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APPENDIX A: PILOT ENERGY PTY LTD ENVIRONMENTAL POLICY

Pilot Energy Limited

ABN: 86 115229 984

ENVIRONMENTAL & SOCIAL SUSTAINABILITY STATEMENT

The Company is an oil and gas exploration and production company that is pursuing the diversification and transition to the development of integrated renewable energy, hydrogen and carbon management projects by leveraging its existing oil and gas tenements and infrastructure to cornerstone these developments.

Pilot strongly believes that the integration of environmental sustainability considerations in our daily business decisions and strategies will make us a more resilient and agile business in the long term, improving our performance and motivating our people. The Company recognises our responsibility to minimise the impact of our operations on the environment and to participate in the transition towards net zero emissions by 2050.

In order to participate in the transition, we are undertaking a range of feasibility assessments related to renewable energy, hydrogen and carbon capture and storage. Subject to these studies, Pilot sees its future business growth in the areas of renewable energy, hydrogen production and carbon capture and storage. In the meantime, the Company is committed to reducing its Scope 1 and 2 GHG emissions through energy efficiency efforts, finding alternative sustainable energy sources, production processes and technology improvements.

The Company has identified, and manages, the Company's environmental, social and governance risks to which it has material exposure, and the Board is responsible for managing those risks in a manner consistent with the Company's Risk Management Policy which is available in the Corporate Governance section of the Company's website here.

In addition, the Company has an Audit and Risk Committee, which is responsible for the review, implementing and managing the Company's risk management program. This Committee ensures that areas of risk (contemporary and emerging) are, and have been, identified and that the appropriate internal controls are being implemented and are operating efficiently in all material respects.

The Board will continue to review Pilot's environmental and social sustainability and associated risk management framework to satisfy itself that it continues to be sound; that Pilot's practices and procedures align; to determine whether there have been any material changes in the business risks the Company faces; and to ensure that the Company is operating within the risk appetite of the Board. Additionally, the Board will continue to evaluate, and seek to improve (as appropriate), Pilot's environmental and internal risk management and control processes by relying on the ongoing reporting obligations of the Company and discussions of the management regarding material environmental and social risks.

October 2021

APPENDIX B: PROTECTED MATTERS SEARCH TOOL REPORTS

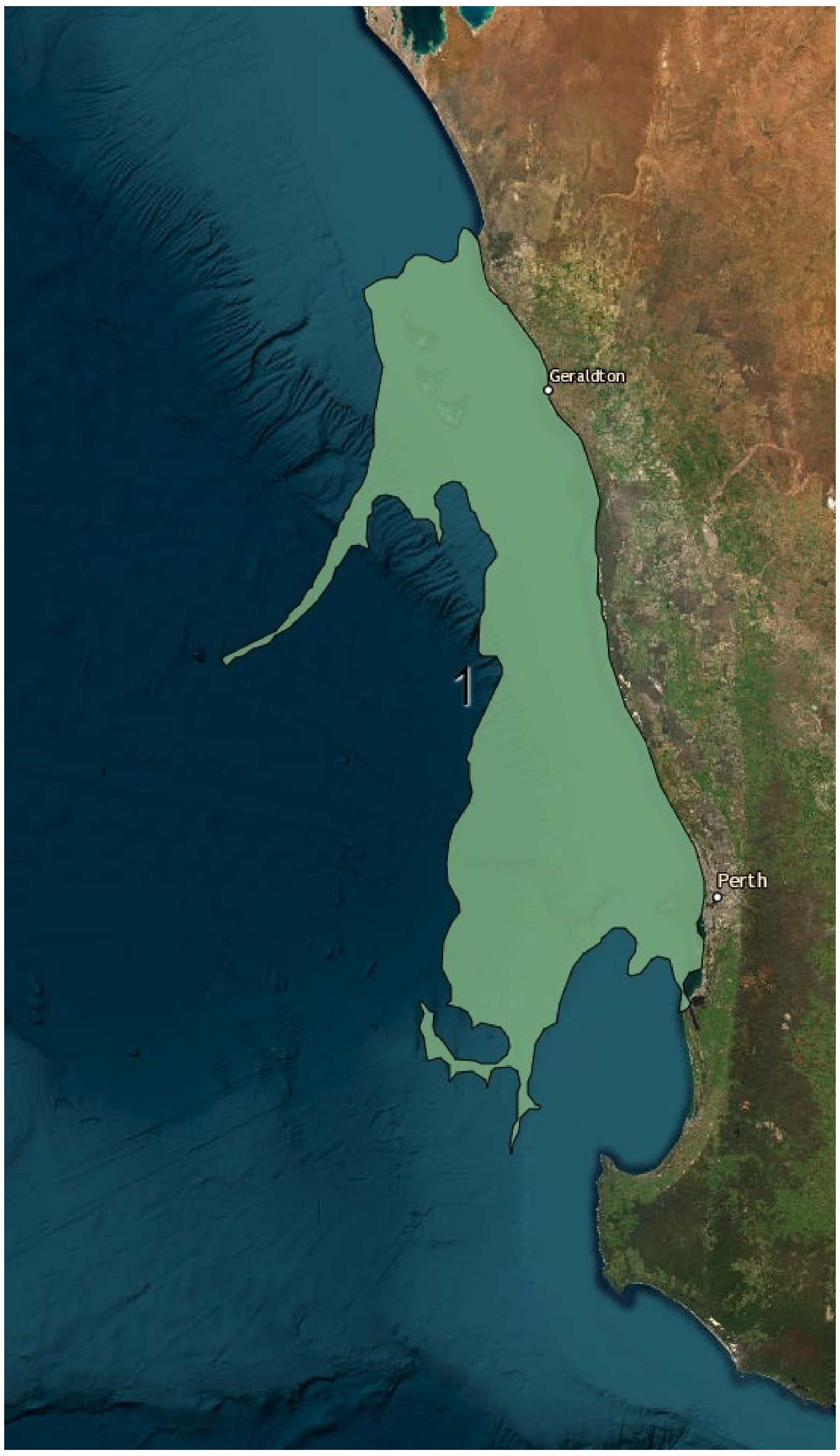
Australian Government

Department of Climate Change, Energy, the Environment and Water

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: 02-Oct-2024



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:	1
National Heritage Places:	3
Wetlands of International Importance (Ramsar	3
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	3
Listed Threatened Ecological Communities:	8
Listed Threatened Species:	109
Listed Migratory Species:	85

