name	Protection Status	Distribution, Habitat and Life Stages	Presence Within the OA and EMBA
MIGRATORY – 14 observed within EMBA and 8 within OA			
Great Frigatebird *Fregata minor*	M	• Great frigatebirds are found in tropical waters globally. The species breeds on small, remote tropical islands, in mangroves or bushes and occasionally on bare ground. • Breeding is known to occur between May to August (DoEE, 2022). • A breeding and foraging BIA has been identified at Ashmore Reef and Cartier Island, located approximately 50 km west from the OA (**Figure 23**).	Breeding KNOWN to occur within EMBA Species MAY occur within OA Given the distribution of the species and preferred habitat, this species may be present in the OA in low numbers. Higher population densities may be encountered in the coastal waters of the EMBA.
White-tailed Tropicbird *Phaethon lepturus*	M	• The white-tailed tropicbird breeds all year round on islands throughout the tropics of the northern Indian Ocean, including Ashmore Reef and Rowley Shoals off the northern coast of WA (Johnstone and Storr, 1998; Marchant and Higgins, 1993; DoEE, 2022). • The white-tailed tropicbird is a rather scarce breeding species at Ashmore Reef, and it is estimated that up to two pairs nest within the reserve each year (Clarke, 2010). • The species are surface foragers that occasionally take shallow dives (Marchant and Higgins, 1990). • A breeding and foraging BIA has been identified at Ashmore Reef, located approximately 60 km west from the OA (**Figure 23**).	Breeding KNOWN to occur within EMBA Species LIKELY to occur within OA Given the distribution of the species and preferred habitat, this species may be present in the OA in low numbers. Higher population densities may be encountered in the coastal waters of the EMBA, particularly in waters surrounding Ashmore Reef.
Lesser Frigatebird *Fregata ariel*	M	• The lesser frigatebird is usually seen in tropical or warmer waters off northern WA, NT, QLD and northern NSW. The species forages in the NMR and breeds in areas adjacent to the region (Marchant and Higgins, 1990). • The species is usually pelagic and often found far from land, but is also found in inshore areas (Marchant and Higgins, 1990). • The lesser frigatebird breeds between May-December in mangroves or bushes (Birdlife, 2022). • The closest breeding BIA of this species is located approximately 17 km south of the OA (**Figure 23**).	Breeding KNOWN to occur within EMBA Species LIKELY to occur within OA Given the distribution of the species and preferred habitat, this species may be present in the OA and EMBA in low numbers.

Common Name(s) Scientific Name	Protection Status	Distribution, Habitat and Life Stages	Presence Within the OA and EMBA
Roseate Tern *Sterna dougallii*	M	• In WA, the species is regularly recorded north from Mandurah to Eighty Mile Beach, in the Pilbara Region. Along the Kimberley coastline, the subspecies occurs at scattered sites, north to the Bonaparte Archipelago and possibly further. • The roseate tern occurs in coastal and marine areas. The species inhabits rocky and sandy beaches, coral reefs and offshore habitats. • Breeding in WA occurs in two periods, with peak months for laying April to November (DoEE, 2022). • The closest breeding BIA of this species is located approximately 125 km southeast of the OA) (**Figure 23**).	Breeding KNOWN to occur within EMBA Given the preferred coastal habitat, the species is unlikely to be present in the OA. Higher population densities may be encountered in the coastal waters of the EMBA.
Little Tern *Sternula albifrons*	M	• The little tern is widespread in Australia, with breeding sites widely distributed. • The little tern is a coastal seabird, which usually forages in very shallow brackish water. • Breeding is thought to occur in June, July and October. The little tern usually forages close to breeding colonies. (DoEE, 2022). • The closest breeding BIA to the OA is on the coastline of the Kimberley (approximately 156 km south of the OA). Little tern also has a resting BIA (Ashmore Reef) located approximately 146 km west of the OA (**Figure 23**).	Species KNOWN to occur within EMBA Given the preferred coastal habitat and migration pattern, this species may be present in the OA and EMBA in low numbers or isolated individuals/ groups.
Red-footed Booby *Sula sula*	M	• The red-footed booby is found worldwide, essentially confined to tropical waters in the Atlantic, Indian and Pacific Oceans (DoEE, 2022). • The species nests on offshore islands and a recent re-established breeding colony is found at Ashmore Reef (Clarke, 2010). Breeding takes place all year round. • Adult red-footed booby's have been detected up to 125 km from the nearest breeding islands during foraging (Clarke, 2010). • The closest breeding BIA to the OA for the red-footed booby is on Ashmore Reef (approximately 50 km west of the OA) (**Figure 23**).	Breeding KNOWN to occur within EMBA Given the distribution of the species and preferred habitat, this species may be present in the OA in low numbers. Higher population densities is likely be encountered in the coastal waters of the EMBA, particularly in waters surrounding Ashmore Reef.

Common Name(s) Scientific Name	Protection Status	Distribution, Habitat and Life Stages	Presence Within the OA and EMBA
Wedge-tailed Shearwater *Ardenna pacifica*	M	• The wedge-tailed shearwater is widespread across the Indian and Pacific Oceans. • In Australia, the species breeds between August-March on the east and west coasts of Australia and on offshore islands (DoEE, 2022). • The closest breeding BIA to the OA for the Wedge-tailed Shearwater is on Ashmore Reef (approximately 56 km west of the OA) (**Figure 23**). • The BIA supports a small colony of breeding wedge-tailed shearwaters, with an estimated 30 active burrows in 2002 (Swan, 2005).	Breeding KNOWN to occur within EMBA Given the distribution of the species and preferred habitat, this species may be present in the OA in low numbers. Higher population densities is likely be encountered in the coastal waters of the EMBA, particularly in waters surrounding Ashmore Reef.
Brown booby *Sula leucogaster*	M	• The brown booby occurs throughout all tropical oceans (DSEWPC, 2012c). In Australia, the brown booby is found in WA, around the coast of the NT, in Queensland and with occasional reports further south in New South Wales and Victoria. • The Brown booby uses both marine and terrestrial habitat. In the northwest WA, Brown boobies are most abundant off-shore (DoEE, 2022). • The species nests all year round on cliffs and steep slopes, beaches, and coral rubble. The species typically leaves breeding islands when not breeding, in search of better foraging grounds (DoEE, 2022). • The closest breeding BIA to the OA for the Brown Bobby is located approximately 114 km west of the OA (**Figure 23**).	Breeding KNOWN to occur within EMBA Given the preferred coastal habitat, the species is unlikely to be present in the OA. Higher population densities may be encountered in the coastal waters of the EMBA.

Common Name(s) Scientific Name	Protection Status	Distribution, Habitat and Life Stages	Presence Within the OA and EMBA
Greater Crested Tern *Thalasseus bergii*	M	• The greater crested tern is widespread and numerous along the NT coastline, with 20 breeding colonies reported (DSEWPC, 2012c). • The species shows a preference for nesting on offshore islands, coral reefs and sandy or rocky coastal islets (DSEWPC, 2012c). • The colony on Seagull Island supports a BIA of approximately 60,000 greater crested terns (Woinarski *et al.*, 2003), (approximately 87 km southeast of the OA) (**Figure 23**), which is thought to be the largest breeding colony of this species and of international significance. • The species forages in a range of habitats including lagoons, coral reefs, bays, estuaries, in mangrove swamps and in offshore and pelagic waters (DSEWPC, 2012c). • The breeding period for the greater crested term is March to July (Chatto, 2001).	Breeding KNOWN to occur within EMBA Given the widespread distribution, this species may be present in the OA in low numbers or isolated individuals/groups. Higher population densities may be encountered in the coastal waters of the EMBA.
Lesser crested tern *Sterna bengalensis*	Not listed	• The lesser crested tern inhabits tropical and sub-tropical sandy and coral coasts and estuaries. • In Australia, lesser crested terns are found on coasts and in coastal waters, primarily in the north. The species occurs around most of the NT. • The species breeds between September-December on low-lying islands, coral flats, sandbanks and flat sandy beaches. A lesser crested tern breeding BIA is located 87 km southeast of the OA. (**Figure 23**). • Lesser crested terns forage in the surf and over offshore waters in areas of reef and deeper shelf waters (DSEWPC, 2012c).	Breeding KNOWN to occur within EMBA Given the preference for habitat and breeding grounds within the EMBA, this species may be present in the OA and is likely to be present within EMBA.

Common Name(s) Scientific Name	Protection Status	Distribution, Habitat and Life Stages	Presence Within the OA and EMBA
Common Noddy *Anous stolidus*	M	• In Australia, the common noddy occurs mainly in the ocean off the QLD coast, but the species also occurs off the northwest and central WA coast. • During the breeding season, the common noddy usually occurs on or near islands. When not at the nest, individuals will forage in the surrounding waters. The seasonality of breeding varies greatly between sites. • During the non-breeding period, the species occurs in groups throughout the pelagic zone (DoEE, 2022).	Breeding KNOWN to occur within EMBA Species MAY occur within OA Given the wide distribution of the species and preferred habitat, the species may be present in low numbers in the OA and higher population densities may be encountered in the EMBA.
Sharp-tailed Sandpiper *Calidris acuminata*	M	• The Sharp-tailed Sandpiper breeds in the short Siberian summer (June to August) and spends the non-breeding season in Australia, in both inland and coastal locations. The species migrates from Australia in March/April. • In WA, they are widely distributed and in NT, the most important area is the area from Darwin to Murgenella Creek and the Port McArthur. • In Australasia, the species prefers muddy edges of shallow fresh or brackish wetlands (DoEE, 2022).	Species KNOWN to occur within EMBA Species MAY occur within OA Given the wide distribution of this species and the migratory pattern, it is likely this species will be encountered in low numbers within the OA and EMBA.
Streaked Shearwater *Calonectris leucomelas*	M	• The streaked shearwater breeds in Asia and migrates to the waters between Papua New Guinea and Australia. The species occurs frequently in northern Australia from October to March, (Marchant and Higgins 1990). • Whilst the species does not breed in Australia, it is known to forage in the NMR (DoEE, 2022).	Species KNOWN to occur within EMBA Species LIKELY to occur within OA Given the distribution of the species and preferred habitat, the species may be present in low numbers in the OA and EMBA during the October - May period.
Common Sandpiper *Actitis hypoleucos*	M	• The common sandpiper breeds in Eurasia and moves south for the boreal winter, individuals usually arrive in WA from July onwards. • Distributed along all coastlines of Australia and many areas inland, the common sandpiper is widespread in small numbers. • Generally, the species forages in shallow water and on bare soft mud at the edges of wetlands (DoEE, 2022).	Species KNOWN to occur within EMBA Species MAY occur within OA Given the distribution of the species and preferred habitat, this species may be present in the OA in low numbers. Higher population densities may be encountered in the coastal waters of the EMBA.

Common Name(s) Scientific Name	Protection Status	Distribution, Habitat and Life Stages	Presence Within the OA and EMBA
Pectoral Sandpiper *Calidris melanotos*	M	• The Pectoral Sandpiper breeds in the high Arctic. Wintering in small numbers in Southeast Asia, Australia, and New Zealand in Australasia. • The species is found at coastal areas as lagoons, estuaries, lakes, floodplains and wetlands. • In WA, the species is rarely recorded. In NT, the species habitat likely occurs along the coast of Darwin, which is 260 km away from the OA (DoEE, 2022).	Species MAY occur within EMBA and OA Given the wide distribution and migration pattern, this species may be present in the OA and EMBA in low numbers or isolated individuals/groups.

EPBC Act List of Migratory Seabirds Potentially Occurring within the Wider EMBA

Common Name(s) (*Scientific Name*)	**Presence within the EMBA**
MIGRATORY - 23 observed within EMBA	
Ruddy Turnstone (*Arenaria interpres)*	Species LIKELY to occur within area
Osprey (*Pandion haliaetus)*	Breeding KNOWN to occur within area
Rufous Fantail (*Rhipidura rufifrons)*	Species LIKELY to occur within area
Common Greenshank (*Tringa nebularia)*	Species LIKELY to occur within area
Barn Swallow (*Hirundo rustica)*	Species KNOWN to occur within area
Sanderling (*Calidris alba)*	Species LIKELY to occur within area
Bridled Tern (*Onychoprion anaethetus)*	Breeding KNOWN to occur within area
Caspian Tern (*Hydroprogne caspia)*	Breeding KNOWN to occur within area
Fork-tailed Swift (*Apus pacificus)*	Species LIKELY to occur within area
Grey Wagtail (*Motacilla cinerea)*	Species KNOWN to occur within area
Bar-tailed Godwit (Northern Siberian) (*Limosa lapponica* menzbier)	Species KNOWN to occur within area
Whimbrel (*Numenius phaeopus)*	Species LIKELY to occur within area
Masked Booby (*Sula dactylatra)*	Breeding KNOWN to occur within area
Yellow Wagtail (*Motacilla flava)*	Species KNOWN to occur within area
Grey Plover (*Pluvialis squatarola)*	Species LIKELY to occur within area
Black-tailed Godwit (*Limosa limosa)*	Species LIKELY to occur within area
Asian Dowitcher (*Limnodromus semipalmatus)*	Species KNOWN to occur within area
Oriental Pratincole (*Glareola maldivarum)*	Species MAY occur within area
Red-tailed Tropicbird (*Phaethon rubricauda)*	Breeding KNOWN to occur within area
Oriental Plover (*Charadrius veredus)*	Species MAY occur within area
Oriental Cuckoo (*Cuculus optatus)*	Species KNOWN to occur within area
Oriental Reed-Warbler (*Acrocephalus orientalis)*	Species KNOWN to occur within area
Red-rumped Swallow (*Cecropis daurica)*	Species MAY occur within area

APPENDIX E

List of Stakeholders

Stakeholders Engaged	
1	Indonesian Government
2	Department of Foreign Affairs and Trade
3	Department of Agriculture, Water and the Environment – Fisheries, Biosecurity & Marine Parks
4	Department Infrastructure, Transport, Regional Development and Communications
5	Australian Maritime Safety Authority
6	Australian Hydrographic Office
7	GeoScience Australia
8	Parks Australia
9	The Director of National Parks
10	Australian Institute of Marine Science
11	WA Marine Science Institution
12	WA Department of Parks and Wildlife
13	WA Department of Mines, Industry Regulation and Safety
14	WA Department of Transport
15	Kimberly Port Authority; Port of Wyndham
16	Conservation Council of Western Australia
17	Centre for Whale Research
18	The Wilderness Society
19	Australian Fisheries Management Authority
20	Commonwealth Fisheries Association
21	Department of Primary Industries and Regional Development
22	Western Australia Department of Fisheries
23	Australian Fisheries Management Authority - Northern Prawn Fishery
24	Australian Fisheries Management Authority - North West Slope Trawl Fishery
25	Australian Fisheries Management Authority - Western Tuna and Billfish Fishery
26	Australian Fisheries Management Authority - Southern Bluefin Tuna
27	Mackerel Managed Fishery - all license holders
28	Northern Demersal Scalefish Managed Fishery (NDSF) – all license holders
29	Marine Aquarium Fishery license holders
30	Specimen Shell Managed Fishery license holders
31	Kimberley Prawn Fishery license holder
32	Western Australian Fishing Industry Council
33	Western Australian Game Fishing Association
34	Australian Southern Bluefin Tuna Industry Association
35	Australia Fisheries Trade Association
36	Recfishwest
37	Coral Expeditions
38	Marine Tourism WA

Stakeholders Engaged	
39	Kimberley Marine Tourism Association
40	BKB Holidays Travel Agency
41	Kimberley Land Council
42	Northern Land Council
43	Department of Biodiversity, Conservation and Attractions
44	Carnarvon Energy - WA523-P, AC/P63
45	Inpex Browse - AC/P66, AC/RL4
46	Finder- AC/P61
47	Santos - AC/P69, AC/P50, AC/P67
48	PTEP Australasia - AC/RL12, AC/RL7, AC/RL/6, AC/P54, AC/RL10, AC/L3

APPENDIX F

Full Unedited Stakeholder Correspondence

Sensitive information – content removed.

APPENDIX G

Meeting Minutes and Memos

Sensitive information – content removed.

APPENDIX H

Information Packs

Bonaparte Basin Marine Seismic Survey

Schlumberger proposes to undertake a three-dimensional (3D) marine seismic survey in Bonaparte Basin, in Commonwealth waters adjacent to Western Australia (**WA**). The operational area is 25,827 km^2 located 300 km northwest of Port Warrender (Western Australia), 260 km northwest of Ashmore Island (Western Australia). Water depths in the survey area are in the range of 100m (**Figure 1**). Planned seismic acquisition activity within this operational area will cover approximately 12,000 km^2 – details of extent and position of survey lines are currently being finalised.

Coordinates for the Operational Area are outlined in **Table 1**. In developing the Operational Area, a 15 km buffer has been applied around the proposed survey area in most cases.

The Bonaparte MC3D MSS may commence as early as September 2022 and will be completed before 30 June 2024. Up to a maximum of 10,000 km^2 may be acquired per calendar year between 2022 and 2024. It is estimated to take approximately 120 and 190 days to acquire 12,000 km^2 (including contingency time for potential vessel or equipment down time and adverse weather conditions). The precise timing of the survey is subject to NOPSEMA's acceptance of the environment plan (EP), weather conditions, vessel availability and other operational considerations, and will take into account the seasonality of environmental sensitivities, where practicable.

PROPOSED ACTIVITY

Offshore seismic surveying is used to improve the understanding of subsurface geology in marine environments.

During 3D marine surveys, seismic data is acquired using a purpose-built seismic survey vessel towing an acoustic source array and a multi cable hydrophone array, also known as a streamer array. Streamers are towed with a tail buoy, radar reflectors and lights to mark the end of the array. The streamers will be up to 8 km long to adequately record the necessary information.

Both the source and streamers are towed beneath the surface, (**Figure 2**). Acoustic energy from the source array is detected by the streamer array and recorded onboard the vessel. The recorded signals are then processed to provide information about geological formations below the seabed.

When recording the data, the seismic vessel traverses the survey area along a series of predetermined sail lines at a speed of approximately 4-5 knots (7-9 km/h). The level of acoustic emissions can be adjusted to provide low-power 'soft start' or 'fauna alert' procedures, at any point during the survey or maintenance operations.

To minimise survey duration, geophysical data will be acquired 24 hours a day. Each 3D pass (swath) is about 140 kilometres long and will take approximately 32 hours to complete. Data for a pre-determined swath only needs to be acquired once, and the survey vessel will not need to collect data in that area again.

A support vessel will work with the seismic vessel to assist in communicating with other vessels that have entered the area of operations and to support the overall operations, such as providing food and supplies.

There is ongoing extensive planning for the proposed survey through the EP development, with feedback being incorporated to minimize potential for disturbance to the surrounding environment. All efforts will be made to ensure the survey's primary objectives can be achieved safely and efficiently, whilst avoiding peak fishing activity in the area.

COMMUNICATION COMMITMENTS

Schlumberger is committed to maintaining regular communication with all relevant stakeholders throughout the duration of the survey and works with communities in a transparent manner.

As part of this continuous consultation, Schlumberger invites feedback on the proposed activities. Details of all consultation received will be provided to the National Offshore Petroleum Safety and Environment Management Authority (**NOPSEMA**) in accordance with EP procedures.

Due to the nature of seismic survey operations, the timing and location of the activity are prone to minor changes. To ensure clarity, Schlumberger commits to notifying stakeholders of survey schedule, finalized survey location and vessel details as they are confirmed. This will be supported with the supply of 48-hour operational detail lookahead plans, with notification being provided to relevant stakeholders during operations. If you wish to receive these notifications, or specific information regarding this survey, please advise in response to this package as soon as possible.