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/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:	329
Commonwealth Heritage Places:	6
Listed Marine Species:	120
Whales and Other Cetaceans:	37
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	17
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:	55
Regional Forest Agreements:	None
Nationally Important Wetlands:	7
EPBC Act Referrals:	165
Key Ecological Features (Marine):	7
Biologically Important Areas:	31
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Legal Status
Australian Convict Sites (Fremantle Prison)	WA	Declared property

National Heritage Places [Resource Information]

Name	State	Legal Status
Historic		
Batavia Shipwreck Site and Survivor Camps Area 1629 - Houtman Abrolhos	WA	Listed place
Fremantle Prison (former)	WA	Listed place
Natural		
Lesueur National Park	WA	Listed place

Wetlands of International Importance (Ramsar Wetlands) [Resource Information]

Ramsar Site Name	Proximity
Becher point wetlands	Within Ramsar site
Forrestdale and thomsons lakes	Within 10km of Ramsar site
Peel-yalgorup system	Within Ramsar site

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside 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
Commonwealth Marine Areas (EPBC Act)
Commonwealth Marine Areas (EPBC Act)
Commonwealth Marine Areas (EPBC Act)

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.
Status of Vulnerable, Disallowed and Ineligible are not MNES under the EPBC Act.

Community Name	Threatened Category	Presence Text
Aquatic Root Mat Community in Caves of the Swan Coastal Plain	Endangered	Community known to occur within area

Community Name	Threatened Category	Presence Text
Banksia Woodlands of the Swan Coastal Plain ecological community	Endangered	Community likely to occur within area
Empodisma peatlands of southwestern Australia	Endangered	Community may occur within area
Honeymyrtle shrubland on limestone ridges of the Swan Coastal Plain Bioregion	Critically Endangered	Community likely to occur within area
Sedgelands in Holocene dune swales of the southern Swan Coastal Plain	Endangered	Community known to occur within area
Subtropical and Temperate Coastal Saltmarsh	Vulnerable	Community likely to occur within area
Thrombolite (microbial) community of coastal freshwater lakes of the Swan Coastal Plain (Lake Richmond)	Endangered	Community known to occur within area
Tuart (Eucalyptus gomphocephala) Woodlands and Forests of the Swan Coastal Plain ecological community	Critically Endangered	Community likely to occur within area

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
Aphelocephala leucopsis Southern Whiteface [529]	Vulnerable	Species or species habitat known to occur within area
Ardenna grisea Sooty Shearwater [82651]	Vulnerable	Species or species habitat may occur within area
Arenaria interpres Ruddy Turnstone [872]	Vulnerable	Roosting known to occur within area
Botaurus poiciloptilus Australasian Bittern [1001]	Endangered	Species or species habitat known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris canutus Red Knot, Knot [855]	Vulnerable	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Vulnerable	Roosting known to occur within area
Calyptorhynchus banksii naso Forest Red-tailed Black-Cockatoo, Karrak [67034]	Vulnerable	Species or species habitat known 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	Roosting known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea dabbenena Tristan Albatross [66471]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat likely to occur within area
Halobaena caerulea Blue Petrel [1059]	Vulnerable	Species or species habitat may occur within area
Leipoa ocellata Malleefowl [934]	Vulnerable	Species or species habitat likely to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Endangered	Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]	Endangered	Roosting known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pachyptila turtur subantarctica Fairy Prion (southern) [64445]	Vulnerable	Species or species habitat known to occur within area
Phaethon rubricauda westralis Red-tailed Tropicbird (Indian Ocean), Indian Ocean Red-tailed Tropicbird [91824]	Endangered	Species or species habitat known to occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Pluvialis squatarola Grey Plover [865]	Vulnerable	Roosting known to occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat likely to occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Tringa nebularia Common Greenshank, Greenshank [832]	Endangered	Species or species habitat known to occur within area
Turnix varius scintillans Painted Button-quail (Houtman Abrolhos) [82451]	Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Xenus cinereus		
Terek Sandpiper [59300]	Vulnerable	Roosting known to occur within area
Zanda baudinii listed as Calyptorhynchus baudinii		
Baudin's Cockatoo, Baudin's Black-Cockatoo, Long-billed Black-cockatoo [87736]	Endangered	Species or species habitat known to occur within area
Zanda latirostris listed as Calyptorhynchus latirostris		
Carnaby's Black Cockatoo, Short-billed Black-cockatoo [87737]	Endangered	Breeding known to occur within area
FISH		
Hoplostethus atlanticus		
Orange Roughy, Deep-sea Perch, Red Roughy [68455]	Conservation Dependent	Species or species habitat likely to occur within area
Nannatherina balstoni		
Balston's Pygmy Perch [66698]	Vulnerable	Species or species habitat likely to occur within area
INSECT		
Hesperocolletes douglasi		
Douglas' Broad-headed Bee, Rottnest Bee [66734]	Critically Endangered	Species or species habitat may occur within area
MAMMAL		
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Foraging, feeding or related behaviour known to occur within area
Balaenoptera physalus		
Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Bettongia penicillata ogilbyi		
Woylie [66844]	Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Dasyurus geoffroii Chuditch, Western Quoll [330]	Vulnerable	Species or species habitat known to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Breeding known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat known to occur within area
Neophoca cinerea Australian Sea-lion, Australian Sea Lion [22]	Endangered	Breeding known to occur within area
Parantechinus apicalis Dibbler [313]	Endangered	Species or species habitat known to occur within area
Petrogale lateralis lateralis Black-flanked Rock-wallaby, Moororong, Black-footed Rock Wallaby [66647]	Endangered	Species or species habitat known to occur within area
Pseudocheirus occidentalis Western Ringtail Possum, Ngwayir, Womp, Woder, Ngoor, Ngoolangit [25911]	Critically Endangered	Species or species habitat known to occur within area
Setonix brachyurus Quokka [229]	Vulnerable	Species or species habitat known to occur within area
PLANT		
Andersonia gracilis Slender Andersonia [14470]	Endangered	Species or species habitat likely to occur within area
Androcalva bivillosa Straggling Androcalva [87807]	Critically Endangered	Species or species habitat likely to occur within area
Anigozanthos viridis subsp. terraspectans Dwarf Green Kangaroo Paw [3435]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Banksia mimica Summer Honeypot [82765]	Endangered	Species or species habitat may occur within area
Beyeria lepidopetala Small-petalled Beyeria, Short-petalled Beyeria [18362]	Endangered	Species or species habitat likely to occur within area
Caladenia barbarella Small Dragon Orchid, Common Dragon Orchid [68686]	Endangered	Species or species habitat may occur within area
Caladenia bryceana subsp. cracens Northern Dwarf Spider-orchid [64556]	Vulnerable	Species or species habitat known to occur within area
Caladenia elegans Elegant Spider-orchid [56775]	Endangered	Species or species habitat known to occur within area
Caladenia hoffmanii Hoffman's Spider-orchid [56719]	Endangered	Species or species habitat known to occur within area
Caladenia huegelii King Spider-orchid, Grand Spider-orchid, Rusty Spider-orchid [7309]	Endangered	Species or species habitat likely to occur within area
Caleana dixonii listed as Paracaleana dixonii Sandplain Duck Orchid [87944]	Endangered	Species or species habitat may occur within area
Chorizema humile Prostrate Flame Pea [32573]	Endangered	Species or species habitat may occur within area
Chorizema varium Limestone Pea [16981]	Endangered	Species or species habitat known to occur within area
Conostylis dielsii subsp. teres Irwin's Conostylis [3614]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Conostylis micrantha Small-flowered Conostylis [17635]	Endangered	Species or species habitat may occur within area
Diuris drummondii Tall Donkey Orchid [4365]	Vulnerable	Species or species habitat likely to occur within area
Diuris micrantha Dwarf Bee-orchid [55082]	Vulnerable	Species or species habitat known to occur within area
Diuris purdiei Purdie's Donkey-orchid [12950]	Endangered	Species or species habitat may occur within area
Drakaea concolor Kneeling Hammer-orchid [56777]	Vulnerable	Species or species habitat likely to occur within area
Drakaea elastica Glossy-leafed Hammer Orchid, Glossy-leaved Hammer Orchid, Warty Hammer Orchid [16753]	Endangered	Species or species habitat likely to occur within area
Drakaea micrantha Dwarf Hammer-orchid [56755]	Vulnerable	Species or species habitat likely to occur within area
Drummondita ericoides Morseby Range Drummondita [9193]	Endangered	Species or species habitat known to occur within area
Eleocharis keigheryi Keighery's Eleocharis [64893]	Vulnerable	Species or species habitat may occur within area
Eucalyptus argutifolia Yanchep Mallee, Wabling Hill Mallee [24263]	Vulnerable	Species or species habitat known to occur within area
Eucalyptus cuprea Mallee Box [56773]	Endangered	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Grevillea batrachioides Mt Lesueur Grevillea [21735]	Endangered	Species or species habitat may occur within area
Grevillea humifusa Spreading Grevillea [61182]	Endangered	Species or species habitat may occur within area
Hemiandra gardneri Red Snakebush [7945]	Endangered	Species or species habitat likely to occur within area
Leucopogon marginatus Thick-margined Leucopogon [12527]	Endangered	Species or species habitat likely to occur within area
Leucopogon obtectus Hidden Beard-heath [19614]	Endangered	Species or species habitat may occur within area
Macarthuria keigheryi Keighery's Macarthuria [64930]	Endangered	Species or species habitat may occur within area
Marianthus paralius [83925]	Endangered	Species or species habitat known to occur within area
Pterostylis sinuata Northampton Midget Greenhood, Western Swan Greenhood [84991]	Endangered	Species or species habitat known to occur within area
Stachystemon nematophorus Three-flowered Stachystemon [81447]	Vulnerable	Species or species habitat likely to occur within area
Tetratheca nephelioides [83217]	Critically Endangered	Species or species habitat may occur within area
Thelymitra stellata Star Sun-orchid [7060]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Wurmbea tubulosa		
Long-flowered Nancy [12739]	Endangered	Species or species habitat known to occur within area
REPTILE		
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
Ctenotus lancelini		
Lancelin Island Skink [1482]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Egernia stokesii badia		
Western Spiny-tailed Skink, Baudin Island Spiny-tailed Skink [64483]	Endangered	Species or species habitat may occur within area
Liopholis pulchra longicauda		
Jurien Bay Skink, Jurien Bay Rock-skink [83162]	Vulnerable	Species or species habitat known to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
SHARK		
Carcharias taurus (west coast population)		
Grey Nurse Shark (west coast population) [68752]	Vulnerable	Congregation or aggregation known to occur within area
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Centrophorus uyato		
Little Gulper Shark [68446]	Conservation Dependent	Species or species habitat likely to occur within area
Galeorhinus galeus		
School Shark, Eastern School Shark, Snapper Shark, Tope, Soupfin Shark [68453]	Conservation Dependent	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
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sphyrna lewini		
Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat known to occur within area
SPIDER		
Idiosoma nigrum		
Shield-backed Trapdoor Spider, Black Rugose Trapdoor Spider [66798]	Vulnerable	Species or species habitat may 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 likely to occur within area
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna carneipes		
Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Foraging, feeding or related behaviour likely to occur within area
Ardenna grisea		
Sooty Shearwater [82651]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea dabbenena Tristan Albatross [66471]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Species or species habitat may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat may occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons Little Tern [82849]		Species or species habitat may occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat likely to occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Migratory Marine Species		
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Foraging, feeding or related behaviour known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Caperea marginata Pygmy Right Whale [39]		Foraging, feeding or related behaviour likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat likely to occur within area
Carcharias taurus Grey Nurse Shark [64469]		Congregation or aggregation known to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Eubalaena australis as Balaena glacialis australis		
Southern Right Whale [40]	Endangered	Breeding known to occur within area
Isurus oxyrinchus		
Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus		
Longfin Mako [82947]		Species or species habitat likely to occur within area
Lagenorhynchus obscurus		
Dusky Dolphin [43]		Species or species habitat likely to occur within area
Lamna nasus		
Porbeagle, Mackerel Shark [83288]		Species or species habitat may occur within area
Megaptera novaeangliae		
Humpback Whale [38]		Congregation or aggregation 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
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]		Foraging, feeding or related behaviour known to 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
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Migratory Terrestrial Species		
Motacilla cinerea		
Grey Wagtail [642]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres		
Ruddy Turnstone [872]	Vulnerable	Roosting known to occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]	Vulnerable	Roosting known to occur within area
Calidris alba		
Sanderling [875]		Roosting known to occur within area
Calidris canutus		
Red Knot, Knot [855]	Vulnerable	Species or species habitat known to occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos		
Pectoral Sandpiper [858]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris pugnax as Philomachus pugnax Ruff [91256]		Roosting known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris subminuta Long-toed Stint [861]		Roosting known to occur within area
Calidris tenuirostris Great Knot [862]	Vulnerable	Roosting known to occur within area
Charadrius bicinctus Double-banded Plover [895]		Roosting known 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	Roosting known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]	Endangered	Roosting known 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 minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Roosting known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]	Vulnerable	Roosting known to occur within area
Thalasseus bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]	Endangered	Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Xenus cinereus		
Terek Sandpiper [59300]	Vulnerable	Roosting known 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 - ARTILLERY BARRACKS - FREMANTLE [50155]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50184]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50185]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50186]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50187]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50182]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50181]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50183]	WA
Defence - GERALDTON TRAINING DEPOT "A" Company 16th Battalion [50197]	WA
Defence - GERALDTON TRAINING DEPOT "A" Company 16th Battalion [50196]	WA
Defence - GERALDTON TRAINING DEPOT "A" Company 16th Battalion [50195]	WA
Defence - GREENOUGH RIFLE RANGE [50234]	WA
Defence - HMAS STIRLING-ROCKINGHAM ;HMAS STIRLING - GARDEN ISLAND [50134]	WA
Defence - HMAS STIRLING-ROCKINGHAM ;HMAS STIRLING - GARDEN ISLAND [50133]	WA
Defence - HMAS STIRLING-ROCKINGHAM ;HMAS STIRLING - GARDEN ISLAND [50117]	WA