Following submission of the EP to NOPSEMA, stakeholder engagement will continue throughout the EP review period and survey acquisition to ensure everyone is kept informed and to minimise potential for disruption to any ongoing activities in the area.

ENVIRONMENTAL PERFORMANCE

Schlumberger is committed to working with all interested parties to ensure risks are identified and reduced to as low as reasonably practicable before activities begin. Latest technology in underwater sound transmission modelling will be used to understand emitted sound levels for the survey across the operational area. This will include detailed impact assessments and the adoption of appropriate mitigation measures that will be documented in the EP.

Early analysis of Flora and Fauna sensitivities in the Operational area have been undertaken and has enabled the proposed survey to incorporate mitigations as a result of the potential environmental concerns and sensitivities. Blue whales, whale sharks and turtles in particular have been identified in the early analysis as being some of the key sensitivities in the area and the EP will focus on these species to minimise disturbance as a result of the seismic activities.

There will be two dedicated Marine Mammal Observers (**MMOs**) onboard who will monitor precaution zones, observation zones, and low power zones during daylight hours in accordance with the Environment Protection and Biodiversity Conservation Act. There will also be Passive Acoustic Monitoring (**PAM**) 24 hours a day to monitor for whales in the vicinity of the survey vessel. Mitigation measures will be implemented to minimize any potential for disturbance to whales during the survey.

NOPSEMA reviews each project-specific EP in accordance with the requirements of the Offshore Petroleum Greenhouse Gas (Environment) Regulations 2009 before any approvals to the proposed seismic survey can be made.

Schlumberger has a reputation for implementing high standards of environmental protection in environmentally sensitive areas to mitigate and minimise impacts on the surrounding marine environment and stakeholders and will implement these procedures for the duration of this proposed survey.

YOUR FEEDBACK

As indicated above, Schlumberger is seeking feedback regarding this proposed activity before making a formal submission to NOPSEMA. The proposed survey is subject to Commonwealth Government regulatory approval and any feedback will be communicated to NOPSEMA, as required under Commonwealth legislation. We intend to lodge the EP to NOPSEMA shortly so please get in touch if you have any questions or comments.

Schlumberger intends to keep all stakeholders fully informed during the course of project planning and execution. However, if you would like to comment on the survey or would like additional information based on this preliminary factsheet please contact us as soon as possible. If you would like to meet with us to discuss the survey further or raise any concerns you have in relation to your activities in the area, please get in touch with me at the contact details below.

Best regards,
Kunal Mishra

Schlumberger Australia Pty Ltd:
Level 5, 10 Telethon Avenue
Perth WA, 6000(08) 9420 4800
Email: environment@slb.com

Figure 1: Location map of operational area

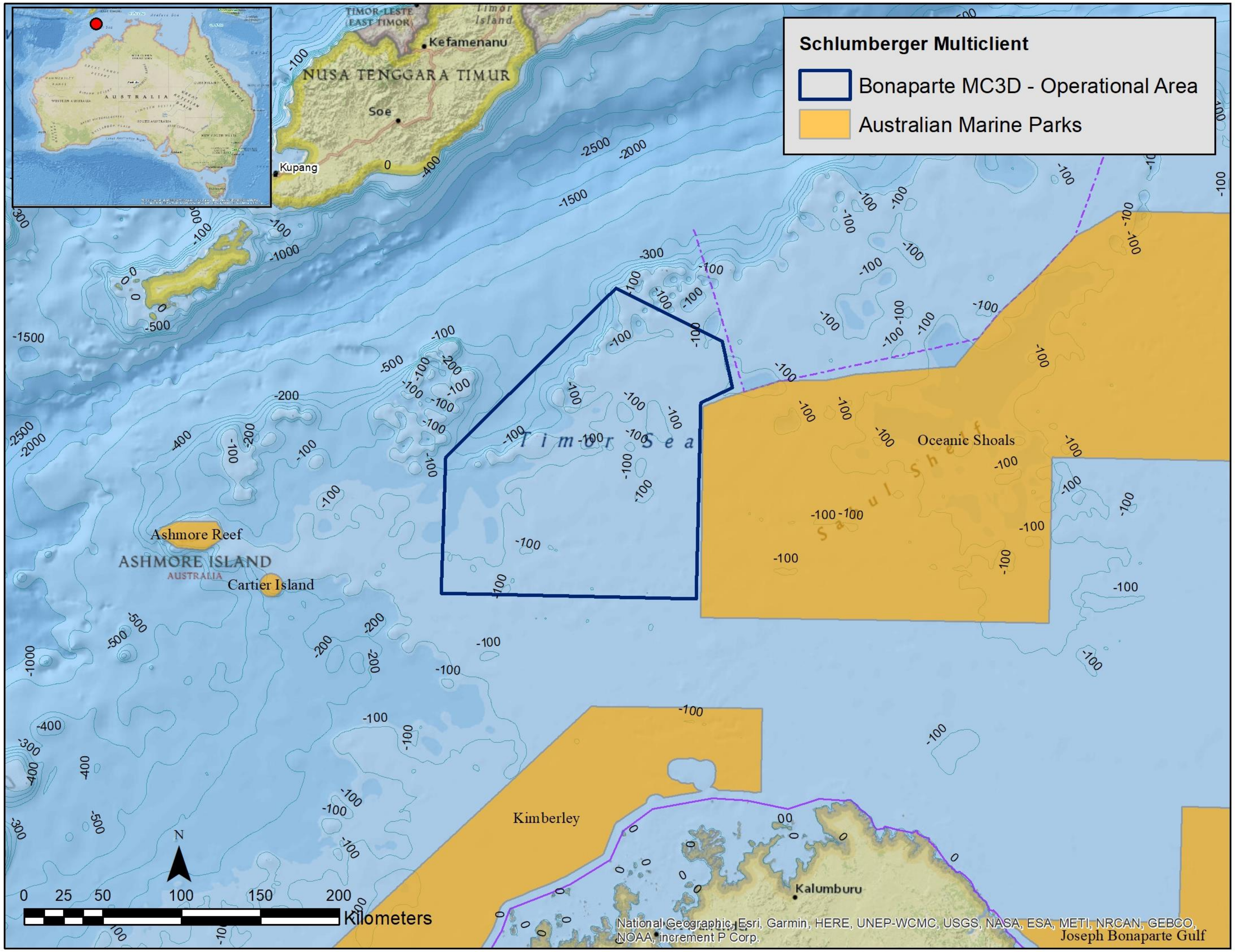
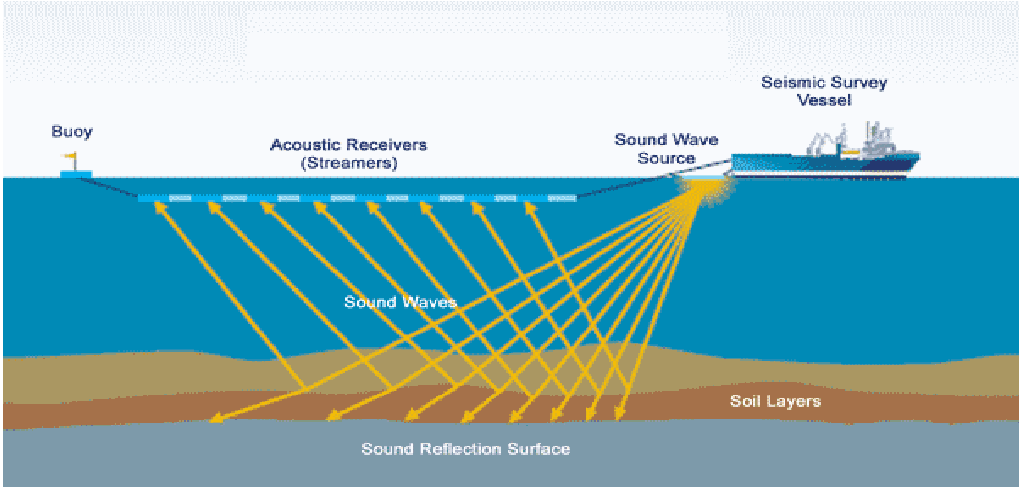


Table 1: Coordinates of the Operational Area (UTM Zone 51S)

S No	X	Y
1	668353.2981	8609707.23
2	670973.134	8696076.658
3	714112.3176	8738881.308
4	779108.1235	8803487.052
5	846839.3232	8769762.117
6	853120.6772	8740481.172
7	833166.8606	8730614.315
8	830319.4782	8606042.698
9	668353.2981	8609707.23

Figure 2: Schematic of typical Seismic geophysical survey



APPENDIX I

Summary of Feedback Received and Responses Provided by SLB

Stakeholder Engagement Table

* To avoid unnecessary repetition in relation to the 'Reference to Location within EP' column, all unedited correspondence is provided within **Appendix E**, and the Fact Sheet provided can be viewed in **Appendix G**.

ID	Stakeholder	Date	Communication/ Engagement Type	Summary of Stakeholder Communication / Feedback / Concerns	Summary of SLB Communication / Response	Assessment of Merit of Stakeholder Concern	Reference to Location within EP
1	Indonesian Government	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
2	Department of Foreign Affairs and Trade	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		17/01/2022	Email incoming	Automated reply acknowledging email		No objections of claims – no response/actions required.	* (see note above table).
		08/02/2022	Email outgoing		Follow up Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
3	Department of Agriculture, Water and the Environment – Fisheries, Biosecurity & Marine Parks	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		01/02/2022	Email incoming	**Response to SLB email dated 17/01/2022** Requested an extension on the comment period		No objections of claims – no response/actions required.	* (see note above table).
		01/02/2022	Email outgoing		**Response email dated 01/02/2022** SLR confirmed that extension to submit comments is fine.	N/A	* (see note above table).
		15/02/2022	Email incoming	**Response to SLB email dated 01/02/2022** It was noted that the Operational Area (**OA**) is adjacent to the Oceanic Shoals Marine Park Multiple Use Zone (IUCN VI), which forms part of the North Network. The following objections/claims were raised in regard to the Seismic Survey: • Detailed consideration is given to the impacts upon flatback, loggerhead and olive ridley turtles that forage adjacent to the OA; • Detailed consideration is given to the impacts upon whale sharks that forage within the OA; • That Part B Additional Management Procedures are applied to areas which overlap the migration areas for pygmy blue whales; • Ensure that the Northern Land Council and Kimberley Land Council are consulted to protect cultural values; and • The EP addresses the impacts and risks on the ecological values of the Sahul Shelf, particularly on benthic communities and marine species that rely on this Key Ecological Feature. In addition to the above, it was requested that they be notified of any oil/gas pollution incidences.		Various objections/claims were raised regarding the Seismic Survey. SLB has taken each of these objections/claims onboard and has addressed each of these points within the relevant section(s) of the EP. These have been addressed by assessments on each of the sensitive receptors as well as implementing temporal and spatial control measures into the proposed Seismic Survey operations.	* (see note above table). Impacts from acoustic disturbance on the Oceanic Shoals Marine Park has been outlined within **Section 7.2.2.4.1**. In addition, specific impacts on the matters identified have been discussed within: • **Sections 7.1.2.1**, **7.2.2.1.5** and **7.2.2.2.4** (Marine Reptiles); • **Sections 7.2.2.1.7** and **7.2.2.2.6** (Elasmobranchs); • **Sections 7.1.2.2**, **7.2.2.1.6** and **7.2.2.2.5** (Marine Mammals); • **Section 7.2.2.4.4** (Key Ecological Features) In addition, consultation with the Northern Land

ID	Stakeholder	Date	Communication/ Engagement Type	Summary of Stakeholder Communication / Feedback / Concerns	Summary of SLB Communication / Response	Assessment of Merit of Stakeholder Concern	Reference to Location within EP
							Council and Kimberley Land Council is discussed within Section 5.4, and in relation to stakeholder ID 47 and 48 below. Provision for notification has been included within the notifications section (**Section 10.9.5.3**) in the case of a hydrocarbon spill.
		11/03/2022	Email incoming	DAWE and JASCO Applied Sciences invited SLR to attend information briefing sessions regarding National Anthropogenic Underwater Noise Guidelines.			
		18/05/2022	Email outgoing		SLR provided fact sheet and invited DAWE to pass onto any others in the department who might be interested or it is of relevance to.		
4	Department Infrastructure, Transport, Regional Development and Communications	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
5	Australian Maritime Safety Authority (**AMSA**)	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		20/01/2022	Email incoming	**Response to SLB email dated 17/01/2022:** AMSA advised notifications to the Australian Hydrograph Office (**AHO**) and AMSA's Joint Rescue Coordination Centre will need to take place before the survey commences. AMSA reminded SLB of vessels obligations to comply with the International Regulations for Preventing Collisions at Sea 1972 (**COLREGs**), in particular around appropriate lights and shapes to reflect the nature of the operations. AMSA also provided links to their portal to download Automatic Identification System traffic data.		SLB has taken onboard the notifications requested by AMSA and have included them within the EP. Adherence to the COLREGs has been included within the control measures and associated Environmental Performance Standards (**EPS**). AIS information on vessel traffic has been incorporated into the EP.	* (see note above table). Pre-activity notifications are included within **Section 5.4.10**. Control measures (including adherence to COLREGs) are outlined within **Section 7.1.4** and associated EPS within **Section 7.1.5**.
		21/01/2022	Email outgoing		**Response to AMSA email dated 20/01/2022:** SLR advised that that the notifications will be incorporated into the EP and operational procedures	N/A	* (see note above table).

ID	Stakeholder	Date	Communication/ Engagement Type	Summary of Stakeholder Communication / Feedback / Concerns	Summary of SLB Communication / Response	Assessment of Merit of Stakeholder Concern	Reference to Location within EP
					and notifications will take place before the survey commences.		
6	Australian Hydrographic Office	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		18/01/2022	Email incoming	**Response to SLB email dated 17/01/2022:** AHO acknowledged receipt of the introductory email are advised that the data supplied will be registered, assessed, prioritised and validated in preparation for updating their Navigational Charting products.		No objections or claims – no response/actions required.	* (see note above table).
		18/01/2022	Email outgoing		**Response to AHO email dated 18/01/2022:** SLR thanked AHO for the response and advised that the survey would run for 4-5 months, and once completed there would be no further navigational restrictions as a result of the proposed activity, including nothing being left on the seafloor or within the water column.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR	N/A	* (see note above table).
7	GeoScience Australia	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		17/01/2022	Email incoming	**Response to SLB email dated 17/01/2022** Automated reply acknowledging email		No objections of claims – no response/actions required.	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
8	Parks Australia (**PA**) and the Director of National Parks (**DNP**)	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		01/02/2022	Email incoming	**Response to SLB email dated 17/01/2022** PA/DNP seeking an extension on the comment period		No objections of claims – no response/actions required.	* (see note above table).
		01/02/2022	Email outgoing		**Response to PA/DNP email dated 01/02/2022** SLR confirmed that an extension to submit comments is fine.	N/A	* (see note above table).
		15/02/2022	Email incoming	**Response to SLB email dated 01/02/2022** PA noted that the Operational Area (**OA**) is adjacent to the Oceanic Shoals Marine Park Multiple Use Zone (IUCN VI), which forms part of the North Network – therefore, there are no authorisation requirements from the DMP. However, given the proximity, the Seismic Survey could impact upon the values of the marine park. AP made the following objections/claims in regard to the Seismic Survey: • Detailed consideration is given to the impacts upon flatback, loggerhead and olive ridley turtles that forage adjacent to the OA; • Detailed consideration is given to the impacts upon whale sharks that forage within the OA;		PA raised various objections/claims regarding the Seismic Survey. SLB has addressed each of these points within the relevant section(s) of the EP. Temporal and spatial mitigations will be implemented, along with observers of marine mammals and marine fauna and consider that the control measures to be implemented will	* (see note above table). Impacts from acoustic disturbance on the Oceanic Shoals Marine Park has been outlined within **Section 7.2.2.4.1**. In addition, specific impacts on the matters identified by PA have been discussed within: • **Sections 7.1.2.1**, **7.2.2.1.5** and **7.2.2.2.4** (Marine Reptiles);

ID	Stakeholder	Date	Communication/ Engagement Type	Summary of Stakeholder Communication / Feedback / Concerns	Summary of SLB Communication / Response	Assessment of Merit of Stakeholder Concern	Reference to Location within EP
				• That Part B Additional Management Procedures are applied to areas which overlap the migration areas for pygmy blue whales; • Ensure that the Northern Land Council and Kimberley Land Council are consulted to protect cultural values; and • The EP addresses the impacts and risks on the ecological values of the Sahul Shelf, particularly on benthic communities and marine species that rely on this Key Ecological Feature. In addition to the above, PA/DNP requested that they be notified of any oil/gas pollution incidences which may impact on the marine park.		mitigate any risk to the sensitive receptors. PA/DNP have been included in the notification list if any oil/gas pollution incidents occur (**Section 10.9.5.3**).	• **Sections 7.2.2.1.7** and **7.2.2.2.6** (Elasmobranchs); • **Sections 7.1.2.2**, **7.2.2.1.6** and **7.2.2.2.5** (Marine Mammals); • **Section 7.2.2.4.4** (Key Ecological Features) In addition, consultation with the Northern Land Council and Kimberley Land Council is discussed within **Section 5.4**, and in relation to stakeholder ID 47 and 48 below. The DNP has been included within the notifications section (**Section 10.9.5.3**) in the case of a hydrocarbon spill.
		22/02/2022	Email outgoing		**Response to PA/DNP email dated 15/02/2022** SLR acknowledged the objections/claims listed and thanked PA for reply and that those issues raised would be incorporated into the EP.	N/A	* (see note above table).
9	The Director of National Parks	See stakeholder 8 above.					
10	Australian Institute of Marine Science	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
11	WA Marine Science Institution	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
12	WA Department of Parks and Wildlife	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		17/01/2022	Email incoming	**Response to SLB email dated 17/01/2022** Automated reply acknowledging email		No objections of claims – no response/actions required.	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email incoming	**Response to SLB email dated 08/02/2022** Department of Parks and Wildlife responded and have forwarded the email to the Department of Biodiversity, Conservation and Attractions as they manage the conservation estate on behalf of the Commission.		No objections of claims – no response/actions required.	* (see note above table).

ID	Stakeholder	Date	Communication/ Engagement Type	Summary of Stakeholder Communication / Feedback / Concerns	Summary of SLB Communication / Response	Assessment of Merit of Stakeholder Concern	Reference to Location within EP
		08/02/2022	Email outgoing		**Response to Department of Parks and Wildlife email dated 08/02/2022** SLR asked for contact details should the Department of Biodiversity, Conservation and Attractions not respond.	N/A	* (see note above table).
		08/02/2022	Email incoming	**Response to SLB email dated 08/02/2022** Department of Parks and Wildlife advised that the Department of Biodiversity, Conservation and Attractions will not need to provide comment due to the location.		No objections of claims – no response/actions required.	* (see note above table).
		08/02/2022	Email outgoing		**Response to Department of Parks and Wildlife email dated 08/02/2022** SLR asked if Department of Parks and Wildlife wanted to stop receiving notifications of the survey.	N/A	* (see note above table).
13	WA Department of Mines, Industry Regulation and Safety (**DMIRS**)	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		25/02/2022	Email incoming	**Response to SLB email dated 08/02/2022** DMIRS reviewed the information and does not require anything further at this stage. However, DMIRS wishes to be included in the pre-start notifications and cessation notifications, and that the EP includes information on reporting environmental incidents that could potentially impact any land or water in State jurisdiction.		SLB has taken onboard the notifications and reporting requirements requested by DMIRS and has included them within the EP	* (see note above table). Pre-activity notifications are included within **Section 5.4.10**, and post-activity notifications are included within **Section 5.4.11**, which have both included DMIRS Notification to DMIRS has been included within **Section 10.9.5.3** in relation to environmental incidents.
		28/02/2022	Email outgoing		**Response to DMIRS email dated 25/02/2022** SLR confirmed the two requirements regarding notification and reporting to be included within the EP.	N/A	* (see note above table).
14	WA Department of Transport	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
15	Kimberly Port Authority; Port of Wyndham	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
16	Conservation Council of Western Australia	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
17	Centre for Whale Research	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).

ID	Stakeholder	Date	Communication/ Engagement Type	Summary of Stakeholder Communication / Feedback / Concerns	Summary of SLB Communication / Response	Assessment of Merit of Stakeholder Concern	Reference to Location within EP
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
18	The Wilderness Society	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
19	Australian Fisheries Management Authority	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
20	Commonwealth Fisheries Association (**CFA**)	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email incoming	**Response to SLB email dated 08/02/2022** CFA confirming that they will leave this with relevant commercial fishers based in WA.		No objections of claims – however, consultation with relevant commercial fishers is being undertaken.	* (see note above table).
		08/02/2022	Email outgoing		**Response to CFA email dated 08/02/2022** SLR confirmed that the relevant commercial fishers are being consulted with.	N/A	* (see note above table).
21	Department of Primary Industries and Regional Development	24/02/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
22	Western Australia Department of Fisheries	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
23	Australian Fisheries Management Authority - Northern Prawn Fishery (**NPF**)	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		18/01/2022	Email incoming	**Response to SLB email dated 17/01/2022** NPF advised that the Seismic Survey sits outside the area of the Northern Prawn and North West Slope Trawl Fisheries. Suggested that Northern Prawn Industry Association is contacted. They advised that they had also forwarded the email and fact sheet through to the Western Skipjack and Western Tuna and Billfish Fisheries.		No objections of claims – however, it is noted that consultation with relevant commercial fishers is also being undertaken by SLB.	* (see note above table).
		18/01/2022	Email outgoing		**Response to NPF email dated 18/01/2022** SLR thanked them for their email and also passing on the fact sheet. For future engagement purposes and keeping them up to date, SLR requested contact details for Western Skipjack and Western Tuna and Billfish Fisheries	N/A	* (see note above table).
		18/01/2022	Email incoming	**Response to SLB email dated 18/01/2022** NPF provided contact details for the Western Skipjack and Western Tuna and Billfish Fisheries		No objections of claims – no response/actions required.	* (see note above table).

ID	Stakeholder	Date	Communication/ Engagement Type	Summary of Stakeholder Communication / Feedback / Concerns	Summary of SLB Communication / Response	Assessment of Merit of Stakeholder Concern	Reference to Location within EP
		19/01/2022	Email outgoing		**Response to NPF email dated 18/01/2022** SLR thanked NPF for providing the contact details.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
24	Australian Fisheries Management Authority - North West Slope Trawl Fishery	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		18/01/2022	Email incoming	Response to SLB email dated 18/01/2022. Confirmation that the survey area sits outside the Northern Prawn and North West Slope Trawl Fisheries. A suggestion to contact the northern prawn industry association and contact details were provided. The email and information sheet were also forwarded on to the Western Skipjack, Western Tuna and Billfish fisheries that overlap with the area.	An email and fact sheet were sent to the northern prawn industry association.	No objections of claims – no response/actions required.	
		18/01/202	Email outgoing		Email and information sheet were sent to the northern prawn industry association and confirmed with AFMA. A request was made for the contact details of the pelagic fisheries that the information sheet was requested so that the stakeholder engagement register could be updated.	N/A	
		18/01/2022	Email incoming	Response to SLB email dated 18/01/2022 Provision of contact details within AFMA for the Western Skipjack, Western Tuna and Billfish fisheries that overlap with the area.	An email and fact sheet were sent to the Western Skipjack, Western Tuna and Billfish fisheries divisions within AFMA to inform them of the survey and provide additional details.	No objections of claims – no response/actions required.	
25	Australian Fisheries Management Authority - Western Tuna and Billfish Fishery	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
26	Australian Fisheries Management Authority - Southern Bluefin Tuna	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
27	Mackerel Managed Fishery – within AFMA and to all license holders	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		22/04/2022	Letter outgoing (from SLR Perth office)		Following engagement with WAFIC, SLB requested contact details of all licence holders in the mackerel managed fishery. Only postage details were provided, and despite a number of attempts, no electronic contact details or phone numbers of the licence holders could be identified. As a result, a letter was sent to various licence holders including the Fact Sheet providing them with details of the survey and a request to get either electronic or phone contact details to undertake further discussion over the proposed survey. It is considered that sufficient information was provided to the licence holders to make an informed	N/A	* (see note above table).

ID	Stakeholder	Date	Communication/ Engagement Type	Summary of Stakeholder Communication / Feedback / Concerns	Summary of SLB Communication / Response	Assessment of Merit of Stakeholder Concern	Reference to Location within EP
					decision of any potential impacts of the survey on their activities. It is also considered that there has been sufficient time since that letter for the licence holders to consider the proposed Seismic Survey and get back to SLB if they have any concerns over the survey or organise further engagement. As a result, it is concluded that the mackerel managed fishery licence holders do not consider the proposed Seismic Survey will impact their fishing activities.		
28	Northern Demersal Scalefish Managed Fishery (NDSF) – Withing AFMA and to all license holders	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		22/04/2022	Letter outgoing (from SLR Perth office)		Following engagement with WAFIC, SLB requested contact details of all licence holders in the Northern Demersal Scalefish Managed Fishery. Only postage details were provided, and despite a number of attempts, no electronic contact details or phone numbers of the licence holders could be identified. As a result, a letter was sent to various licence holders including the Fact Sheet providing them with details of the survey and a request to get either electronic or phone contact details to undertake further discussion over the proposed survey. It is considered that sufficient information was provided to the licence holders to make an informed decision of any potential impacts of the survey on their activities. It is also considered that there has been sufficient time since that letter for the licence holders to consider the proposed Seismic Survey and get back to SLB if they have any concerns over the survey or organise further engagement. As a result, it is concluded that the Northern Demersal Scalefish Managed Fishery licence holders do not consider the proposed Seismic Survey will impact their fishing activities.	N/A	* (see note above table).
29	Marine Aquarium Fishery (MAF) license holders	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
30	Specimen Shell Managed Fishery license holders	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).

ID	Stakeholder	Date	Communication/ Engagement Type	Summary of Stakeholder Communication / Feedback / Concerns	Summary of SLB Communication / Response	Assessment of Merit of Stakeholder Concern	Reference to Location within EP
31	Kimberley Prawn Fishery license holders	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
32	Western Australian Fishing Industry Council (**WAFIC**)	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Further follow up to different WAFIC email address	N/A	* (see note above table).
		08/02/2022	Email incoming	**Response to SLB email dated 08/02/2022** WAFIC confirmed they had received the email and will review and provide a response before 28 February 2022.		No objections of claims – no response/actions required.	* (see note above table).
		08/02/2022	Email outgoing		**Response to WAFIC email dated 08/02/2022** SLR confirmed that key contact for SLR is available by email for any further follow up questions, or by phone after 21 February. Confirmed that it would be great to receive any feedback on the proposed survey and are available for a teams call after the 21st of February.	N/A	* (see note above table).
		11/02/2022	Email incoming	**Response to SLB email dated 08/02/2022** WAFIC requested information on the gun array volume and also requested more info around peak fishing and spawning times.		No objections of claims – the further information that was requested was provided, and a commitment was made to provide the information when it became available.	* (see note above table).
		22/02/2022	Email outgoing		**Response to WAFIC email dated 11/02/2022** SLR advised the source volume is 3,000 in^3. Also advised that SLR are currently still preparing the EP and that a request has been submitted on fisheries information in the area. Until then we cannot comment but will do so once the fishing effort data is received. Confirmed that there is no overlap with the southern bluefin fishery and also asked if there is any particular fishery they are concerned with to please let us now. Commitment to provide the information once it was received and meet either virtually or face to face to discuss.	N/A	* (see note above table).
		03/03/2022	Email incoming	**Response to SLB email dated 22/02/2022** Confirmed receipt of email and information and stated that they will wait for the additional information. Confirmed that a meeting can be arranged, if required.		No objections of claims – further fisheries information to be provided once received.	* (see note above table).
		08/03/2022	Email outgoing		**Response to WAFIC email dated 03/03/2022**	N/A	* (see note above table).

ID	Stakeholder	Date	Communication/ Engagement Type	Summary of Stakeholder Communication / Feedback / Concerns	Summary of SLB Communication / Response	Assessment of Merit of Stakeholder Concern	Reference to Location within EP
					SLR confirmed that there have been data requests for the fisheries information within and around the proposed survey area. It was advised that there will be no data available until end of March 2022; however, if WAFIC has any specific concerns regarding the proposed survey area or any relevant fisheries to let us know.		
		17/03/2022	Email outgoing		**Response to WAFIC email dated 03/03/2022** SLR provided a summary of the northern demersal Scalefish managed fishery and the mackerel managed fishery based on what the fisheries assessment had provided. The information provided included a summary of what fish are being targeted. What areas they are fishing in relation to the survey area, the overlap with the survey area, volume (weight of fish caught within the area (inside vs outside operational area) and maps showing the fishing effort and fish caught within and surrounding the Operational Area. This was then used to determine any potential overlaps with commercial fishers. A request was made to WAFIC for the contact details of the relevant fishers so SLB can engage directly with the fishers and discuss details of the survey, survey timing and the ability to provide them with the 48-hour lookaheads once survey commences. Request for WAFIC to propose a time to meet and discuss the results.	N/A	* (see note above table).
		28/03/2022	Email outgoing		Follow up email to organise a time to meet and go through the results, as well as discuss any concerns that WAFIC may have following the provision of fisheries data.	N/A	* (see note above table).
		29/03/2022	Email incoming	**Response to SLB email dated 28/03/2022** Acknowledgment and thanks for passing on the fisheries information. WAFIC suggested a MS Teams meeting on 31 March to discuss the survey.	SLR and SLB were available on this data so accepted the meeting invite.	No objections of claims – meeting to be arranged.	* (see note above table).
		29/03/2022	Email outgoing		**Response to WAFIC email dated 29/03/2022** SLR organised a virtual meeting.	N/A	* (see note above table).
		31/03/2022	Meeting	Meeting between SLB, SLR and WAFIC. See meeting minutes for further details (**Appendix F**) on action items resulting from meeting and the rows below addressing each of the meeting action items required, and the responses (where relevant) to WAFICs requests.			
		31/03/2022	Email incoming	WAFIC provided additional information that may assist SLB to understand the commercial fisheries in the area. A status report of the fisheries and aquatic resources was even provided. A summary was also provided on the additional information that may assist in understanding commercial fisheries in the AOI. Contact details were provided for DPIRD where the contact details for individual commercial fishers in WA can be found.	SLB submitted a request for licence holders in the two fisheries identified as having a potential overlap with the Operational Area.	No objections of claims – the information that was provided by WAFIC was incorporated into the EP, and likewise, a request was made for the contact details of the relevant licence holders.	* (see note above table).

ID	Stakeholder	Date	Communication/ Engagement Type	Summary of Stakeholder Communication / Feedback / Concerns	Summary of SLB Communication / Response	Assessment of Merit of Stakeholder Concern	Reference to Location within EP
		31/03/2022	Email outgoing		**Response to WAFIC email dated 31/03/2022** Acknowledgement of the recent status report on fisheries. And following the meeting, SLR submitted a request for a finer scale in data, by month over the years to get an indication of seasonality of the fishery. SLR advised that WAFIC will be informed when the monthly fisheries data is obtained.	N/A	* (see note above table).
		11/04/2022	Email outgoing		SLB advised that they are reaching out to Department of Primary Industries and Regional Development and haven't had a response to form sent on 1 April.	N/A	* (see note above table).
		20/04/2022	Email outgoing		SLR advised WAFIC that a list of the licence holders has been received from DPIRD and these were also provided to WAFIC. It was confirmed that no contact details were available apart from PO Box's making direct contact with the licence holders difficult. It was questioned of WAFIC whether there was any other way to contact individual fishers so we can incorporate any concerns they may have and currently in the process of developing mitigation measures and operational procedures. It was also asked whether WAFIC had forwarded any information on the proposed survey or fact sheet on to any licence holders.	N/A	* (see note above table).
		26/04/2022	Email incoming	**Response to SLB email dated 20/04/2022** WAFIC confirmed that the issues around lack of contact details is an ongoing issue for others in the oil and gas industry. WAFIC also confirmed that they do not send out any oil and gas notifications to their members, only in certain circumstances. It was stated that WAFIC are working with APPEA and NOPSEMA to resolve this issue around contact details of licence holders, but there is no immediate solution other than posting the notifications to licence holders.		No objections of claims – no response/actions required. SLB to send out the fact sheet and a cover letter via post to PO Box addresses of licence holders.	* (see note above table).
		28/04/2022	Email outgoing		**Response to WAFIC email dated 26/04/2022** SLR advised WAFIC that letters have been sent to fishers to their relevant PO Box. In addition, monthly fisheries data has been received and this information and map was provided showing the breakdown of fishing effort per month across the Operational Area and wider fishery management area for WAFICs records.	N/A	* (see note above table).
		29/04/2022	Email incoming	**Response to SLB email dated 28/04/2022** WAFIC thanked SLB for information and to contact should SLB have any further questions.	No further questions were raised by WAFIC around the proposed Seismic Survey and any potential overlap with licence holders. There were also no further questions around compensation to fishers so it is assumed that this was not as much of a concern	No objections of claims – no response/actions required. It is considered that sufficient information	* (see note above table).

ID	Stakeholder	Date	Communication/ Engagement Type	Summary of Stakeholder Communication / Feedback / Concerns	Summary of SLB Communication / Response	Assessment of Merit of Stakeholder Concern	Reference to Location within EP
					following the provision of the fisheries data and the identification of the small overlap with fisheries. Likewise, as SLB have reached out directly to licence holders about the survey, providing sufficient data to make an informed decision as to whether the proposed seismic survey activities will have any impact on fishing activities, and the fact that no responses were received after sufficient time was given, it is concluded that there is not going to be any significant conflict or impact on fisheries and as such no compensation to any fishers is required.	has been provided and all attempts have been made to engage directly with fishers. As such no objections were received and subsequently no additional actions or compensation to fishers is required.	
		29/04/2022	Email outgoing		**Response to WAFIC email dated 29/04/2022** SLR thanked WAFIC.	N/A	* (see note above table).
33	Western Australian Game Fishing Association	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
34	Australian Southern Bluefin Tuna Industry Association (**ASBTIA**)	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		18/01/2022	Email incoming	**Response to SLB email dated 17/01/2022** ASBTIA advised that they do not fish in that area nor is it within the spawning area for SBT stock. No need to keep them informed of this activity.		No objections of claims – no response/actions required due to no conflict of activities.	* (see note above table).
		18/01/2022	Email outgoing		**Response to ASBTIA email dated 18/01/2022** SLR acknowledging that ASBTIA no longer require notification of the proposed activity.	N/A	* (see note above table).
35	Australia Fisheries Trade Association	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
36	Recfishwest	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		04/02/2022	Email incoming	**Response to SLB email dated 17/01/2022** Recfishwest thanked SLR for informing them and request that they are given opportunity to comment on any future proposals. Given the distance from shore, the potential impact on recreational fishers will be low.		No objections of claims – Recfishwest to be informed as the project develops.	* (see note above table).
		05/02/2022	Email outgoing		**Response to Recfishwest email dated 05/02/2022** SLR acknowledged that we will keep Recfishwest informed as the project develops and that they will be kept up to date with any notifications in the future.	N/A	* (see note above table).
37	Coral Expeditions	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).

ID	Stakeholder	Date	Communication/ Engagement Type	Summary of Stakeholder Communication / Feedback / Concerns	Summary of SLB Communication / Response	Assessment of Merit of Stakeholder Concern	Reference to Location within EP
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
38	Marine Tourism WA	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
39	Kimberley Marine Tourism Association (**KMTA**)	24/02/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		29/03/2022	Email outgoing		Follow up email to confirm if KMTA had any concerns.	N/A	* (see note above table).
		06/4/2022	Email incoming	**Response to SLB email dated 29-03-2022** KMTA responded advising they have passed details onto their members to respond directly.		No objections of claims – no response/actions required.	* (see note above table).
		06/4/2022	Email outgoing		**Response to KMTA email dated 06/04/2022** SLR acknowledging response	N/A	* (see note above table).
40	BKB Holidays Travel Agency	24/02/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		29/03/2022	Email outgoing		Follow up email to confirm if BKB Holidays had any concerns.	N/A	* (see note above table).
41	Kimberley Land Council	24/02/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
42	Northern Land Council	24/02/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
43	Department of Biodiversity, Conservation and Attractions (**DBCA**)	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		20/01/2022	Email incoming	**Response to SLB email dated 17/01/2022** DBCA advised that given the location of proposed activities they are unlikely to cause and impacts to Western Australian Marine Parks and provided contact details for future correspondence.		No objections of claims – contact details to be updated.	* (see note above table).
		21/01/2022	Email outgoing		**Response to DBCA email dated 20/01/2022** SLR acknowledged the new contact details and that our engagement register will be updated and keep DBCA included in all future correspondence.	N/A	* (see note above table).
44	Carnarvon Energy - WA523-P, AC/P63	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
45	Inpex Browse - AC/P66, AC/RL4	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
46	Finder- AC/P61	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).

ID	Stakeholder	Date	Communication/ Engagement Type	Summary of Stakeholder Communication / Feedback / Concerns	Summary of SLB Communication / Response	Assessment of Merit of Stakeholder Concern	Reference to Location within EP
		17/01/2022	Email incoming	**Response to SLB email dated 17/01/2022** Finder requested shapefile of the OA		No objections of claims – however, requested shapefile provided.	* (see note above table).
		18/01/2022	Email outgoing		**Response to Finder email dated 17/01/2022** Shapefiles provided by SLR	N/A	* (see note above table).
47	Santos - AC/P69, AC/P50, AC/P67	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		18/01/2022	Email incoming	**Response to SLB email dated 17/01/2022** Santos requested future correspondence is made to another contact and those contact details were provided.		No objections of claims – contact details to be updated.	* (see note above table).
		18/01/2022	Email outgoing		**Response to Santos email dated 18/01/2022** SLR noted the request and updated stakeholder register	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email incoming	**Response to SLB email dated 08/02/2022** Santos has been in touch with SLB and requests 48hr operational look ahead plan		No objections of claims – Santos included in 48hr look-ahead.	* (see note above table).
		08/02/2022	Email outgoing		**Response to Santos email dated 18/01/2022** SLR confirmed Santos will be included in 48hr look-ahead plan.	N/A	* (see note above table).
48	PTEP Australasia - AC/RL12, AC/RL7, AC/RL/6, AC/P54, AC/RL10, AC/L3	17/01/2022	Email outgoing		Introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).
		08/02/2022	Email outgoing		Follow up to introductory email from SLR with Fact Sheet attached.	N/A	* (see note above table).