Commonwealth Land Name	State
Defence - HMAS STIRLING-ROCKINGHAM ;HMAS STIRLING - GARDEN ISLAND [50131]	WA
Defence - HMAS STIRLING-ROCKINGHAM ;HMAS STIRLING - GARDEN ISLAND [50132]	WA
Defence - IRWIN BARRACKS - KARRAKATTA [50175]	WA
Defence - LANCELIN TRAINING AREA [50121]	WA
Defence - LANCELIN TRAINING AREA [50120]	WA
Defence - ROCKINGHAM - NAVY CPSO [50135]	WA
Defence - SWANBOURNE RIFLE RANGE [50188]	WA
Defence - SWANBOURNE RIFLE RANGE [50190]	WA
Defence - SWANBOURNE RIFLE RANGE [50191]	WA
Unknown	
Commonwealth Land - [50437]	WA
Commonwealth Land - [50438]	WA
Commonwealth Land - [51987]	WA
Commonwealth Land - [50430]	WA
Commonwealth Land - [50528]	WA
Commonwealth Land - [51980]	WA
Commonwealth Land - [50434]	WA
Commonwealth Land - [50436]	WA
Commonwealth Land - [50432]	WA
Commonwealth Land - [50433]	WA
Commonwealth Land - [50415]	WA
Commonwealth Land - [50417]	WA
Commonwealth Land - [50418]	WA
Commonwealth Land - [50410]	WA
Commonwealth Land - [50413]	WA
Commonwealth Land - [50412]	WA

Commonwealth Land Name	State
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Commonwealth Land - [50496]	WA
Commonwealth Land - [50419]	WA
Commonwealth Land - [50449]	WA
Commonwealth Land - [50381]	WA
Commonwealth Land - [52111]	WA
Commonwealth Land - [52119]	WA
Commonwealth Land - [51891]	WA
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Commonwealth Land - [50480]	WA
Commonwealth Land - [51434]	WA
Commonwealth Land - [50483]	WA
Commonwealth Land - [50615]	WA
Commonwealth Land - [50616]	WA
Commonwealth Land - [50613]	WA
Commonwealth Land - [50614]	WA

Commonwealth Land Name	State
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Commonwealth Land - [50619]	WA
Commonwealth Land - [50610]	WA
Commonwealth Land - [50404]	WA
Commonwealth Land - [50618]	WA
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Commonwealth Land - [50678]	WA
Commonwealth Land - [50511]	WA
Commonwealth Land - [50697]	WA

Commonwealth Land Name	State
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Commonwealth Land - [50570]	WA
Commonwealth Land - [50562]	WA
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Commonwealth Land - [50567]	WA
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Commonwealth Land - [50565]	WA

Commonwealth Land Name	State
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Commonwealth Land - [50521]	WA
Commonwealth Land - [50529]	WA
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Commonwealth Land - [50561]	WA
Commonwealth Land - [50555]	WA
Commonwealth Land - [50553]	WA

Commonwealth Land Name	State
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Commonwealth Land - [50462]	WA
Commonwealth Land - [50460]	WA
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Commonwealth Land - [50477]	WA
Commonwealth Land - [50578]	WA
Commonwealth Land - [50452]	WA

Commonwealth Land Name	State
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Commonwealth Land - [50451]	WA
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Commonwealth Land - [51897]	WA
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Commonwealth Land - [50536]	WA