APPENDIX J

PAM Specifications

PAM Specifications

Cetacean Detection Capability

The vocalisations made by the full range of marine mammal species can be detected by our PAM systems. Typical system configuration has the capability of detecting sounds within a frequency range of 200 Hz to 200 kHz. This frequency band covers most marine mammal vocalisations. The system sensitivity may be extended to 10 Hz to 200 kHz for surveys in which it is necessary to monitor for baleen whales that vocalise at very low frequencies. However, in some circumstances, vessel noise at low frequencies can mask marine mammal vocalisations and limit the performance of PAM. The frequency response of some hydrophone channels is set to counter this (e.g. lower frequency response of 2 kHz for channels designed to detect the majority of species vocalisations). Seiche can readily tailor the frequency sensitivity of the hardware to suit the project application and the range of marine mammal species likely to be encountered. Additionally, PAMGuard software can be configured to focus on the detection of the vocalisations of particular species of interest or concern.

PAMGuard Software

PAMGuard software is integrated into all our PAM systems. PAMGuard is industry-standard software for the acoustic detection, localization and classification of vocalizing marine mammals. It is a sophisticated and extendible software package that assists trained operators in robust decision-making during real-time mitigation operations. As an open source development, PAMGuard is publicly owned and freely available. PAMGuard development is led by a team of specialists at the University of St Andrews, U.K. This has to date been funded by industry via the IOGP Sound and Marine Life Joint Industry Program. Funding is now transitioning to a self-funding mechanism operated through voluntary user contributions.

Table 1. Hydrophone elements frequency range

Hydrophone Elements	
H1	10 Hz to 200 kHz (-3 dB points)
H2	10 Hz to 200 kHz (-3 dB points)
H3	2 Hz to 200 kHz (-3 dB points)
H4	2 Hz to 200 kHz (-3 dB points)

Table 2. Hydrophone sensitivity

Hydrophone sensitivity	
Broadband channel sensitivity	-166 dB re 1V/µPa (nominal)
Standard channel sensitivity	-157 dB re 1V/µPa (nominal)

APPENDIX K

Summary of Proposed Marine Mammal Control Measures

Summary of Proposed Marine Mammal Control Measures

Based on the distribution and likelihood of marine mammals in the OA (as described in Section 4.5.6 of the EP) and as per the definitions outlined in the EPBC Act Policy Statement 2.1:

- There is a moderate to high likelihood of encountering whales in the OA; and
- The OA overlaps with biologically important habitat (i.e. the blue whale migratory BIA).

On this basis, the application of both standard management procedures and additional management procedures is necessary to ensure that impacts to marine mammals are minimised from the proposed Seismic Survey.

Modelling of underwater noise from the 3,000 in^3 acoustic source has been conducted (both conventional Underwater Acoustic Modelling and Animat modelling, see Section 7.2.1.1 of the EP), and while the modelling results indicate that the standard management procedures outlined in EPBC Act Policy Statement 2.1 will be sufficient to protect high- and very high-frequency cetaceans and sirenians from predicted noise levels, additional control measures are required to protect baleen whales. The control measures below are therefore proposed to ensure full compliance with the EPBC Act Policy Statement 2.1 and the Blue Whale Recovery Plan. Where species identification is uncertain, a precautionary approach will be adopted, and additional management procedures will be applied.

In accordance with the EPBC Act Policy Statement 2.1, no control measures are required for dolphins and porpoises, and the modelling results (see Section 7.2.1.1 of the EP) support this approach.

STANDARD MANAGEMENT PROCEDURES – ALL WHALES

In accordance with the EPBC Act Policy Statement 2.1, the term 'whale' refers to baleen whales and other large, toothed whales such as, sperm whales, killer whales, false killer whales, pilot whales and beaked whales.

Unless otherwise stated, the following standard management procedures as outlined in the EBPC Act Policy Statement 2.1 will be followed throughout the entire OA[1] for the duration of the survey.

- The following Precaution Zones will be implemented as outlined in Figure 1:
    - 3+ km Observation Zone;
    - 2 km low power zone; and
    - 500 m shutdown zone.
- During daylight hours, Pre Start-up Visual Observations for the presence of whales will be undertaken for at least 30 minutes before the commencement of the Soft Start Procedure;
- If no whales have been sighted within the low power or shut-down zones, Soft Start Procedures will commence over a 30-minute period.
- A Start-up Delay will occur if a whale enters the low power or shut-down zone during the soft start. Whale presence within the low power zone will trigger the source to be powered down to the lowest possible setting (i.e. a single airgun – preferably that with the lowest energy output and volume), and presence within the shut-down zone will trigger an immediate and complete shut-down;

[1] Including the blue whale migratory BIA and proposed 17 km buffer.

- During daylight hours at least one observer will be on duty at all times to undertake continuous visual observations for marine mammals;
- If a whale is sighted within the observation zone during the Seismic Survey, an additional observer will be stationed on bridge to assist with observations;
- Stop Work Procedures will be implemented for the entire duration in which operations are underway as follows 1) the acoustic source will power-down whenever a whale is detected in the low power zone and 2) the acoustic source will shut-downs whenever a whale is detected in the shut-down zone;
- Low visibility or night-time operations may occur provided that there have not been three or more whale instigated power-down or shut-down situations during the preceding 24-hour period; and
- When species identification is uncertain, a precautionary approach will be taken, and the additional management procedures for 'other baleen whales' will be followed until identification is otherwise confirmed.

ADDITIONAL MANAGEMENT PROCEDURES - GENERAL

- Soft start procedures throughout the OA will be limited to conditions that allow visual inspection of the Observation Zone;
- Marine mammal observations made during the Seismic Survey will be undertaken by dedicated, trained and experienced marine mammal observers (**MMOs**). MMOs must have logged a minimum of 20 weeks' relevant sea-time engaged in MSS operations in Australian waters as an MMO or MFO and have proven 'at sea' experience in whale identification and behaviour, and distance estimation. The MMOs used must be confident in the identification of those species that the EP predicts will be present in the OA;
- A minimum of two MMOs will be onboard the Seismic Vessel for the duration of the Seismic Survey and two additional MMOs will be stationed on the Chase Vessel;
- A passive acoustic monitoring system (**PAM**) will run 24 hours per day on the Seismic Vessel during the Seismic Survey, with dedicated, trained and experienced PAM Operators conducting acoustic monitoring for the presence of cetaceans;
- Two trained, dedicated and experienced PAM Operators will be on the Seismic Vessel for the duration of the survey, with at least one PAM Operator maintaining 'acoustic watch' at all times;
- PAM Operators must have logged a minimum of 20 weeks' relevant sea-time engaged in seismic survey operations in Australian waters as a PAM Operator; and
- A full replacement PAM system will be kept onboard the Seismic Vessel and will be used as a back-up if the PAM system malfunctions and is unable to be repaired.

ADDITIONAL MANAGEMENT PROCEDURES – BLUE WHALES

The onset distance for cumulative TTS exceedance is predicted to be 17 km for blue whales from the Animat modelling. Based on the findings of the animat results, the following additional management procedures are proposed to be implemented for blue whales during the seismic survey:

- A 2 km Extended Shut-down Zone for baleen whales will be implemented throughout the entire OA at all times. On this basis a low power zone is deemed unnecessary;
- A 17 km buffer will be established around the blue whale migratory BIA where it overlaps with the OA;

- The Seismic Vessel will not activate the acoustic source(s) within the blue whale migratory BIA or buffer from mid-April (14th) to mid-January (14th);
- Outside of this period (15 Jan to 13 April), any seismic operations inside the blue whale migratory BIA or buffer will:
    - Implement an extended observation zone of 5 km;
    - The extended observation zone in the BIA and buffer will be monitored using the Chase Vessel as an additional observation platform with two MMO's onboard. The Chase Vessel will travel c. 3 km ahead of the Seismic Vessel[2] and will conduct visual surveillance for marine mammals during daylight hours. Trained and experienced MMOs will be required to undertake these observations;
    - Whenever possible, two experienced MMOs will be on the bridge of the Seismic Vessel during daylight hours when the source is active within the blue whale migratory BIA or buffer;
    - Limit soft start procedures to conditions that allow visual inspection of the 5 km Observation Zone;
    - Cease night-time or low visibility operations in the blue whale migratory BIA or buffer if three or more whale instigated shut-downs or power-downs are made during the preceding 24 hour period. Note that this applies irrespective of shut-down/power-down locations relative to the blue whale migratory BIA or buffer. Night-time and low visibility operations may only resume in the blue whale migratory BIA or buffer after 24 hours of no blue whale instigated shut-downs (again, irrespective of location relative to the blue whale migratory BIA or buffer);
    - If species identity is uncertain at any location inside the blue whale migratory BIA or buffer, any unidentified whale will be assumed to be a blue whale;
    - Note: PAM is not considered to be a particularly reliable method for detecting low-frequency cetaceans. On this basis, the proposed adaptive management approach at night or during periods of low visibility serves to remove the reliance on PAM while still maintaining a high level of protection for low frequency cetaceans, particularly blue whales, and
    - Note: The Precaution Zones for operations inside the blue whale migratory BIA and buffer are depicted in Figure 2.
- For operations outside of the blue whale migratory BIA or buffer, the standard observation zone of 3+ km will be implemented (Figure 3);
- If three or more blue whale instigated shut-downs occur within a 24-hour period, the Seismic Vessel will relocate to another area at least 17 km away (and outside of the blue whale migratory BIA or buffer) before commencing Pre Start-up Visual Observations and Soft Start Procedures. This control measure will be implemented throughout the entire OA (i.e. shut-downs both inside and outside the blue whale migratory BIA and buffer will contribute to this count); and
- If a blue whale mother and calf pair is observed during the Seismic Survey, the acoustic source will be immediately shut-down and the Seismic Vessel will relocate to another area at least 17 km away (and outside of the blue whale migratory BIA or buffer). This control measure will be implemented throughout the entire OA (i.e. sightings both inside or outside the blue whale migratory BIA and buffer will trigger this control measure).

[2] Defined as an 180° arc ahead of the Seismic Vessel, noting that the Chase Vessel should focus on the portion of the arc closest to the blue whale migratory BIA and buffer.

ADDITIONAL MANAGEMENT PROCEDURES – OTHER BALEEN WHALES

The following control measures are proposed for other baleen whales (i.e. all baleen whales excepting blue whales; e.g. humpback, fin, sei, Bryde's, Omura's and dwarf minke whales) during the Seismic Survey on the basis that free-ranging pelagic animals are not expected to remain in the vicinity of the Seismic Vessel for extended periods and the movement of the Seismic Vessel means that any potential exposure will be transitory:

- A 2 km Extended Shut-down Zone for baleen whales will be implemented throughout the entire OA at all times. On this basis a low power zone is deemed unnecessary;
- If three or more baleen whale instigated shut-downs occur within a 24-hour period, the Seismic Vessel will relocate at least 10 km away;
- If a baleen whale mother and calf pair is observed during the Seismic Survey, the acoustic source will be immediately shut-down and the Seismic Vessel will relocate to another area at least 10 km away; and
- For any adaptive management procedures outside of the blue whale migratory BIA or buffer, if species identity is uncertain, any unidentified whale will be assumed to be an 'other baleen' whale.

Figure 1 Standard Precaution Zones: Toothed Whales

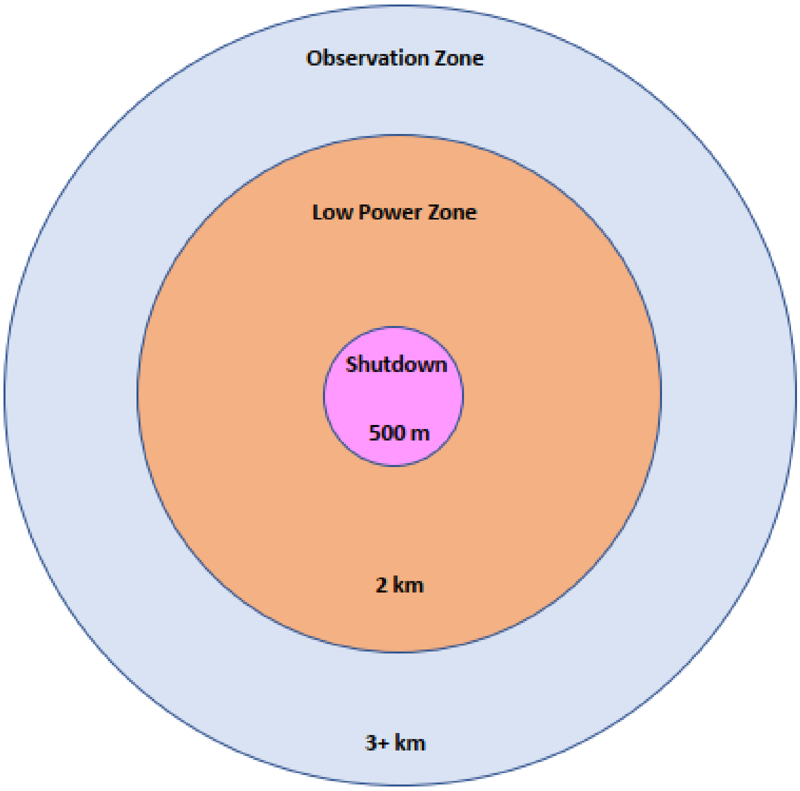


Figure 2 Extended Precaution Zones: Baleen Whales Outside Blue Whale Migratory BIA or Buffer

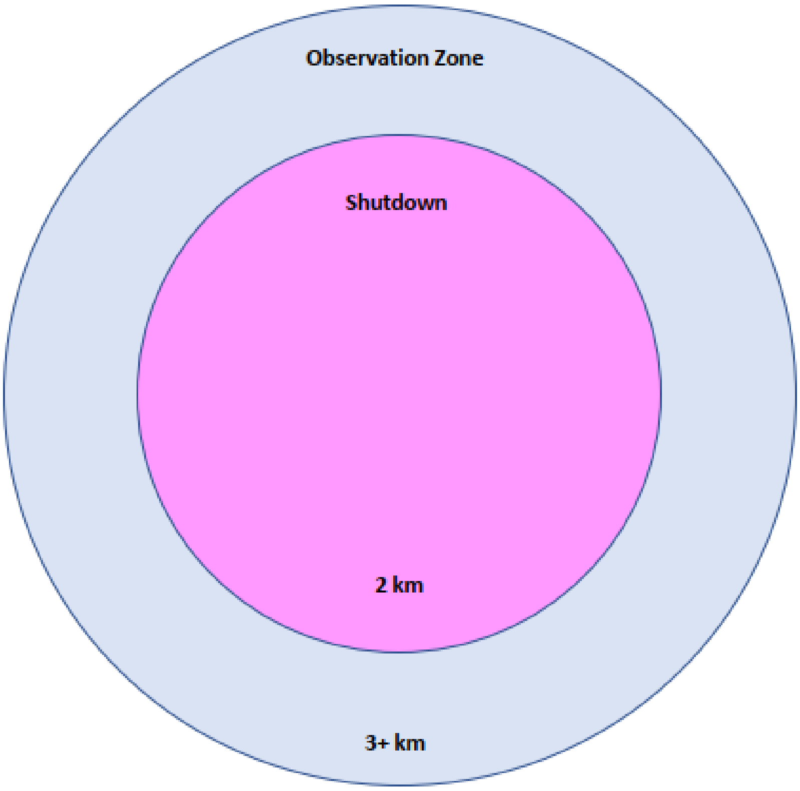
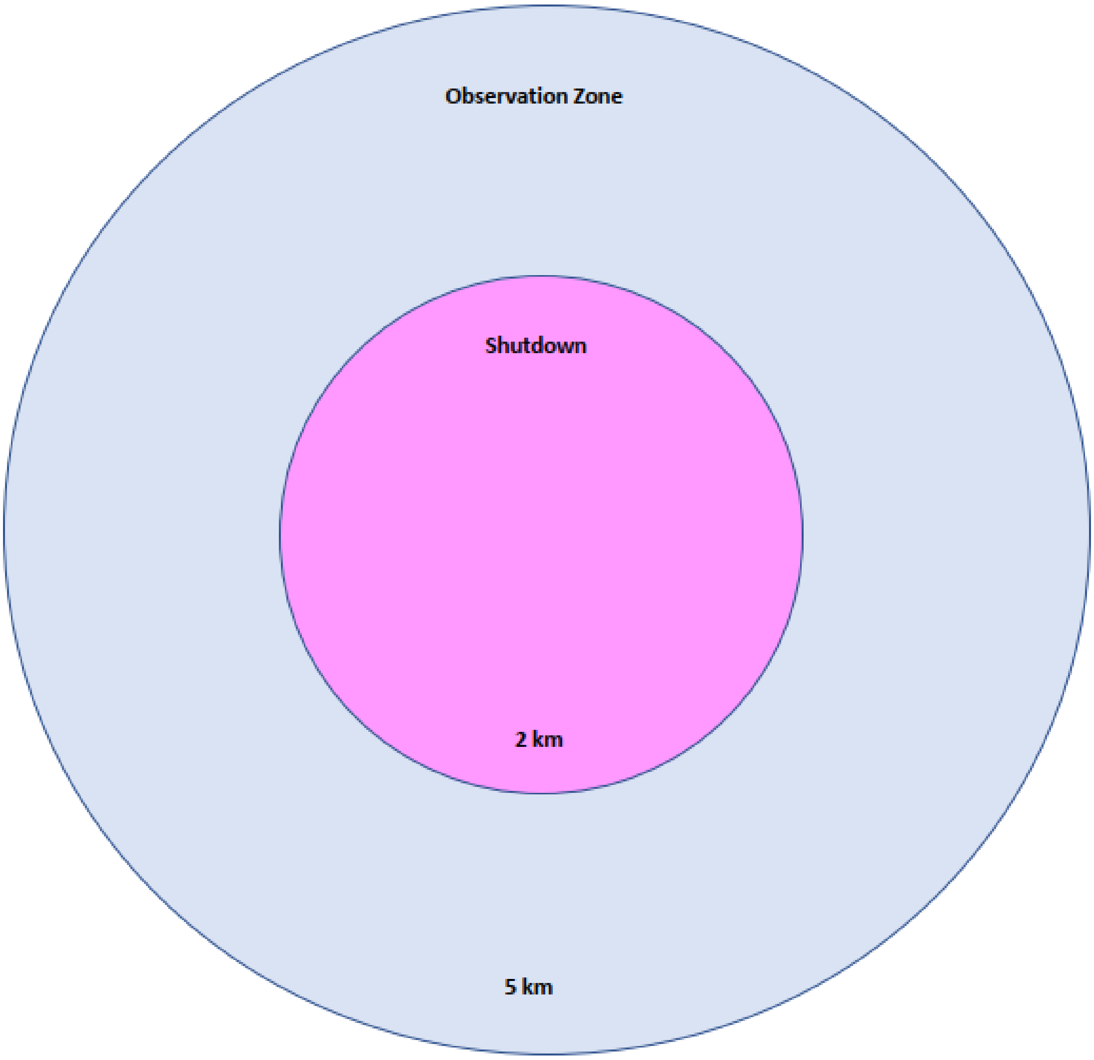


Figure 3 Extended Precaution Zones: Baleen Whales Inside Blue Whale Migratory BIA or Buffer



APPENDIX L

Operational and Scientific Monitoring Plan

BONAPARTE BASIN MC3D MARINE SEISMIC SURVEY

Operational and Scientific Monitoring Plan (OSMP) - Logistics and Monitoring Plan

Prepared for:

Schlumberger Australia Pty Ltd.
Level 5, Capital Building
256 St Georges Terrace
Perth
WA 6000

SLR Ref: 675.30093.00000-R02
Version No: -v1.0
May 2022

SLR

PREPARED BY

SLR Consulting Australia Pty Ltd
ABN 29 001 584 612
Ground Floor, 503 Murray Street
Perth WA 6000 Australia

T: +61 8 9422 5900
E: perth@slrconsulting.com   www.slrconsulting.com

BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Schlumberger Australia Pty Ltd. (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
675.30093.00000-R02-v1.0	25 May 2022	SLR Consulting	Dan Govier	Dan Govier

CONTENTS

CONTENTS

CONTENTS

DOCUMENT REFERENCES

TABLES

FIGURES

APPENDICES

1 Introduction

1.1 Background and purpose

Schlumberger Australia Pty Limited (**SLB**) is proposing to acquire the Bonaparte Basin Multiclient 3D Marine Seismic Survey. Hereafter, these activities are referred to as the Seismic Survey. An Environment Plan (**EP**) has been prepared concurrently with this Operational and Scientific Monitoring Plan (**OSMP**).

The objective of the Seismic Survey is to provide an improved subsurface image of the eastern flank of the Vulcan Sub-basin and Londonderry High. The new data will provide an improved understanding of the subsurface, which to-date has been limited due to legacy surveys being unable to resolve shallow carbonate intervals and complex faulting. The Operational Area is located off the coasts of North-Western Australia, mostly within the Exclusive Economic Zone and outside Coastal Waters covering 25,827 km^2.

Section 10.9 of the EP contains an Oil Pollution Emergency Plan (**OPEP**) which includes a functional Operational and Scientific Monitoring Program (**OSMP**) in Section 10.9.6 of the EP. The OSMP section broadly outlines the details of Type I Operational Monitoring and Type II Scientific Monitoring studies which would be undertaken in the event of a Level 2 hydrocarbon spill. These plans are an integrated package of environmental management documents designed to manage environmental issues and protect the environment during the Seismic Survey.

This document provides further detail on how the OSMP will be implemented in the event of a Level 2 spill. Specifically, this OSMP Logistics and Monitoring Plan demonstrates how the Type I Operational and Type II Scientific monitoring tasks assigned to SLR would be implemented on behalf of SLB in the event that monitoring is initiated.

This document is consistent with the guidance from NOPSEMA in "Operational and Scientific Monitoring Programs – Information Paper – N-04700-IP1349".

1.2 Worst-case Spill Scenario

The worst-case spill scenario from the Seismic Survey is the catastrophic rupture of a seismic vessel fuel tank via vessel collision. Accidental release of hydrocarbon during bunkering is also recognised as a risk, but lower and with preventative operational procedures in place to reduce this risk. Thus, the worst-case is based on a vessel collision. As a result of vessel collision/sinking, the integrity of the hull of the vessel(s) may be compromised, leading to the release of marine gas oil (**MGO**) or other hydrocarbon products into the marine environment. The very worst-case scenario for a hydrocarbon spill would likely arise where the entire contents of the seismic vessel's fuel tanks were released into the surrounding ocean. Pending confirmation of vessel type to be used for the Seismic Survey, a hypothetical worst-case spill was simulated to determine the extent of the Environment that May be Affected (**EMBA**) for any spill event.

Calypso Science (2022) utilised the OpenOil simulation framework to model the weathering dispersal and trajectory of a spill. The OpenOil module is part of the OpenDrift[1] project – an open-source code base. The OpenOil module was modified to include dissolution processes, and is consistent with that adopted in other oil spill simulation software modules (e.g. OSCAR, SIMAP).

[1] Introduction to OpenDrift — OpenDrift documentation; GitHub - OpenDrift/opendrift: Open source framework for ocean trajectory modelling

Conservatively, MGO was used as the fuel type, which has a greater environmental persistence than marine diesel oil (**MDO**). The release of up to 1,000 m^3 MGO over a six-hour period was simulated and included three potential release locations within the proposed Operational Area. The model framework applied annual average conditions (as well as seasonal conditions) to simulate the spatial extent of a potential spill, accounting for the spreading, dispersion, entrainment and beaching of the spill.

The Operational Area is predominantly in an offshore marine environment which is within the Indonesian Throughflow, where the current primarily flows from NE to SW, north of the West Australian coastline.

The results for oil spill assessment are represented in **Figure 1**. Two thresholds are depicted for the EMBA, the low threshold (green line) and the moderate threshold (orange line). The lines represent the outline of the total scenarios assessed for the three potential release areas[2] that show the extent of the entrained surface oil (from the surface to 10 m deep) at a concentration at 10 ppb (low, threshold, green line), and the extent of entrained oil at a concentration up at 100 ppb (moderate threshold, orange line).

This representation of the EMBA for both the low and moderate thresholds are conservative and are regarded as worst-case scenarios. Given these are the cumulative results across all modelled scenarios for the entrained surface oil (0-10 m), in the event of an actual oil spill, it is expected that the extent of any potential impact will incur a much smaller 'footprint' than represented here.

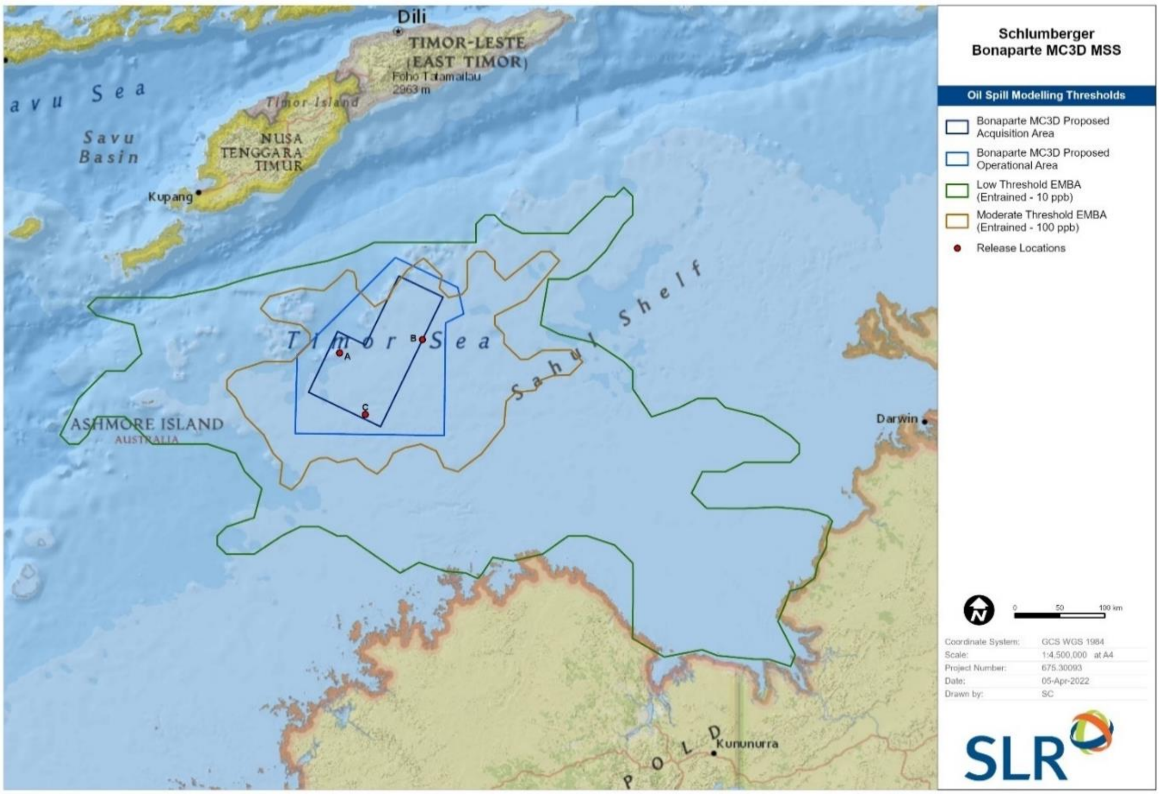


Figure 1 Total extent of modelled Low Thresholds and Moderate Threshold EMBA for entrained surface oil under all modelled scenarios for accidental release of oil from three potential release sites (A, B. C)

[2] EMBA extent is the total output of 300 scenarios, 100 each for summer, transition period and winter period

In addition to the extent of the EMBA thresholds, the potential beaching of oil is depicted in **Figure 2**. As with the EMBA thresholds, this represents a cumulative worst case scenario of the total of beached droplets, across all scenarios, for the three potential release locations (A,B,C). In the event of an actual oil spill, it is expected that the extent of any potential beach impact will incur a much smaller 'footprint' than represented in **Figure 2**.

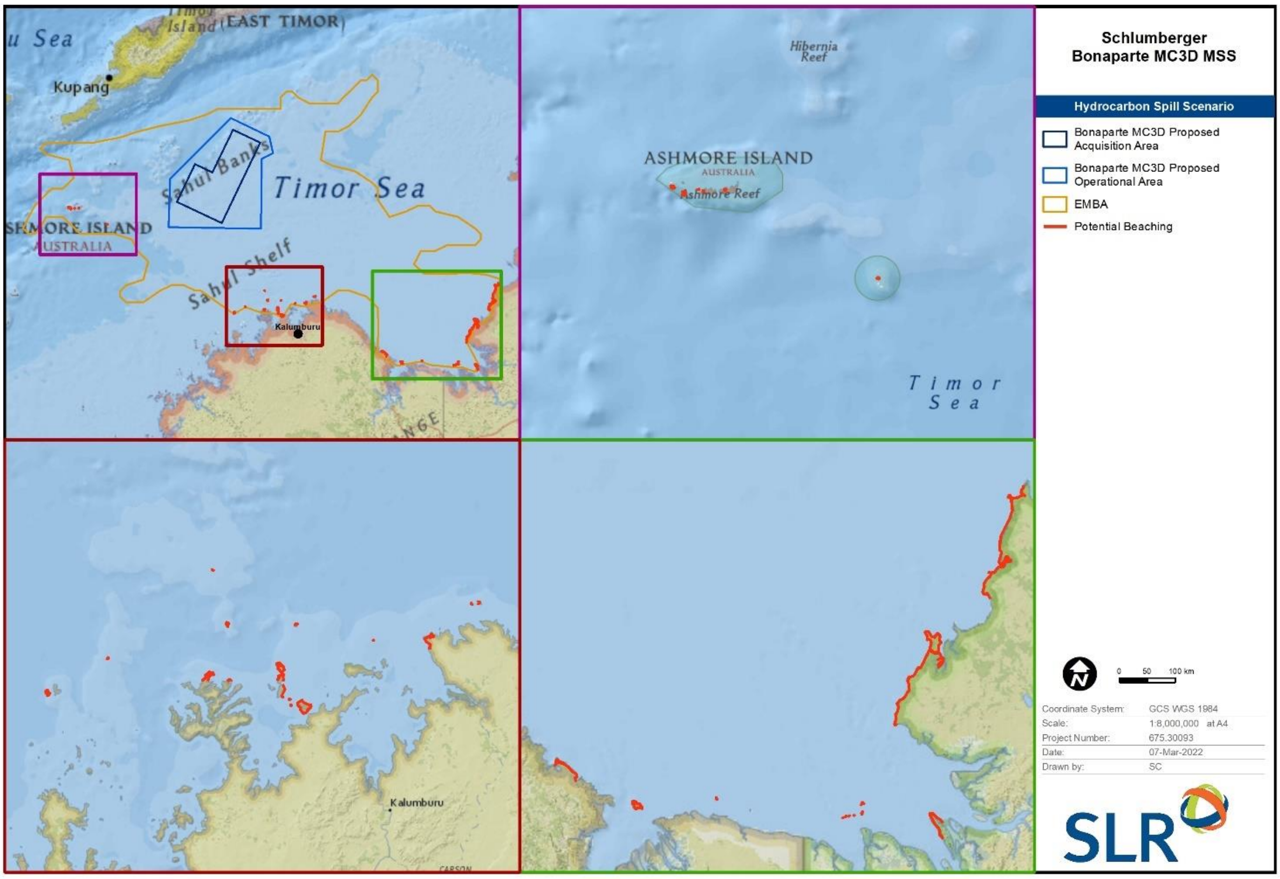


Figure 2 Total extent of potential beached oil under all modelled scenarios for accidental release of oil from three potential release sites (A, B. C).

Hydrodynamic modelling of the MGO (see Calypso, 2022) concluded the fate of spilled MGO in the Bonaparte Basin is highly dependent on the wind and wave climate. During the transitional months (March, September, October and November) winds and waves are relatively calm and the fuel persists on sea surface for a long period of time than other seasons.

Results of the modelling demonstrated there is less dispersion within the water column and more surface trajectory toward Joseph Bonaparte Gulf. During the winter months (April, May, June, July and August) the plume tends to spread toward the South-West (i.e., Ashmore reef and Cartier Island), whereas during the summer months (December, January, February) the plume trajectory is predominantly directed toward the North-East (Calypso, 2022)

Worst-case scenario modelling demonstrates in the event of a worst-case spill scenario (simulated for October transition conditions), the bulk of hydrocarbons would disperse and evaporate rapidly in the higher-energy offshore marine environment. This is demonstrated in the timeseries output representing the fate and mass budget averaged across scenarios (see Calypso, 2022). A worst-case beaching outcome is likely to result in an average of 1.7% of the spilled volume expected to be beached for a release from location B, and on average less than 1% if released from location A or C. A worst-case scenario, simulated for a seasonal transition period would, however, potentially result in up to 13% of the spilled volume beaching on the North Kimberly Coast.

1.3 OSMP Studies

Section 10.9 of the EP contains various monitoring programs, both Type I Operational and Type II Scientific, which may be implemented in the case of a Level 2 spill (consistent with the worst-case scenario) and these are further detailed below.

1.3.1 Type I – Operational Monitoring

As an integral part of the response to a spill 'Type 1', 'response phase' or 'operational monitoring', is used to collect information about the oil spill and associated response operations for the purposes of aiding decision-making during the response.

Type I 'Operational Monitoring' will be implemented where it is safe to do so and when there is a net benefit in doing so (as agreed with the Control Agency). This monitoring will be implemented to:

- Determine the extent and character of a spill;
- Visual tracking of the movement/ trajectory of surface slicks;
- Identify areas/ resources potentially affected by surface slicks; and
- Determine sea conditions/ other constraints.

Table 1 provides a description of operational monitoring plans (**OMP**) likely required in the event of a Level 2 spill (consistent with the worst-case scenario), the key receptors and the aims of the plan. These include:

- OMP1 (Oil Spill Modelling) - real-time spill trajectory modelling to provide assurances that response options can be tailored to the specific spill situation. The modelling will be based on continuous weather monitoring which will be utilised in conjunction with hindcast data to predict any potential beaching locations of the hydrocarbon, if any exist. This real-time spill trajectory modelling will be utilised to focus any potential scientific monitoring if it were to be required (and directed by the Control Agency) in order to monitor the impacts from a spill occurrence;
- OMP2 (Surveillance and Tracking) - field-based monitoring, including vessel and/or aerial surveillance, will be undertaken immediately following a spill event. This monitoring will enable the Vessel Master to provide up-to-date information to the relevant Control Agency via the POLREP form to appropriate plan any response options; and
- OMP3 (Monitoring of Hydrocarbons: Weathering and Behaviour in Marine Waters). This field-based monitoring will be led by an SLR MMO onboard the support vessel. A draft plan is included in **Appendix B**.

Operational monitoring and observation in the event of a spill will inform an adaptive spill response and scientific monitoring of relevant key sensitive receptors.

1.3.2 Type II – Scientific Monitoring

'Type II', 'recovery phase' or 'scientific monitoring', comprises a series of Scientific Monitoring Plans (**SMPs**) designed to be implemented at the termination of the response phase to quantify impacts from the spill.

Table 1 provides a description of the Type II Scientific Monitoring Plans, including the key receptors and the aims of the plans.

Table 1 Monitoring Plans for the Seismic Survey – key receptors, aims and responsibilities

Plan Reference	Title	Key Receptor(s)	Aim	Implementation
OMP1	Oil Spill Modelling	Multiple receptors at local- to regional-level scales	Provide information that can be used to define the spatial extent of the spill, for comparison with the pre-defined EMBA	**SLB**
OMP2	Surveillance and Tracking	Multiple receptors at local- to regional-level scales	Provide situational awareness to the Incident Management Team (**IMT**), to allow effective ongoing planning and management of spill response activities and identify any significant changes in risk Provide information to allow the assessment of the efficacy and potential impacts (positive and negative) of spill response strategies and tactics	**SLB**
OMP3	Monitoring of hydrocarbons in seawater - Weathering and Behaviour in Marine Waters	Offshore pelagic habitats (i.e., water column) exposed or at risk of exposure from spill hydrocarbons	Provide information that can be used to define the spatial extent of the spill, for comparison with the pre-defined EMBA, and inform SMP requirements	SLR
SMP1	Marine water quality	Background water quality	To monitor the hydrocarbons in marine waters to inform assessment of impacts and recovery of sensitive receptors, and to verify hindcast/real-time modelling to inform ongoing SMP requirements	SLR
SMP2	Intertidal and shoreline sediment quality	Background sediment quality, particularly focused on sensitive locations	Characterise the state, persistence and fate of spilled hydrocarbons within sediments	SLR
SMP3	Intertidal and shoreline habitats and benthos	Invertebrates, filter feeders, benthic primary producers, demersal fish, shorelines and intertidal habitats	Determine the impacts of spilled hydrocarbons on intertidal benthos and habitats	SLR
SMP4	Seabirds and shorebirds population and recovery	Foraging seabirds and coastal shorebird populations	Assess impacts on seabird and shorebird populations.	SLR
SMP5	Marine fauna (excluding avifauna)	Marine mammals, marine reptiles, bony fish, elasmobranchs	Assess impacts on non-avian marine fauna potentially impacted by a hydrocarbon spill.	SLR
SMP6	Socio economic impact monitoring (fisheries, aquaculture and tourism)	Target species or areas of importance for fishing/tourism	Assess impacts on fisheries (including aquaculture) and tourism activities	SLR

2 Preparedness

This section includes information relating to contractual arrangements, communication protocols, roles and responsibilities and resources to activate the OSMP, initial mobilisation and ongoing maintenance of the response.

2.1 Contractual Arrangements

2.1.1 SLR and SLB

In accordance with Section 10.9.6.2.1 of the EP, **SLB** have a service agreement with SLR. This agreement, a signed Cost-Time-Resource (**CTR**) will enable SLR to initiate the planning and commence preparation in anticipation that a field response may be required. Authorisation to commit funds, will be confirmed within 12 hours of the spill under the approved CTR.

Contractual arrangements with third parties will be in place with key third-party suppliers, service providers and organisations (e.g. CSIRO, AIMS) as part of a demonstration of preparedness prior to mobilisation.

Information on contractual status of resources will be included in the Resource Register (**Section 2.4.1**). Contractual arrangements for any additional suppliers/personnel identified during the OSMP response planning (e.g. for newly-available technologies or processes that would have a positive impact on HSE and/or data collection/quality) that were not identified during the preparedness phase will be facilitated by SLB to support a rapid response.

2.1.2 Logistics

Logistical requirements (including but not limited to arrangement of transport, accommodation, victualling, shipping, vessels, etc.) will be contracted directly by SLB via existing contracts, direct sourcing or Master Service Agreements.

2.2 Roles and Responsibilities

Section 10.2 of the EP provides a description of the roles and responsibilities of all personnel involved in the Seismic Survey. Those relevant to the OSMP implementation are described below.