Commonwealth Land Name	State
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Commonwealth Land - [51098]	WA
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Commonwealth Land - [50577]	WA
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Commonwealth Land - [50479]	WA

Commonwealth Land Name	State
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Commonwealth Land - [50601]	WA
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Commonwealth Land - [50603]	WA
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Commonwealth Land - [50594]	WA
Commonwealth Land - [50444]	WA
Commonwealth Land - [50627]	WA
Commonwealth Land - [50447]	WA

Commonwealth Land Name	State
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Commonwealth Land - [50598]	WA
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Commonwealth Land - [50604]	WA
Commonwealth Land - [50592]	WA
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Commonwealth Land - [50660]	WA
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Commonwealth Land - [50422]	WA
Commonwealth Land - [50420]	WA
Commonwealth Land - [50427]	WA

Commonwealth Land Name	State
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Commonwealth Land - [50423]	WA
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Commonwealth Land - [50466]	WA
Commonwealth Land - [50461]	WA
Commonwealth Land - [51116]	WA
Commonwealth Land - [51974]	WA

Commonwealth Land Name	State
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Commonwealth Land - [51481]	WA
Commonwealth Land - [50554]	WA
Commonwealth Land - [50552]	WA
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Commonwealth Land - [50608]	WA
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Commonwealth Land - [50510]	WA
Commonwealth Land - [50515]	WA
Commonwealth Land - [50695]	WA
Commonwealth Land - [50589]	WA

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Historic		
Artillery Barracks	WA	Listed place
Cliff Point Historic Site	WA	Listed place
Geraldton Drill Hall Complex	WA	Listed place
J Gun Battery	WA	Listed place
Natural		
Garden Island	WA	Listed place

Name	State	Status
Lancelin Defence Training Area	WA	Listed place

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area
Ardenna carneipes as Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Foraging, feeding or related behaviour likely to occur within area
Ardenna grisea as Puffinus griseus Sooty Shearwater [82651]	Vulnerable	Species or species habitat may occur within area
Ardenna pacifica as Puffinus pacificus Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Arenaria interpres Ruddy Turnstone [872]	Vulnerable	Roosting known 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]	Vulnerable	Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Vulnerable	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 known to occur within area overfly marine area
Calidris pugnax as Philomachus pugnax Ruff [91256]		Roosting known to occur within area overfly marine area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area overfly marine area
Calidris subminuta Long-toed Stint [861]		Roosting known to occur within area overfly marine area
Calidris tenuirostris Great Knot [862]	Vulnerable	Roosting known to occur within area overfly marine area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat known to occur within area overfly marine area
Charadrius bicinctus Double-banded Plover [895]		Roosting known 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

Scientific Name	Threatened Category	Presence Text
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Roosting known to occur within area overfly marine area
Chroicocephalus novaehollandiae as Larus novaehollandiae Silver Gull [82326]		Breeding known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea dabbenena Tristan Albatross [66471]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Species or species habitat may occur within area
Eudyptula minor Little Penguin [1085]		Breeding known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area overfly marine area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat known to occur within area overfly marine area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Halobaena caerulea Blue Petrel [1059]	Vulnerable	Species or species habitat may occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Roosting known to occur within area overfly marine area
Hydroprogne caspia as Sterna caspia Caspian Tern [808]		Breeding known to occur within area
Larus pacificus Pacific Gull [811]		Breeding known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting 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]	Endangered	Roosting known to occur within area overfly marine area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Foraging, feeding or related behaviour likely to occur within 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 may 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 minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area overfly marine area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Onychoprion anaethetus as Sterna anaethetus Bridled Tern [82845]		Breeding known to occur within area
Onychoprion fuscatus as Sterna fuscata Sooty Tern [90682]		Breeding known to occur within area
Pachyptila turtur Fairy Prion [1066]		Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Pelagodroma marina White-faced Storm-Petrel [1016]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat may occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Phalacrocorax fuscescens Black-faced Cormorant [59660]		Breeding likely to occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Roosting known to occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]	Vulnerable	Roosting known to occur within area overfly marine area
Pterodroma macroptera Great-winged Petrel [1035]		Foraging, feeding or related behaviour known to occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Puffinus assimilis Little Shearwater [59363]		Breeding known to occur within area
Puffinus huttoni Hutton's Shearwater [1025]		Foraging, feeding or related behaviour known to occur within area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Roosting known to occur within area overfly marine area
Rostratula australis as Rostratula benghalensis (sensu lato) Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Stercorarius antarcticus as Catharacta skua Brown Skua [85039]		Species or species habitat may occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons as Sterna albifrons Little Tern [82849]		Species or species habitat may occur within area
Sternula nereis as Sterna nereis Fairy Tern [82949]		Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat likely to occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Thalasseus bergii as Sterna bergii Greater Crested Tern [83000]		Breeding known to occur within area
Thinornis cucullatus as Thinornis rubricollis Hooded Plover, Hooded Dotterel [87735]		Species or species habitat known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Tringa brevipes as Heteroscelus brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area overfly marine area
Tringa nebularia Common Greenshank, Greenshank [832]	Endangered	Species or species habitat known to occur within area overfly marine area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area overfly marine area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area overfly marine area
Xenus cinereus Terek Sandpiper [59300]	Vulnerable	Roosting known to occur within area overfly marine area
Fish		
Acentronura australe Southern Pygmy Pipehorse [66185]		Species or species habitat may occur within area
Campichthys galei Gale's Pipefish [66191]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Heraldia nocturna Upside-down Pipefish, Eastern Upside-down Pipefish, Eastern Upside-down Pipefish [66227]		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 breviceps Short-head Seahorse, Short-snouted Seahorse [66235]		Species or species habitat may occur within area
Hippocampus subelongatus West Australian Seahorse [66722]		Species or species habitat may occur within area
Histiogamphelus cristatus Rhino Pipefish, Macleay's Crested Pipefish, Ring-back Pipefish [66243]		Species or species habitat may occur within area
Lissocampus caudalis Australian Smooth Pipefish, Smooth Pipefish [66249]		Species or species habitat may occur within area
Lissocampus fatiloquus Prophet's Pipefish [66250]		Species or species habitat may occur within area
Lissocampus runa Javelin Pipefish [66251]		Species or species habitat may occur within area
Maroubra perserrata Sawtooth Pipefish [66252]		Species or species habitat may occur within area
Mitotichthys meraculus Western Crested Pipefish [66259]		Species or species habitat may occur within area
Nannocampus subosseus Bonyhead Pipefish, Bony-headed Pipefish [66264]		Species or species habitat may occur within area
Phycodurus eques Leafy Seadragon [66267]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Phyllopteryx taeniolatus Common Seadragon, Weedy Seadragon [66268]		Species or species habitat may occur within area
Pugnaso curtirostris Pugnose Pipefish, Pug-nosed Pipefish [66269]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Stigmatopora argus Spotted Pipefish, Gulf Pipefish, Peacock Pipefish [66276]		Species or species habitat may occur within area
Stigmatopora nigra Widebody Pipefish, Wide-bodied Pipefish, Black Pipefish [66277]		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
Urocampus carinirostris Hairy Pipefish [66282]		Species or species habitat may occur within area
Vanacampus margaritifer Mother-of-pearl Pipefish [66283]		Species or species habitat may occur within area
Vanacampus phillipi Port Phillip Pipefish [66284]		Species or species habitat may occur within area
Vanacampus poecilolaemus Longsnout Pipefish, Australian Long-snout Pipefish, Long-snouted Pipefish [66285]		Species or species habitat may occur within area
Mammal		
Arctocephalus forsteri Long-nosed Fur-seal, New Zealand Fur-seal [20]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Neophoca cinerea		
Australian Sea-lion, Australian Sea Lion [22]	Endangered	Breeding known to occur within area
Reptile		
Aipysurus pooleorum		
Shark Bay Sea Snake [66061]		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 known to occur within area
Hydrophis kingii as Disteira kingii		
Spectacled Sea Snake [93511]		Species or species habitat may occur within area
Hydrophis major as Disteira major		
Olive-headed Sea Snake [93512]		Species or species habitat may occur within area
Hydrophis platura as Pelamis platurus		
Yellow-bellied Sea Snake [93746]		Species or species habitat may occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Whales and Other Cetaceans [Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera acutorostrata		
Minke Whale [33]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Foraging, feeding or related behaviour known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Caperea marginata Pygmy Right Whale [39]		Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Breeding known to 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
Globicephala melas Long-finned Pilot Whale [59282]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Hyperoodon planifrons Southern Bottlenose Whale [71]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima 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
Lagenorhynchus obscurus Dusky Dolphin [43]		Species or species habitat likely to occur within area
Lissodelphis peronii Southern Right Whale Dolphin [44]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Congregation or aggregation known to occur within area
Mesoplodon bowdoini Andrew's Beaked Whale [73]		Species or species habitat may occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Mesoplodon grayi Gray's Beaked Whale, Scamperdown Whale [75]		Species or species habitat may occur within area
Mesoplodon layardii Strap-toothed Beaked Whale, Strap-toothed Whale, Layard's Beaked Whale [25556]		Species or species habitat may occur within area
Mesoplodon mirus True's Beaked Whale [54]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Foraging, feeding or related behaviour known to 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