2.2.1 OSMP Management

The roles responsible for the overall management of the OSMPs, and integration, data transfer and communications between SLB and the Service Provider (SLR) are defined in **Table 2**.

Table 2 OSMP Management Roles and Responsibilities

Tile	Role	Responsibilities
SLB Project Manager (SLB PM)	- The SLB PM is the direct line of communication and Management between and the OSMP Service Provider (SLR). - The role facilitates information transfer between SLB internal management and stakeholders and Service Provider, manages the day-today needs of the project (including addressing operational needs/requests), and makes sure that the OSMP meets the needs of SLB (including regulatory requirements) and external independent review/stakeholder groups	- Has overall responsibility for the implementation of the OSMP. - Ensures all required reporting (including to regulators and AMSA) has occurred in accordance with the relevant requirements. - Notifies SLR in the event of a Level 2 spill within 2 hours and provide the relevant information discussed in Section 10.9.5.3 in the EP. - Coordinates communication/liaison between SLR, AMSA, SLB and any other relevant parties. - Provides and/or facilitates support to the OSMP service provider (e.g. in the application of permits).
SLR Project Manager (SLR PM)	- Direct engagement with the SLB PM. - Responsible for the implementation and day-to-day management of the OSMPs, and information transfer between SLB and the OSMP response teams. - Management of communications between the OSMP Service Provider (SLR) and SLB	- First point of contact in the event that an OSMP response is required. - Response initiation. - Management of SLR personnel and subcontractors. - Day-to-day responsibility for facilitating/coordinating OSMP monitoring activities. - Direct engagement with the SLB PM. - Maintenance of SLR' preparedness - Overall responsibility for HSE of SLR personnel and subcontractors.
SLB Onboard Representative	- Direct engagement with the SLR Monitoring Coordinator.	- Day-to-day responsibility for the provision of the spill characteristics and operational monitoring required to implement the OSMP. - Day-to-day responsibility for facilitating/coordinating OSMP monitoring activities on behalf of SLB.
SLR Monitoring Coordinator	- Direct engagement with the SLR Monitoring Coordinator. - Oversight of the Field Operations Coordinator (see **Table 3**).	- Responsible for the development of detailed OSMP plans and their implementation. - Responsibility for overseeing an OSMP is initiated and performed.

2.2.2 Operational Management Personnel

The roles responsible for the day-to-day management of survey operations and operational activities (including data management, QA/QC and reporting) are outlined in **Table 3**.

Table 3 Operational personnel roles and responsibilities

Tile	Role	Responsibilities
SLR Field Operations Coordinator	- Supporting the mobilisation and the day-to-day field management of OSMPs. They are required to engage with the internal management team and SLB logistics (in line with the communications protocol) to resource, equip and maintain all survey operations	- Day-to-day management of field teams - Engagement with subcontractors and analytical laboratories - Sourcing personnel, equipment and consumables for OSMPs, including managing shifts and periodic shift rotations - Coordinating logistics with SLB (equipment, sample containers, travel and accommodation, supporting infrastructure, etc.) - Managing relevant survey permit applications and notifications - Coordinating sample pick-up and shipping to labs in line with sample holding times - Arranging sample labels (e.g. barcodes) with laboratory - First point of contact for field teams - Management of personnel qualification, medical and accreditation database - Communicating survey platform requirements (e.g. winches, a-frames, deck cranes, deck space, etc.) - Identification of additional survey requirements
HSE Coordinator	- Health, safety and environment (**HSE**) aspects of the OSMP scope	- Management of HSE plan, HAZIDs, and JHA preparation - Point of contact for Health, Safety and Environment issues - Provision of guidance in all HSE matters - Management of HSE reviews, incident investigation and reporting - Management of post-survey debriefs and lessons learned as part of an ongoing improvement process - Review of load testing information for equipment and additional components
Data Manager/ Quality Lead	- Managing the collection, transmittal, QA/QC and delivery of all OSMP and laboratory data. Responsible for ensuring all QA/QC procedures are in place and that processes have been adhered to	- Management of the preparation and implementation of Standard Operating Procedures (**SOPs**) in line with appropriate guidance and standards - Management of QA/QC reviews - Development and implementation of the data and metadata management plan - Provision of data management and QA/QC guidance throughout the OSMP response - Responsible for managing data quality (QA/QC), issues and lessons learned

Tile	Role	Responsibilities
Field Technical Leads	- Technical quality of survey operations, data and sample collection in the field - Responsible for all non-vessel-based survey management (e.g. HSE, field communications, field operational management decisions)	- Supporting mobilisation and demobilisation of equipment - Participating in HSE processes (e.g. HSE briefings, toolbox talks) - Coordinating day-to-day survey planning with the Vessel Party Chief and/or other Field technical leads (where appropriate) - Pre-survey vessel contamination risk assessment (to plan deck operations to minimise vessel-related sample contamination risks) - Field management of technical survey protocols, equipment, personnel and subcontractors - Deployment and retrieval of survey equipment - In situ collection of samples in line with approved SAP/PEP procedures - QA/QC of samples and sampling procedures - In situ identification of biota (where required) - Collection of relevant environmental meta data (e.g. time, sampling coordinates, depth, conditions etc.) - Management of sampling data records (e.g. field sheets, data records) and imagery - Sample processing and proper handling and storage - Sample transfer and Chain of Custody (**CoC**) forms - All field personnel have stop work authority – safety is everyone's responsibility
Field Survey Personnel (Field Teams)	- Collection of data and samples under the direction of the field technical lead	- Supporting mobilisation and demobilisation of equipment - Participating in HSE processes (e.g. HSE briefings, toolbox talks) - Deployment and retrieval of survey equipment - Labelling of sample containers - In situ collection of samples in line with approved SAP/PEP procedures - Sample processing and proper storage - Data entry - Sample transfer and CoC forms - All field personnel have stop work authority – safety is everyone's responsibility

2.3 Communication

All OSMP response communications will be managed by the SLB Project Manager (**PM**) in accordance with the OPEP (Section 10.9 of the EP).

2.4 Resources

Information regarding sub-contractors, equipment, personnel, analytical laboratories and survey platform requirements are compiled and maintained in an Excel spreadsheet format (subsequently referred to as the 'Resource Register'). Resource suppliers will be identified based on a series of criteria that include, but are not limited to:

- Appropriate accreditation (e.g. laboratories with National Association of Testing Authorities (NATA) accreditation of relevant analytical methods);
- Able to provide the relevant services to the required level of accuracy/reliability/environmental parameter/limit of detection;
- Able to calibrate equipment (where required);
- Able to provide robust, commonly used, scientifically accepted survey equipment;
- Multiple units of appropriate survey equipment available (preferably within Australia) with spares;
- Previous experience with the supplier/subcontractor;
- Reliability and reputation of supplier/subcontractor;
- Qualifications, accreditation and experience of subcontractor personnel;
- Able to source and mobilise equipment rapidly;
- Availability to respond to queries/issues with survey equipment should they arise;
- Location (e.g. based in Australia or international); and
- Minimum mobilisation times.

This approach allows continual evolution and development of the understanding of the OSMP support resources available. The intent is to incorporate redundancy through the identification of a greater range of resources than should be required to support an OSMP response to the scenario defined in the activity-specific EP.

Appendix B includes details regarding personnel and equipment requirements to implement the OSMP.

2.4.1 Resource Register

The Resource Register will be used to manage and demonstrate preparedness. It will be maintained as a 'live' document and will be the responsibility of the SLR PM (though this task may be delegated to the Field Operations Coordinator following activation of the OSMP response). The Resource Register can be continually updated and enhanced to include additional personnel, equipment and suppliers to allow incorporation of new technologies or techniques where appropriate to study objectives (additional information to support implementation will be provided in appendices to relevant OSMPs). This approach also allows consideration of the natural movement of personnel within the employment market.

The Resource Register also allows for testing of the availability of resources, providing records (e.g. date/time-stamped pdf files) that can be used to assess adequacy in preparedness over time. Where gaps or inadequacies are identified, the QA/QC process requires that additional resources relevant to non-compliances be identified and resourced.

2.4.2 Core OSMP Personnel and Equipment Requirements

The core personnel requirements for OMP3 and SMP1, SMP2 and SMP3 are included in Appendix and summarised in **Table 8**. The core requirements (= 'survey units') specified are the minimum required to implement a specific OMP or SMP response for a single shift on a single survey platform (e.g. vessel) or shoreline. These survey units have been defined to allow a flexible response to an evolving situation. To increase response, the number of survey units can be increased. This approach allows flexibility to implement multiple monitoring plans from the same survey vessel through undertaking different scopes on different shifts (24/7 operations).

2.4.3 Personnel Safety and Security Training Requirements

Field personnel will require the following valid and in-date safety and security training, accreditation and assessments as a minimum:

- Medical (e.g. United Kingdom Oil and Gas (UKOG) offshore medical, or equivalent);
- Maritime Security Identification Card (**MSIC**); and
- Basic Offshore Safety Induction and Emergency Training (**BOSIET**) or Tropical Basic Offshore Safety Induction and Emergency Training (**TBOSIET**). The BOSIET and TBOSIET include Helicopter Underwater Escape Training (**HUET**).

In addition, there will be a requirement for at least one person with current Senior First Aid certification (or equivalent) per field team as a minimum.

Before commencing field work for any project, all field personnel (including subcontractors) must undertake the SLR Project Induction, the SLR HSE Induction, as well as any additional client required inductions. The purpose of these is to brief all personnel on project scopes and the risks identified during a Hazard Identification (**HAZID**) workshop.

Any required port- or site-specific inductions will be arranged during mobilisation. Vessel inductions will include a survival suit/cold water survival component, to familiarise those with TBOSIETs with the use of survival suits and identify key cold-water survival recommendations. Vessel safety drills will incorporate survival suits to develop practical experience in their fitting and use.

2.5 Health, Safety and Environment

HSE performance will be managed through SLB's Management System. This system requires all contracted companies to have an HSE management system in place. The SLR Safety Management System is an integrated component of its total Integrated Management System and is AS/NZS 4801:2001 & BS OHSAS 18001 certified. It defines the SLR processes used to achieve consultation, management ownership, periodic management system reviews and ongoing continual improvement, and forms the framework around which health and safety is managed within the organisation.

2.5.1 SLR HSE Personnel

SLR has identified senior HSE personnel who are available to provide rapid response capability during an oil spill emergency:

Ben Simpson, Health & Safety Manager – APAC.

Mobile: +61 407 602 377, Email: mailto:srothman@slrconsulting.com bsimpson@slrconsulting.com

2.5.2 HSE Plan

An HSE Plan for OSMP activities will be developed prior to mobilisation. Operational monitoring will be undertaken during the response phase to support situational awareness and allow evaluation of spill response activities. There are inherent risks associated with working in a hydrocarbon spill area that need full consideration. Such risks include the potential exposure of operational personnel to hazardous hydrocarbon compounds (e.g. volatile organic compounds (**VOCs**) such as benzene, toluene, ethylbenzenes and xylenes (**BTEX**)), and management actions such as safe work limits will be defined based on recommendations in the SLB HSE plan.

2.5.3 JHAs and MSDSs

SLR will prepare a number of draft Job Hazard Analyses (**JHAs**) for the implementation of operational and scientific monitoring plans, prior to mobilisation of the MODU. These will be reviewed following SLR activation and updated as required for the specific response requirements and situation at the time. Additional JHAs will be developed and implemented as required. Some sampling may require the use of chemicals for cleaning and/or storage of samples, in which case Material Safety Data Sheets (**MSDSs**) for relevant chemicals (and copies of the draft JHAs) will be appended to the HSE Plan.

2.5.4 Personal Protective Equipment

All field staff will have appropriate Personal Protective Equipment (PPE) in suitable condition. As a minimum, these will include:

- Long-sleeved high visibility work shirts;
- Spare safety overalls;
- AS compliant hard hat with wide brim;
- Sun visors/shade hat;
- AS compliant boots with protective steel toecaps and/or gumboots with protective steel toecaps;
- AS compliant gloves (rigger gloves and access to rubber/nitrile gloves for sample processing);
- Glove clips;
- AS compliant eye protection – both clear safety glasses (AS/NZS1337) and polarised sunglasses;
- Wet weather gear (appropriate for the Timor Sea if offshore);
- Cold weather gear (appropriate for the Timor Sea, and able to be worn beneath wet weather gear where necessary);
- Beanie hats and warm gloves (suitable for wearing under hard hats and waterproof protective gloves);

- Sunscreen;
- Insect repellent (jungle formula);
- Earplugs; and
- Personal first aid kit.

Additional items of PPE will be issued where appropriate to the environment to be sampled (e.g. personal flotation devices (**PFDs**) on vessels to meet Australian Standards Offshore (ISO 12402-1), ear defenders and personal radios for intertidal or vessel-based surveys).

2.6 Permit Requirements

OSMP field survey operations may be undertaken in both Commonwealth and state waters (the latter extend from the mean low water mark to the three-nautical mile limit) and a hydrocarbon release could conceivably reach the mainland and Ashmore Island waters (which are determined based on modelling outcomes and to be verified through surveillance during the event of a spill). The permits generally required by the Commonwealth, Western Australia, and Northern Territory governments are listed in **Table 4**.

In general, permit applications require details on the samples to be collected (including timing, species, numbers, methods to be used, etc.) and specific details of the survey platforms (e.g. vessel names and registration details) and personnel. Permits can take 4–6 weeks (or longer) to be approved, though in the event of an oil spill, the Responsible Agencies can expedite the process and/or possibly offer exemptions (depending on the legal ramifications to the relevant agency).

Notification SHALL be given to relevant government agencies in the region to be sampled, prior to mobilisation. Post-survey reports must also be filed in accordance with the requirements of the specific permit(s) in place.

Confirmation of any reporting requirements shall be sought should an exemption be granted.

Table 4 Commonwealth and State/Territory permit requirements for the collection of survey samples

Permit	Relevance	Legislation	Responsible Agency
Commonwealth			
General Permit Application for: - threatened species and ecological communities - migratory species - whales and dolphins - listed marine species.	- Required for scientific sampling of matters listed under the Environment Protection and Biodiversity Conservation Act 1999 (**EPBC Act 1999**)	- EPBC Act 1999	- Department of the Environment and Energy (DEE)
Access to Biological Resources in a Commonwealth Area for Non-Commercial Purposes	An applicant must obtain written permission from each Access Provider. The Access Provider must state permission for the applicant to: - enter the Commonwealth area - take samples from the biological resources of the area - remove samples from the area.		

Permit	Relevance	Legislation	Responsible Agency
Western Australia			
Authority to Take Fish for Scientific Purposes: Permit to take fish for the purpose of scientific research. Taking fish includes catching, capturing, trapping, enclosing, gathering, removing, poisoning, stunning, killing or destroying fish by any means	Required to ensure that research does not impact on populations, environmental integrity of habitats or conservation values of protected areas. Exemption/Separate approvals required for: - taking fish from a state reserve or marine park - taking fish for genetic or chemical extraction or analysis, as well as handling, delivering, receiving, storing, packaging, purchasing or selling of fish for that purpose.	- Fish Resources Management Act 1994 Western Australia - Fish Resources Management Regulations 1995 Western Australia	Department of Primary Industries and Regional Development Fisheries
Scientific Purposes Licence (Marine) required for the take flora or fauna (including fish and pearl oysters) from a marine nature reserve, marine park or marine management area for scientific purposes. Taking includes injuring, destroying, hunting or otherwise interfering with flora and fauna	Required for research in any aquatic parks under Western Australian legislation (in State waters or in relation to any waters on the landward side of waters adjacent to the State that are within the Australian fishing zone	- Conservation and Land Management Act 1984 - Conservation and Land Management Regulations 2002	Department of Biodiversity, Conservation and Attractions (WA)
Requirement to be licensed for the purpose of using animals for scientific purposes, and adhere to Scientific Use Code. The scientific use of animals other than those defined by the Animal Welfare Act 2002 (such as fish, cephalopods and insects) are not subject to the Act.	Taking tissue samples for hydrocarbon analysis from live vertebrates (excludes fish, noted here that the Fish Resources Management Act 1994 does not include regulation for welfare of fish)	- Animal Welfare Act 2002 - Animal Welfare (Scientific Purposes) Regulations 2003	Department of Primary Industries and Regional Development
Heritage Permits Activities within a Protected area or Aboriginal site	Most people passing through or visiting communities on Aboriginal Lands Trust reserves proclaimed under Part III of the Aboriginal Affairs Planning Authority Act 1972 must obtain an Aboriginal Affairs Planning Authority (AAPA) Lands Permit (ALPS) to comply with the Act. Consent is required under Regulation 10(b) of the Aboriginal Heritage Act (1972) to: *dig any hole or otherwise disturb the surface of the ground, or remove or disturb any stone, soil, sand, rock or gravel, or any other natural object;*	- Heritage Act 2018 - Aboriginal Heritage Act 1972 (Effective during Transitional period to Aboriginal Cultural Heritage Act 2021) - Aboriginal Cultural Heritage Act 2021	Department of Planning, Lands and Heritage

Permit	Relevance	Legislation	Responsible Agency
Northern Territory			
A Scientific Permit Application is required to: - take or interfere with wildlife, with the purpose to - watch, collect, survey, measure, assess or monitor wildlife in the wild for scientific research	Required for the take, interference with, or for undertaking scientific research in the NT. Permits required for flora and fauna under the Biological Resources Act 2006 NT Note – an application for a benefit sharing agreement must accompany the Science Permit application.	- Biological Resources Act 2006 Northern Territory - Biological Resources Regulations 2007 Northern Territory	Department of Industry, Tourism and Trade Northern Territory Fisheries (for land access) Parks and Wildlife Commission of the NT (for marine access)
Animal Welfare Authority (NT) licence is required for the use of animals in any kind of research	Required for the use of animals in any form of research. Likely to be required for the taking tissue samples for hydrocarbon analysis from live vertebrates	Animal Protection Act 2018 Animal Welfare Regulations 2020	Department of Industry, Tourism and Trade
Entry to Aboriginal Land requiring a written permit	Access to Aboriginal Land for work purposes, including research activities on Aboriginal Land, requires a permit to be administer by the Northern Land Council	NLC seeks approval from the relevant Traditional Aboriginal owners as required.	Northern Land Council

2.7 Quality Control

Standard Operating Procedures (**SOPs**) for QA/QC, such as ISO 9000, will be applied by SLR and SLB to all relevant components including:

- Training;
- Protocols for the management of positional data;
- Pre-mobilisation, in situ and demobilisation equipment checks;
- Protocols for the download of data and preliminary field QA/QC of data quality;
- Protocols for the calibration/adjustment (e.g. conversion) of raw data in line with accepted scientific methods; and
- Data management protocols and security and data audits.

3 Initiation and termination of the OSMP

Initiation and termination criteria for the OSMP as per the approved EP are defined below.

3.1 Initiation Criteria

Initiation criteria for the Type 1 Operational and Type II Scientific monitoring tasks are shown in Table 5. In the case of a Level 2 spill, AMSA would likely request trajectory modelling indicates that sensitive receptors may be impacted in consultation with AMSA, a Net Environmental Benefits Assessment will be performed to help identify the most appropriate studies to initiate.

Once the extent of the spill and required response effort is understood, SLR and the SLB Project Manager will agree any additional costs, time and resources required to implement the appropriate elements of the OSMP. As soon as possible after notification (but within 12 hours), a teleconference will be held between the SLR and SLB project managers, the responsible program and response managers, the vessel operator and vessel master (or representative if unavailable) to determine requirements for scientific monitoring. The Monitoring Coordinator(s) will then begin coordinating the development of the detailed monitoring plans.