Current Scientific Name	Status	Type of Presence
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks

[Resource Information]

Park Name	Zone & IUCN Categories
Perth Canyon	Habitat Protection Zone (IUCN IV)
Perth Canyon	Habitat Protection Zone (IUCN IV)
Perth Canyon	Habitat Protection Zone (IUCN IV)
Abrolhos	Multiple Use Zone (IUCN VI)
Perth Canyon	Multiple Use Zone (IUCN VI)
Perth Canyon	Multiple Use Zone (IUCN VI)
Two Rocks	Multiple Use Zone (IUCN VI)
Abrolhos	National Park Zone (IUCN II)
Jurien	National Park Zone (IUCN II)
Perth Canyon	National Park Zone (IUCN II)
Perth Canyon	National Park Zone (IUCN II)
South-west Corner	National Park Zone (IUCN II)
Two Rocks	National Park Zone (IUCN II)
Abrolhos	Special Purpose Zone (IUCN VI)
Abrolhos	Special Purpose Zone (IUCN VI)

Park Name	Zone & IUCN Categories
Jurien	Special Purpose Zone (IUCN VI)
South-west Corner	Special Purpose Zone (Mining Exclusion) (IUCN VI)

Extra Information

State and Territory Reserves [Resource Information]

Protected Area Name	Reserve Type	State
Abrolhos Islands	Fish Habitat Protection Area	WA
Beagle Islands	Nature Reserve	WA
Beekeepers	Nature Reserve	WA
Bold Park	Botanic Gardens	WA
Boullanger, Whitlock, Favourite, Tern And Osprey Islands	Nature Reserve	WA
Buller, Whittell And Green Islands	Nature Reserve	WA
Carnac Island	Nature Reserve	WA
Cervantes Islands	Nature Reserve	WA
Cottesloe Reef	Fish Habitat Protection Area	WA
Dongara	Nature Reserve	WA
Drovers Cave	National Park	WA
Escape Island	Nature Reserve	WA
Essex Rocks	Nature Reserve	WA
Fisherman Islands	Nature Reserve	WA
Houtman Abrolhos Islands	National Park	WA
Jurien Bay	Marine Park	WA
Kalbarri	National Park	WA
Lancelin And Edwards Islands	Nature Reserve	WA