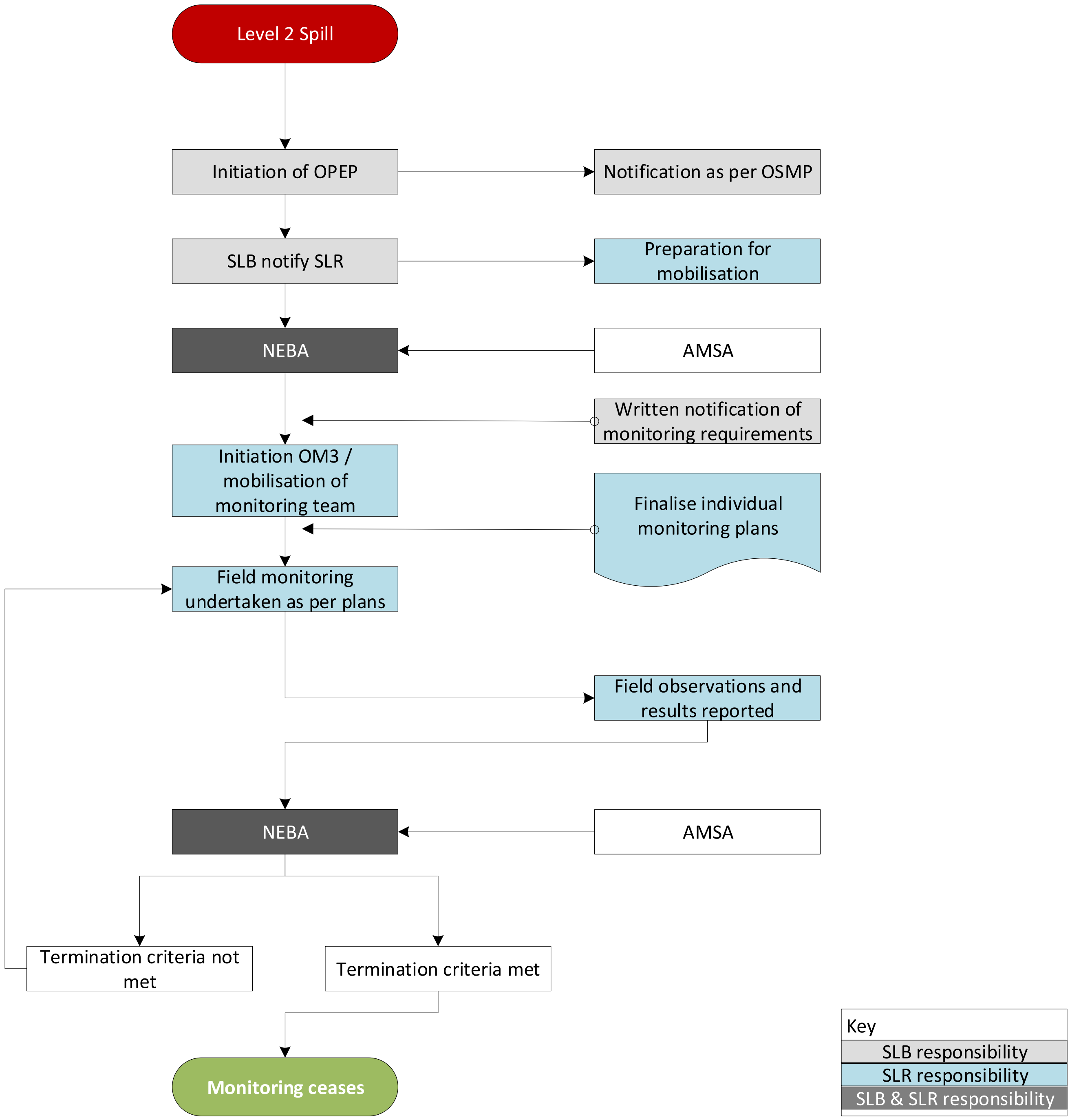
An overview of the response process, through the mobilisation of personnel and equipment is provided in **Figure 2**. Termination criteria and provided in **Section 4** (**Table 6**).

Table 5 Initiation Criteria - Operational and Scientific Monitoring Plan

Plan	Criteria
OM1 - Oil Spill Modelling	Notification of a Level 2 or greater hydrocarbon spill
OM2 – Surveillance and Tracking	Notification of a Level 2 or greater hydrocarbon spill
OM3 - Monitoring of hydrocarbons in seawater	Notification of a Level 2 or greater hydrocarbon spill
SMP1 - Marine water quality	Notification of a Level 2 or greater hydrocarbon spill
SMP2 - Intertidal and shoreline sediment quality	Notification of a Level 2 or greater hydrocarbon spill and Where modelling and/or Operational Monitoring indicates likely exposure to intertidal and/or shoreline sediments or Reports are received of shoreline and/or shoreline contact from hydrocarbon spill
SMP3 - Intertidal and shoreline habitats and benthos	Notification of a Level 2 or greater hydrocarbon spill and Where modelling and/or Operational Monitoring indicates likely exposure to intertidal and/or shoreline habitats or benthos, or Reports are received of shoreline and/or shoreline contact from hydrocarbon spill
SMP4 - Seabirds and shorebirds population and recovery	Notification of a Level 2 or greater hydrocarbon spill and Where modelling and/or Operational Monitoring indicates likely exposure to seabird and/or shorebird populations and/or Reports are received of contact with avifauna from hydrocarbon spill And/or Reports of oiled or dead avifauna are received
SMP5 - Marine fauna (excluding avifauna)	Notification of a Level 2 or greater hydrocarbon spill and Where modelling and/or Operational Monitoring indicates likely exposure to non-avian marine fauna and/or Reports are received of contact with non-avian marine fauna from hydrocarbon spill and/or Reports of oiled or dead non-avian marine fauna are received
SMP6 - Socio economic impact monitoring (fisheries, aquaculture and tourism)	Notification of a Level 2 or greater hydrocarbon spill and Where modelling and/or Operational Monitoring indicates likely exposure to aquaculture operations and/or Reports are received of commercial fisheries closures due to hydrocarbon contamination and/or Reports are received of tourism operation closures due to hydrocarbon contamination.

The initiation criteria (**Table 5**) for each monitoring plan is broadly applied to enact the response described within the EP. However, it is important to note that the final decision to commence each monitoring plan will be based on the net environmental benefit in which the environmental sensitivities should be avoided if the monitoring proposed may reasonably result in further impacts and offer no net benefit.

Figure 3 OSMP Implementation Process



3.2 Termination Criteria

Each monitoring plan that is initiated will continue until certain termination criteria have been met (Table 3), in consultation with the relevant Control Agency (**AMSA**).

Table 6 Termination criteria

Plan	Criteria
OM1 - Surveillance and Tracking	It can be demonstrated that no further environmental improvement outcomes can be achieved through continued implementation of OM1 and/or Notification of termination of spill response phase.
OM2 - Surveillance and Tracking	It can be demonstrated that no further environmental improvement outcomes can be achieved through continued implementation of OM2 and/or Notification of termination of spill response phase.
OM3 - Monitoring of hydrocarbons in seawater	It can be demonstrated that no further environmental improvement outcomes can be achieved through continued implementation of OM3 and/or Notification of termination of spill response phase.
SMP1 - Marine water quality	Hydrocarbon spill has ceased, there are no visible sheens present and no further sheens are predicted by the modelling. Monitoring data of in-water concentrations of hydrocarbons have been compiled and analysed. Reporting on sampling has been completed detailing extent and severity of spilled hydrocarbons which can enable further analysis of impacts on other receptors in any further scientific monitoring plans.
SMP2 - Intertidal and shoreline sediment quality	Hydrocarbon spill has ceased, there are no visible sheens present and no further sheens are predicted by the modelling. Any monitoring done shows concentrations of hydrocarbons present within sediments fall below relevant guidelines (e.g. ANZECC). Reporting on the sampling has been completed detailing the extent and severity of spilled hydrocarbons which can enable further analysis of impacts on benthic communities.
SMP3 - Intertidal and shoreline habitats and benthos	Hydrocarbon spill has ceased, there are no visible sheens present and no further sheens are predicted by the modelling. Impacts from hydrocarbon spill on benthos quantified and recovery evaluated. Reporting on the monitoring has been completed detailing the extent and severity of spilled hydrocarbon impacts on benthos.
SMP4 - Seabirds and shorebirds population and recovery	Hydrocarbon spill has ceased, are no visible sheens present and no further sheens are predicted by the modelling. Objectives and values associated with any relevant species recovery plans and/or conservation advices have been met. Impacts from hydrocarbon spill on avifauna quantified and recovery evaluated. Reporting on the monitoring has been completed detailing the extent and severity of spilled hydrocarbon impacts on avifauna.
SMP5 - Marine fauna (excluding avifauna)	Hydrocarbon spill has ceased, there are no visible sheens present and no further sheens are predicted by the modelling. Objectives and values associated with any relevant species recovery plans and/or conservation advices have been met. Impacts from hydrocarbon spill on marine fauna (excluding avifauna) quantified and recovery evaluated. Reporting on the monitoring has been completed detailing the extent and severity of spilled hydrocarbon impacts on marine fauna (excluding avifauna)
SMP6 - Socio economic impact monitoring (fisheries, aquaculture and tourism)	Hydrocarbon spill has ceased, there are no visible sheens present and no further sheens are predicted by the modelling. Impacts to important commercial fisheries quantified and recovery evaluated. Impacts to seafood quality and secondary impacts on human health evaluated. Impacts on tourism ventures quantified and evaluated. Reporting on the monitoring has been completed detailing the extent and severity of spilled hydrocarbon impacts on commercial fisheries, aquaculture and tourism operations.

4 Development of Detailed Monitoring Plans

Following the initial notification of a spill, a NEBA will be undertaken in consultation with the Control Agency to identify applicable operational and scientific monitoring requirements. Where a net environmental benefit is identified and the Control Agency recommends field monitoring, SLR will develop detailed OSMP plans in accordance with the EP.

Draft detailed monitoring plans will be provided to SLB as soon as practicable, but within 24 hours after receiving the initial notification that monitoring is required.

Detailed monitoring plans will be developed in consultation with the Control Agency and **SLB**. Each plan will include as a minimum:

- Objectives and rationale of the monitoring plan: Each plan developed will outline the key objectives, rationale and focus of the plan.
- Baseline information: It is important for each monitoring plan to specify the details of the baseline to be applied, or a method for selection of suitable reference/control sites. If possible, previous monitoring from published studies and findings is to be utilised.
- Spatial awareness: It is important for any scientific monitoring plan to provide information and outcomes obtained from the operational monitoring (such as real-time spill trajectory modelling) to support the proposed design.
- Methodology: The proposed survey methodology should consider the statistical methods and sampling effort required to achieve the objectives of the scientific monitoring plan. If sampling is proposed as part of the monitoring plan, industry recognised methods for collection and analysis of the samples must be used. This includes utilising accredited laboratories and following best practice guidelines and applicable legislation where applicable. The methodology should include, as a minimum:
  - Details of any permits or approvals required to undertake the work, including whether there are any exemptions;
  - Collection and analysis requirements (i.e. permits);
  - Personnel proposed to undertake the monitoring, including appropriate qualifications and skills;
  - Equipment required to complete the proposed monitoring;
  - HSSE requirements to complete the survey; and
  - QA/QC requirements if appropriate.
- Initiation criteria: The criteria used to initiate the proposed scientific monitoring plan.
- Termination criteria: Each monitoring plan will include a termination date at which time the monitoring can stop which is consistent with the objectives of the monitoring plan. These criteria must be adaptive and be able to change based on the actual circumstances of the impacts and/or risks of assessment.

- Management of change: The monitoring plans must be adaptive to ensure the impacts and risks are managed appropriately. As such, if a monitoring plan is required to change to adapt to these circumstances, then a process for change needs to be detailed so that any revision is provided to SLB and the relevant Control Agency for acceptance as soon as practicable. Any revisions undertaken must be tracked to clearly communicate the current status of the monitoring requirements.
- Reporting: Each monitoring plan is required to detail the reporting of results during and post monitoring. This reporting will include ongoing situation reports during the implementation of monitoring; the timing of these situation reports will be based on the nature and scale of the impacts/risks. Post monitoring, a draft report and third-party peer reviewed report will be provided to SLB, the Control Agency and NOPSEMA which will include any recommendations resulting from the monitoring plan.

5 Activation and Initial Mobilisation

5.1 Immediate Response

1. Following notification of a Level 2 spill by the SLB Project Manager, the SLR Program Manager will confirm availability of scientific personnel and instruct each team member to stand-by.
2. Incident control will be established at the Qube Supply Base, Portland Victoria.
3. Equipment (see **Appendix B**) will be prepared for shipping and laboratories and freight contractors placed 'on-call'. Flights and accommodation will be booked. Vessel operators will be contacted and advised to prepare for mobilisation. The analytical laboratory will prepare and dispatch all sample containers. Security arrangements for sample handling and transport will be confirmed with both laboratory personnel and the courier company.
4. Inductions under the SLR HSE Management System will be conducted prior to any site / field work. Any additional HSE inductions required by SLB will also be completed at this time.

5.2 Mobilisation

5.2.1 Freight

SLB will be responsible for logistical management of freight during the response phase.

Shipping of equipment will be managed by SLR during the scientific monitoring phase, or where otherwise requested by SLB (e.g. to support freight management during periods of exceptionally high demand for logistical support). SLR has an existing national contract with TOLL Group. All freight will be handled by TOLL Express or TOLL Priority and delivered to the point of embarkation. SLR believes that the freight can be ready to ship within 24 hours of being notified. It is estimated that shipping to the offshore departure point would require an additional 24 to 36 hours.

Refrigerated transport will be required for all samples between Portland and the analytical laboratory. Sample transfer is described separately in **Section 5.4**.

5.2.2 Personnel

Personnel mobilised for scientific studies may require accommodation. This will be managed by SLB. Where SLB direct SLR to arrange accommodation (e.g. to support scientific monitoring), the SLR administration team will source and book accommodation as per instructions from SLR Program Manager.

It is anticipated that all personnel will arrive at Portland Victoria, within 24 hours.

5.3 Daily Field Reporting

All field teams will prepare daily reports for transmittal to the SLR Field Operations Coordinator. The Daily Progress Reports (DPRs) will contain the following information:

- Project and scope (OSMP) reference;
- Date;
- Name or person completing report;

- Permit number (if relevant);
- Vessel name/registration number;
- Name and contact details of vessel master (where relevant);
- Location (e.g. nearest geographic location, or closest survey site reference if at sea);
- Work day/shift start time(s) and end time(s);
- Daily HSE statistics and lessons learned;
- Daily weather observations (e.g. wind and sea state);
- Daily events reported with event times;
- Plans for subsequent day(s);
- List of vessel's complement; including names and details (company, role, date mobilised, date demobilised, total days on board) of all vessel crew and survey personnel; and
- Records of loss of equipment and/or down-time related to survey equipment and vessel deployment gear shall be kept allowing office-based support staff to identify if particular equipment is likely to need replacement during the next rotation.

5.4 Sample Transfer and management

Samples collected for laboratory analysis as part of OSMP field operations will be stored and transferred as per the specific instructions provided by the analytical laboratory for each analytical method. Samples will be collated based on holding times, storage requirements and sample type, to maximise sample management and facilitate transfer of samples within holding times.

All samples submitted for analysis will be accompanied by a CoC form, which details the laboratory the samples will be sent to, the analytical methods and the limits of detection required. The CoC form will accompany samples during transport and delivery. The form will be signed with the time and date recorded by each individual responsible for the samples including SLR staff and laboratory personnel. Upon each exchange, the CoC form is countersigned and duplicated by the relinquisher. The recipient retains the original. When samples are received by the laboratory, a duplicate of the original will be issued to SLR confirming arrival. The CoC allows SLR to track the samples and ensure that samples arrive at the intended destinations on schedule.

Where holding times are shorter than the survey rotation period (e.g. seven days for water samples, with up to three weeks between survey personnel rotations), then alternative arrangements will be made to collect samples for transfer to the laboratory). Samples will either be freighted from site/ports to laboratories or accompany survey personnel on return flights for hand-delivery to laboratories. Refrigerated transport will be required for the majority of samples. In the event the refrigerated truck is not available on the day, previous survey experience in Australia has demonstrated that ice-packed eskies will suffice to store and transport samples to the laboratory.

5.5 Data Transfer and Management

During implementation, the Data Manager/Quality Lead will be responsible for finalising the following SOPs:

- Pre-mobilisation, in situ and demobilisation equipment checks;
- Protocols for the download of data and preliminary field QA/QC checks of data quality;
- Protocols for the calibration/adjustment (e.g. conversion) of raw data in line with accepted scientific methods; and
- Data management protocols and security and data audits.

These SOPs will require internal approval (facilitated by the OSMP Program Manager).

Following field-based QA/QC check protocols, data collected in the field will be collated on a survey laptop and backed up on two secure (password-protected) external hard drives. Data will be partitioned on the drive-in folders, as defined in the OSMP metadata requirements. Files will also be re-named in the field in line with metadata requirements, where time allows. Where this is not feasible, a comment to this effect will be included in daily progress reports and this task will then be allocated to office-based support personnel upon receipt of the raw field data.

Where critical to support situational awareness (following pre-approval by the SLB OSMP PM), some data may be transferred via email or cloud storage drive. Most data will be transferred from the field via password-protected external hard drives, which will then be returned with survey personnel during their shift rotation (after a period of up to a maximum of three weeks in the field).

Laboratory data will be received by SLR approximately two weeks following receipt of the samples by the analytical laboratory. SLR will undertake a QA/QC review of laboratory reports and collate relevant data into files for subsequent analysis. Field and laboratory data will be imported into an appropriate database. Relevant data and metadata will be transferred to SLR and/or SLB GIS teams to support situational awareness and for reporting purposes. Data (comprising QA/QC'd field data, laboratory reports, collated data or a high-level summary) will be transferred to SLB in line with the relevant SOP. This may be achieved via the transmission of data files (in an electronic data deliverable format) or through provision of access to an online data portal.

6 Reporting and Closeout

Upon termination and demobilisation of the final active OSMP, the operational and scientific monitoring program finalisation and close-out phase will commence. This phase incorporates:

- Data collation and delivery;
- Analysis and interpretation;
- Final reporting; and
- Archiving.

6.1 Data Collation and Delivery

QA/QC'd data will be compiled in OSMP databases throughout the OSMP response. Data collation includes digital (scanned) copies of all field survey reports, field survey logbooks, CoCs and other records completed by hand.

The Data Manager/Quality Lead will ensure the compiled datasets have been checked against data records to confirm that all data (and metadata) for each scope are accounted for and will confirm details of the QA/QC assessments undertaken on the data. Any remaining data gaps will be identified and addressed, with records generated detailing the outcomes.

Once all digital data (or sets of data) have been compiled and final checks have been completed, databases will either be transferred to SLB via appropriate password-protected storage media, or (where applicable and in line with Corporate data management requirements) transferred via online resources (e.g. secure websites/data portals, cloud services and/or Corporate internet-based file transfer systems).

6.2 Analysis and Interpretation

Final datasets for individual scopes (SMPs) will be analysed to provide interpretation of:

- Impacts of the spill on the values or sensitivities for each plan;
- Potential impacts of spill response activities;
- Recovery over time; and
- Consideration of the potential effects of other natural and anthropogenic impacts.

Statistical analyses of quantitative data will be undertaken using appropriate, commonly-used and scientifically-robust univariate and multivariate statistical analysis techniques. Depending on the size of datasets for each scope, data analyses may be undertaken solely by SLR or in conjunction with a third-party service provider.

6.3 Final Reporting

Reporting will comprise:

- OSMP program status reports;
- Field daily progress reports;
- Health, safety and environment (HSE) reports;
- Technical reports;
- A summary report, collating the outcomes of each OSMP report; and
- A 'lessons learned' report, detailing OSMP challenges, solutions and future recommendations.

6.4 Archiving and Close-out

All digital and paper records, data and reports will be archived in accordance with SLR internal archiving procedures and standards. Completion of the archiving process will be the final requirement of the operational and scientific monitoring program close-out phase. SLB will then be informed that the OSMP response has been completed.

7 References

Calypso Science, 2022. '*Oil spill trajectory modelling arising from a vessel collision in the Bonaparte Basin*'. Report prepared for Schlumberger Australia Pty Ltd.

Oil spill monitoring handbook / editors: Sharon Hook, Graeme Batley, Michael Holloway, Paul Irving and Andrew Ross. CSIRO 2016

APPENDIX A

SLB HSE Policy

Quality, Health, Safety, and Environmental (QHSE) Policy

Schlumberger

The long-term business success of Schlumberger depends on our ability to continually improve the quality of our services and products while protecting people and the environment. Emphasis must be placed on ensuring human health, operational safety, environmental protection, quality enhancement and community goodwill. This commitment is in the best interests of our customers, our employees and contractors, our stockholders and the communities in which we live and work.

Schlumberger requires the active commitment to and accountability for, QHSE from all employees and contractors. Line management has a leadership role in the communication and implementation of, and ensuring compliance with, QHSE policies and standards. We are committed to:

- Protect, and strive for improvement of, the health, safety and security of our people at all times;
- Eliminate Quality non-conformances and HSE accidents;
- Meet specified customer requirements and ensure continuous customer satisfaction;
- Set Quality & HSE performance objectives, measure results, assess and continually improve processes, services and product quality, through the use of an effective management system;
- Plan for, respond to and recover from any emergency, crisis and business disruption;
- Minimize our impact on the environment through pollution prevention, reduction of natural resource consumption and emissions, and the reduction and recycling of waste;
- Apply our technical skills to all HSE aspects in the design and engineering of our services and products;
- Communicate openly with stakeholders and ensure an understanding of our QHSE policies, standards, programs and performance. Reward outstanding QHSE performance;
- Improve our performance on issues relevant to our stakeholders that are of global concern and on which we can have an impact, and share with them our knowledge of successful QHSE programs and initiatives.

This Policy shall be regularly reviewed to ensure ongoing suitability. The commitments listed are in addition to our basic obligation to comply with Schlumberger standards, as well as all applicable laws and regulations where we operate. This is critical to our business success because it allows us to systematically minimize all losses and adds value for all our stakeholders.

Olivier Le Peuch
Chief Executive Officer, Schlumberger Limited

For further information regarding this policy:
CONTACT: Mohamed Kermoud, Vice President HSE
LOCATION: Schlumberger Limited, Houston
EMAIL: Mohamed Kermoud

SLB-QHSE-L001
Released on 5 June 1997
Last update on 9 August 2019

APPENDIX B

Personnel and Equipment Requirements

OMP3: Monitoring of hydrocarbons: weathering and behaviour in marine waters

Table 7 Field survey unit personnel requirements for OMP3

Tile	Role Requirements	Qualifications / experience required
Water Quality Field Lead	Contribution to HSE briefings, pre-start checks, and toolbox talks Management of the technical components of field operations Pre-start assessment of potential sources of contamination Daily sampling plans (with Party Chief and vessel master, where appropriate) QA/QC of sampling methods QA/QC of field sampling logs Management of sample integrity and storage Health and safety during field operations Supervision of field scientists/technicians In-field management and QA/QC of data Preparation and QA/QC of Chain of Custody (CoC) documents Preparation of samples for transport	Qualifications: Bachelor's degree in relevant subject (as a minimum), plus: - TBOSIET - medical (UKOG or acceptable alternative) - MSIC Optional: Senior First Aid Experience: At least five years' offshore and coastal WQ and water column profiling experience in both field scientist and field lead role, preferably with the use of fluorimeters in the field. Previous experience of intertidal field surveys.
Water Quality Field Scientist/ Technician	Mobilisation and de-mob of field equipment Active engagement at HSE briefings, pre-start checks, and toolbox talks Undertaking technical scopes of OMP3 operations Take personal responsibility for management of contamination risks, safety, sampling, sample integrity and field logs Supporting the Water Quality Field Lead Setting up and deployment of sampling equipment Collecting and labelling samples Sample storage Downloading field data Securing field sampling equipment during vessel transits	Qualifications: Bachelor's degree in relevant subject (as a minimum), plus: - TBOSIET - medical (UKOG or acceptable alternative) - MSIC Optional: Senior First Aid Experience: Offshore and coastal WQ and water column profiling experience.

Table 8 Core equipment requirements for OMP3 with recommendations for different sampling environments

Sampling Environment	Equipment Requirements
General (all survey areas)	- Spares kits for survey equipment and technologies - Tool kits, including spanners, shifting spanners (large and small), socket sets, wire cutters/snips, pliers (needle-nosed and standard), Allen key sets (imperial and metric), screwdrivers (Phillips, flat head and screwdriver watch repair kits), Stanley knives and spare blades, tape measures (up to 30 m+), silicone grease, superglue, neoprene glue, duct tape, electrical tape, packaging tape, hose clamps (Jubilee clips) and cable ties (various sizes) - Sample containers, appropriate to samples - Thin foam/bubble wrap sample jar pockets - Aluminium foil - Laptop computer and backup (with appropriate software) - UPS unit plus spare - Hand-held GPS plus spare unit - Nitrile gloves - Decontamination cleaning product (e.g. Decon 90, or dichloromethane for cleaning of the slick sampler fishing pole) - Eskies with ice blocks (frozen) - Consumables (e.g. batteries)
Offshore (e.g. Commonwealth waters)	Mandatory - Survey navigation software plus GPS unit/vessel GPS access and/or handheld GPS plus spare - 3 × bomb samplers and/or Niskin Bottles (plus 2 spares and 2 extra spare messenger weights) - \WQ profiler with self-recording polycyclic aromatic hydrocarbon fluorimeter, pH meter, and conductivity/ temperature/depth (CTD) sensors - GO nets (pre-cleaned or new pre-packaged nets) - AGI slick samplers with fishing pole, line and disposable floats (which will be discarded after every sampling attempt) - Wide-mouth amber glass jars with Teflon-lined lid (min. 350 ml) for sampling - surface hydrocarbons and for GO nets - 2 × extendable sampling pole/boat hooks Optional (additions to the water quality (WQ) profiler): - turbidity logger - particle analyser - coloured dissolved organic matter (CDOM) fluorimeter - chlorophyll fluorimeter - dissolved oxygen (DO) sensor - Wave glider(s)** with: hydrocarbon fluorimeter - CTD sensor - DO sensor weather station current profiler

Sampling Environment	Equipment Requirements
Coastal (e.g. State waters to ≤100 m water depth)	- Survey navigation software plus GPS unit/vessel GPS access and/or handheld - GPS plus spare - 3 × bomb samplers, Niskin Bottles and/or van Dorn water samplers (plus 2 spares and 2 extra spare messenger weights) - WQ profiler with self-recording polycyclic aromatic hydrocarbon fluorimeter, pH meter, and conductivity/ temperature/depth (CTD) sensors - GO nets (pre-cleaned or new pre-packaged nets) - AGI slick samplers with fishing pole, line and disposable floats (which will be discarded after every sampling attempt) - Wide-mouth amber glass jars with Teflon-lined lid (min. 350ml) for sampling surface hydrocarbons and for GO nets - 2× extendable sampling pole/boat hooks Optional: - Additions to the WQ profiler: - turbidity logger - particle analyser - coloured dissolved organic matter (CDOM) fluorimeter - chlorophyll fluorimeter - dissolved oxygen (DO) sensor
Intertidal zone (e.g. shorelines)	- Wide-mouth amber glass jars with Teflon-lined lid (min. 350 ml - 2 × extendable sampling pole/boat hooks - Booms and absorbent pads

Table 9 Core OMP3 logistical requirements

Component	Requirement
OSMP equipment logistics	OSMP mobilisation will require consideration of the process of supply of equipment and mobilisation of survey equipment consignments to each survey unit. Each survey unit will have specific equipment needs, which will be sourced from a range of suppliers/service providers. Batches of bulk-ordered items will need to be broken down and split into survey team consignments (based on pre-prepared equipment lists). This will require organisation of personnel and suitable location(s). Single-order items may be shipped directly to survey deployment locations (e.g. ports) where possible.
Core field survey team	Intertidal surveys: - 2 technical personnel (Field Lead and Field Technician) - Vessel-based surveys: - 2 technical personnel (Field Lead and Field Technician) - 1 operational personnel (Party Chief)

Component	Requirement
Survey platform requirements	Vehicles for intertidal surveys: - 4WD off-road vehicles (preferably mine-rated) - Off-road trailers for shelter and sample transport - Quad bikes may be appropriate in some areas Vessel specifications: - Sufficient deck space for sampling - Covered area of deck for shelter from the elements - Sample storage space (refrigerated) - Access at stern or via gunwale for deployment of sampling equipment - Hi-Ab, crane and/or A-frame (suitably rated) - Winches with sufficient winch wire (rated to a minimum of 2T) - Winch with sufficient Dyneema - Deckhands with appropriate certifications - Deck hoses (freshwater and seawater) - Dynamic positioning systems (DPS) preferable (critical in offshore deep-water environments) - Indoor table access with direct access to work deck - Access to bridge (for Party Chief) - GPS access/outputs - Sufficient bunking space for vessel crew and field survey teams - Sufficient crew to allow 24-hour operations where appropriate - Potential for dual deployments (in offshore environments) - Potential requirement for tender vessel (small, shallow-draft vessel) for shallow water sampling
Sample transfer requirements	Vessel-based surveys are likely to require regular pick-up of samples to enable shipment and analysis within holding times.
Data management	2 × 2 TB external hard drives with password protection to allow transfer of data with returning field personnel

SMP1: Assessment of Water Quality

Table 10 Field survey unit personnel requirements for SMP1

Tile	Role Requirements	Qualifications / experience required
Water Quality Field Lead	Contribution to HSE briefings, pre-start checks, and toolbox talks Management of the technical components of field operations Pre-start assessment of potential sources of contamination Daily sampling plans (with Party Chief and vessel master, where appropriate) QA/QC of sampling methods QA/QC of field sampling logs Management of sample integrity and storage Health and safety during field operations Supervision of field scientists/technicians In-field management and QA/QC of data Preparation and QA/QC of Chain of Custody (CoC) documents Preparation of samples for transport	Qualifications: Bachelor's degree in relevant subject (as a minimum), plus: - TBOSIET - medical (UKOG or acceptable alternative) - MSIC Optional: Senior First Aid Experience: At least five years' offshore and coastal WQ and water column profiling experience in both field scientist and field lead role, preferably with the use of fluorimeters in the field. Previous experience of intertidal field surveys.

Tile	Role Requirements	Qualifications / experience required
Water Quality Field Scientist/ Technician	Mobilisation and de-mob of field equipment Active engagement at HSE briefings, pre-start checks, and toolbox talks Undertaking technical scopes of OMP3 operations Take personal responsibility for management of contamination risks, safety, sampling, sample integrity and field logs Supporting the Water Quality Field Lead Setting up and deployment of sampling equipment Collecting and labelling samples Sample storage Downloading field data Securing field sampling equipment during vessel transits	Qualifications: Bachelor's degree in relevant subject (as a minimum), plus: - TBOSIET - medical (UKOG or acceptable alternative) - MSIC Optional: Senior First Aid Experience: Offshore and coastal WQ and water column profiling experience.

Table 11 Core Equipment Requirements for SMP1

Sampling Environment	Equipment Requirements
General (all survey areas)	- Spares kits for survey equipment and technologies - Tool kits, including spanners, shifting spanners (large and small), socket sets, wire cutters/snips, pliers (needle-nosed and standard), Allen key sets (imperial and metric), screwdrivers (Phillips, flat head and screwdriver watch repair kits), Stanley knives and spare blades, tape measures (up to 30 m+), silicone grease, superglue, neoprene glue, duct tape, electrical tape, packaging tape, hose clamps (Jubilee clips) and cable ties (various sizes) - Sample containers, appropriate to samples - Thin foam/bubble wrap sample jar pockets - Aluminium foil - Laptop computer and backup (with appropriate software) - UPS unit plus spare - Hand-held GPS plus spare unit - Nitrile gloves - Decontamination cleaning product (e.g. Decon 90, or dichloromethane for cleaning of the slick sampler fishing pole) - Eskies with ice blocks (frozen) - Consumables (e.g. batteries)

Sampling Environment	Equipment Requirements
Offshore (e.g. Commonwealth waters)	Mandatory - Survey navigation software plus GPS unit/vessel GPS access and/or handheld GPS plus spare - 3 × bomb samplers and/or Niskin Bottles (plus 2 spares and 2 extra spare messenger weights) - \WQ profiler with self-recording polycyclic aromatic hydrocarbon fluorimeter, pH meter, and conductivity/ temperature/depth (CTD) sensors - GO nets (pre-cleaned or new pre-packaged nets) - AGI slick samplers with fishing pole, line and disposable floats (which will be discarded after every sampling attempt) - Wide-mouth amber glass jars with Teflon-lined lid (min. 350 ml) for sampling - surface hydrocarbons and for GO nets - 2 × extendable sampling pole/boat hooks Optional (additions to the water quality (WQ) profiler): - turbidity logger - particle analyser - coloured dissolved organic matter (CDOM) fluorimeter - chlorophyll fluorimeter - dissolved oxygen (DO) sensor - Wave glider(s)** with: hydrocarbon fluorimeter - CTD sensor - DO sensor weather station current profiler
Coastal (e.g. State waters to ≤100 m water depth)	- Survey navigation software plus GPS unit/vessel GPS access and/or handheld - GPS plus spare - 3 × bomb samplers, Niskin Bottles and/or van Dorn water samplers (plus 2 spares and 2 extra spare messenger weights) - WQ profiler with self-recording polycyclic aromatic hydrocarbon fluorimeter, pH meter, and conductivity/ temperature/depth (CTD) sensors - GO nets (pre-cleaned or new pre-packaged nets) - AGI slick samplers with fishing pole, line and disposable floats (which will be discarded after every sampling attempt) - Wide-mouth amber glass jars with Teflon-lined lid (min. 350ml) for sampling surface hydrocarbons and for GO nets - 2× extendable sampling pole/boat hooks Optional: - Additions to the WQ profiler: - turbidity logger - particle analyser - coloured dissolved organic matter (CDOM) fluorimeter - chlorophyll fluorimeter - dissolved oxygen (DO) sensor
Intertidal zone (e.g. shorelines)	- Wide-mouth amber glass jars with Teflon-lined lid (min. 350 ml - 2 × extendable sampling pole/boat hooks - Booms and absorbent pads

Table 12 Core SMP1 Logistical Requirements

Component	Requirement
OSMP equipment logistics	OSMP mobilisation will require consideration of the process of supply of equipment and mobilisation of survey equipment consignments to each survey unit. Each survey unit will have specific equipment needs, which will be sourced from a range of suppliers/service providers. Batches of bulk-ordered items will need to be broken down and split into survey team consignments (based on pre-prepared equipment lists). This will require organisation of personnel and suitable location(s). Single-order items may be shipped directly to survey deployment locations (e.g. ports) where possible.
Core field survey team	Intertidal surveys: - 2 technical personnel (Field Lead and Field Technician) - Vessel-based surveys: - 2 technical personnel (Field Lead and Field Technician) - 1 operational personnel (Party Chief)
Survey platform requirements	Vehicles for intertidal surveys: - 4WD off-road vehicles (preferably mine-rated) - Off-road trailers for shelter and sample transport - Quad bikes may be appropriate in some areas Vessel specifications: - Sufficient deck space for sampling - Covered area of deck for shelter from the elements - Sample storage space (refrigerated) - Access at stern or via gunwale for deployment of sampling equipment - Hi-Ab, crane and/or A-frame (suitably rated) - Winches with sufficient winch wire (rated to a minimum of 2T) - Winch with sufficient Dyneema - Deckhands with appropriate certifications - Deck hoses (freshwater and seawater) - Dynamic positioning systems (DPS) preferable (critical in offshore deep-water environments) - Indoor table access with direct access to work deck - Access to bridge (for Party Chief) - GPS access/outputs - Sufficient bunking space for vessel crew and field survey teams - Sufficient crew to allow 24-hour operations where appropriate - Potential for dual deployments (in offshore environments) - Potential requirement for tender vessel (small, shallow-draft vessel) for shallow water sampling
Sample transfer requirements	Vessel-based surveys are likely to require regular pick-up of samples to enable shipment and analysis within holding times.
Data management	2 × 2 TB external hard drives with password protection to allow transfer of data with returning field personnel

ASIA PACIFIC OFFICES

ADELAIDE
60 Halifax Street
Adelaide SA 5000
Australia
T: +61 431 516 449

BRISBANE
Level 16, 175 Eagle Street
Brisbane QLD 4000
Australia
T: +61 7 3858 4800
F: +61 7 3858 4801

CAIRNS
Level 1 Suite 1.06
Boland's Centre
14 Spence Street
Cairns QLD 4870
Australia
T: +61 7 4722 8090

CANBERRA
GPO 410
Canberra ACT 2600
Australia
T: +61 2 6287 0800
F: +61 2 9427 8200

DARWIN
Unit 5, 21 Parap Road
Parap NT 0820
Australia
T: +61 8 8998 0100
F: +61 8 9370 0101

GOLD COAST
Level 2, 194 Varsity Parade
Varsity Lakes QLD 4227
Australia
M: +61 438 763 516

MACKAY
21 River Street
Mackay QLD 4740
Australia
T: +61 7 3181 3300

MELBOURNE
Level 11, 176 Wellington Parade
East Melbourne VIC 3002
Australia
T: +61 3 9249 9400
F: +61 3 9249 9499

NEWCASTLE CBD
Suite 2B, 125 Bull Street
Newcastle West NSW 2302
Australia
T: +61 2 4940 0442

NEWCASTLE
10 Kings Road
New Lambton NSW 2305
Australia
T: +61 2 4037 3200
F: +61 2 4037 3201

PERTH
Grd Floor, 503 Murray Street
Perth WA 6000
Australia
T: +61 8 9422 5900
F: +61 8 9422 5901

SYDNEY
Tenancy 202 Submarine School
Sub Base Platypus
120 High Street
North Sydney NSW 2060
Australia
T: +61 2 9427 8100
F: +61 2 9427 8200

TOWNSVILLE
12 Cannan Street
South Townsville QLD 4810
Australia
T: +61 7 4722 8000
F: +61 7 4722 8001

WOLLONGONG
Level 1, The Central Building
UoW Innovation Campus
North Wollongong NSW 2500
Australia
T: +61 2 4249 1000

AUCKLAND
Level 4, 12 O'Connell Street
Auckland 1010
New Zealand
T: 0800 757 695

NELSON
6/A Cambridge Street
Richmond, Nelson 7020
New Zealand
T: +64 274 898 628

WELLINGTON
12A Waterloo Quay
Wellington 6011
New Zealand
T: +64 2181 7186

SINGAPORE
39b Craig Road
Singapore 089677
T: +65 6822 2203