Protected Area Name	Reserve Type	State
Lancelin Island Lagoon	Fish Habitat Protection Area	WA
Leda	Nature Reserve	WA
Lesueur	National Park	WA
Lipfert, Milligan, Etc Islands	Nature Reserve	WA
Marmion	Marine Park	WA
Nambung	National Park	WA
Neerabup	National Park	WA
Nilgen	Nature Reserve	WA
Outer Rocks	Nature Reserve	WA
Penguin Island	Conservation Park	WA
Port Gregory	NRS Addition - Gazettal in Progress	WA
Port Kennedy Scientific Park	Nature Reserve	WA
Ronsard Rocks	Nature Reserve	WA
Rottnest Island	State Reserve	WA
Sandland Island	Nature Reserve	WA
Shoalwater Bay Islands	Nature Reserve	WA
Shoalwater Islands	Marine Park	WA
Southern Beekeepers	Nature Reserve	WA
Swan River	Management Area	WA
Unnamed WA11883	5(1)(h) Reserve	WA
Unnamed WA33799	Nature Reserve	WA
Unnamed WA34039	5(1)(h) Reserve	WA
Unnamed WA43903	Nature Reserve	WA
Unnamed WA44004	Nature Reserve	WA
Unnamed WA44682	5(1)(h) Reserve	WA
Unnamed WA46983	5(1)(h) Reserve	WA

Protected Area Name	Reserve Type	State
Unnamed WA46984	5(1)(h) Reserve	WA
Unnamed WA48205	5(1)(h) Reserve	WA
Unnamed WA48858	Nature Reserve	WA
Unnamed WA48968	5(1)(h) Reserve	WA
Unnamed WA49994	Conservation Park	WA
Unnamed WA51658	5(1)(h) Reserve	WA
Utcha Well	Nature Reserve	WA
Wanagarren	Nature Reserve	WA
Wedge Island	Nature Reserve	WA
Yalgorup	National Park	WA
Yanchep	National Park	WA

Nationally Important Wetlands

[Resource Information]

Wetland Name	State
Becher Point Wetlands	WA
Herdsman Lake	WA
Hutt Lagoon System	WA
Lake Thetis	WA
Loch McNess System	WA
Rottnest Island Lakes	WA
Swan-Canning Estuary	WA

EPBC Act Referrals

[Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Abercrombie Road Quarry	2023/09465		Assessment
Alkimos Seawater Desalination	2019/8453		Completed
Anketell Road Upgrade (Leith Road to Kwinana Freeway)	2024/09841		Assessment
Commercial Development of Lots 12 and 13 Lodge Drive, East Rockingham, WA	2021/9069		Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Freight handling expansion, Kwinana Rail Depot	2023/09474		Assessment
Fremantle District Police Complex Project	2022/09345		Completed
Gonneville Nickel-Copper-Platinum Group Element Mine Development Project	2024/09839		Assessment
H2Perth hydrogen and ammonia project	2023/09559		Completed
Hale School Development	2022/09273		Completed
Jurien East Road Upgrade, 3 km NNE Jurien Bay, WA	2020/8740		Post-Approval
Marine Route Survey for Subsea Fibre Optic Data Cable System - Australia West	2024/09826		Completed
Midwest Offshore Wind Farm	2022/09264		Assessment
Outer Harbour Port Development, Kwinana	2024/09859		Referral Decision
Samphire Offshore Wind Farm	2022/09306		Assessment
Submarine Rotational Force ? West, Priority Infrastructure Works: Maritime Upgrades	2024/09943		Referral Decision
Yanchep Rail Extension, WA	2018/8262		Post-Approval
Yogi Magnetite Project, 225km east, northeast of Geraldton, WA	2017/8124		Approval
Controlled action			
Airborne sonar trials	2001/540	Controlled Action	Completed
Alkimos city centre and central development, WA	2015/7561	Controlled Action	Post-Approval
Alkimos Coastal Node	2020/8861	Controlled Action	Further Information Request
Butler North District Open Space playing fields development, Wanneroo, WA	2017/8053	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Catalina Residential Development	2010/5785	Controlled Action	Post-Approval
Coburn Mineral Sand Project	2003/1221	Controlled Action	Post-Approval
construction and operation of a unmanned platform at the Cliff Head oil field, a	2003/1300	Controlled Action	Post-Approval
Construction of a Deepwater, General Container Port	2009/5178	Controlled Action	Proposed Decision
Construction of New Perth Bunbury Highway project	2005/2193	Controlled Action	Post-Approval
Construction of the Oakajee Port and Rail Project	2011/5797	Controlled Action	Post-Approval
Development of Kwinana Quay port facility	2008/4387	Controlled Action	Completed
development of land based tourist facilities on Long Island	2006/2792	Controlled Action	Post-Approval
Eglinton/South Yanchep Residential Development	2011/6021	Controlled Action	Post-Approval
Eglinton Estates - Clearing of native vegetation from Lot 1007 & part Lot 1008	2010/5777	Controlled Action	Post-Approval
Extend a section of Mundijong Road	2011/5971	Controlled Action	Post-Approval
Hematite (iron ore) Mine and Beneficiation Plant	2001/542	Controlled Action	Completed
Industry Zone	2010/5337	Controlled Action	Post-Approval
Jindee Residential Development	2012/6631	Controlled Action	Post-Approval
Karara Magnetite Project	2006/3017	Controlled Action	Post-Approval
Mangles Bay Marina Based Tourist Precinct	2010/5659	Controlled Action	Post-Approval
Mitchell Freeway Extension and Wanneroo Road Upgrade, WA	2018/8367	Controlled Action	Post-Approval
Mitchell Freeway Extension between Burns Beach Rd and Hester Av, Neerabup, WA	2013/7091	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Mount Gibson Iron Ore Pellet Project	2000/95	Controlled Action	Completed
Natural Gas Pipeline Expansion	2006/2813	Controlled Action	Post-Approval
Nava-1 Cable System	2001/510	Controlled Action	Completed
Neighbourhood Shopping Centre and Mixed Business Centre, Ocean Road, Dawesville	2006/3155	Controlled Action	Post-Approval
Oakajee Rail Development	2010/5500	Controlled Action	Post-Approval
Ocean Reef Marina Development	2009/4937	Controlled Action	Completed
open cut mine & assoc infrastructure	2005/2381	Controlled Action	Post-Approval
Peel's Retreat Estate - Residential development	2006/3063	Controlled Action	Post-Approval
Point Grey Marina Project	2010/5515	Controlled Action	Post-Approval
Point Grey Residential Development - Terrestrial Component	2011/5825	Controlled Action	Post-Approval
Port Enhancement Project	2001/266	Controlled Action	Post-Approval
Proposed Urban Development of Lots 1005 & 1006	2008/4638	Controlled Action	Post-Approval
Residential development,Lot 609, Yanchep Beach Road, Yanchep, WA	2014/7146	Controlled Action	Post-Approval
Residential Development at Shenton Park	2007/3386	Controlled Action	Completed
Residential development Lot 1004 Alkimos WA	2011/5902	Controlled Action	Post-Approval
Shark Hazard Mitigation Drum Line Program, WA	2014/7174	Controlled Action	Completed
Shenton Park Subdivision	2004/1479	Controlled Action	Completed
Subdivision Lot 1 Dawesville Rd	2005/2394	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Tourism Facility and Associated Infrastructure	2005/2038	Controlled Action	Post-Approval
Urban and Residential Development at Lot 9 Brighton	2011/6137	Controlled Action	Post-Approval
Urban development in accordance with the Local Structure Plan	2008/4601	Controlled Action	Post-Approval
Urban Residential Development at Lot 9049 Marmoin Avenue	2009/5155	Controlled Action	Post-Approval
Warders Hotel, Block 1 Warders Cottages, Fremantle, WA	2018/8144	Controlled Action	Post-Approval
Not controlled action			
'Looping 10' gas transmission pipeline from Kwinana to Hopelands	2005/2212	Not Controlled Action	Completed
Alkimos seawater desalination plant, offshore investigations, WA	2018/8224	Not Controlled Action	Completed
Amberton West urban development - Part lot 9005 Eglington WA	2013/7068	Not Controlled Action	Completed
APX-West Fibre-optic telecommunications cable system, WA to Singapore	2013/7102	Not Controlled Action	Completed
Bold Park St John's Wood Mt Claremont residential development,Claremont WA	2014/7248	Not Controlled Action	Completed
Bushfire Mitigation Works - City of Mandurah	2020/8674	Not Controlled Action	Completed
Butler Railway Extension Project - Nowergup Depot Eastern Alignment	2011/5989	Not Controlled Action	Completed
Clear Lot 503, 54 Ocean Road Dawesville, WA	2014/7375	Not Controlled Action	Completed
Cliff Head 6 appraisal well	2004/1702	Not Controlled Action	Completed
Cliff Head Appraisal Wells	2003/938	Not Controlled Action	Completed
Construction and operation of an 8 turbine wind farm at Rous Head Harbour, Frema	2003/933	Not Controlled Action	Completed
Construction of Secret Harbour High School	2004/1489	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Construction of several passing lanes between Lancelin and Jurien Bay, WA	2015/7509	Not Controlled Action	Completed
Container Deposit Scheme Project	2019/8517	Not Controlled Action	Completed
Development of a Diagnostic Laboratory	2011/6089	Not Controlled Action	Completed
Development of Existing Lots 9970 & 10754, Bedbrook Pl, Shenton Park, WA	2013/7033	Not Controlled Action	Completed
Development of new Alkimos Wastwater Treatment Plant	2007/3259	Not Controlled Action	Completed
Disposal of residential properties, Fremantle, WA	2019/8593	Not Controlled Action	Completed
Drilling between Kalbarri and Cliff Head	2005/2185	Not Controlled Action	Completed
Eastport canal estate development stage 5	2007/3737	Not Controlled Action	Completed
Eradication of the European House Borer, Perth metropolitan area, WA	2009/5027	Not Controlled Action	Completed
Establishment of a 12.7 ha Gypsum Mine	2007/3398	Not Controlled Action	Completed
Establishment of a National Lifestyle Village	2011/6081	Not Controlled Action	Completed
Expansion of berthing facilities at Kwinana Bulk Terminal	2006/2509	Not Controlled Action	Completed
Expansion of existing Ammonium Nitrate Production Facility	2005/1941	Not Controlled Action	Completed
Expedition 369-Australian Cretaceous Climate and Tectonics, Australian EEZ waters	2017/7891	Not Controlled Action	Completed
Exploration drilling program located in exploration permits WA-286-P and TP/15	2002/676	Not Controlled Action	Completed
Extension of 7.5km of the Joondalup Line electrified passenger railway from Cla	2010/5632	Not Controlled Action	Completed
Florida Estate Residential Subdivision Development Stage 13	2011/6045	Not Controlled Action	Completed
Florida North residential development, Lot 9008, Ocean	2015/7462	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Road, Dawesville, WA			
Fremantle Ports Inner Harbour Capital Dredging Proposal	2005/2477	Not Controlled Action	Completed
Gas-fired Power Station	2005/2213	Not Controlled Action	Completed
Geo-science Investigations	2005/2069	Not Controlled Action	Completed
Glenfield Beach Project	2012/6359	Not Controlled Action	Completed
Hadda 1,Flying Foam 1,Magnat 1 exploration drill	2004/1697	Not Controlled Action	Completed
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed
Indian Ocean Drive Passing Lane and Widening 52-258 SLK	2017/7884	Not Controlled Action	Completed
Indian Ocean Drive Widening, Gingin Shire, WA	2018/8346	Not Controlled Action	Completed
INDIGO Central Submarine Telecommunications Cable	2017/8127	Not Controlled Action	Completed
INDIGO West Submarine Telecommunications Cable, WA	2017/8126	Not Controlled Action	Completed
Kennedy Bay urban development, Port Kennedy, WA	2014/7122	Not Controlled Action	Completed
Kennedy Park Estate Residential Development	2003/1044	Not Controlled Action	Completed
Kwinana Depot Upgrade	2011/6035	Not Controlled Action	Completed
Kwinana Gas-Fired Power Station	2005/2101	Not Controlled Action	Completed
Lancelin Caravan Park Project, Hopkins Dve & Casserley Way, Lancelin	2015/7546	Not Controlled Action	Completed
Maintenance Dredging in the Geraldton Port Outer Channel	2010/5488	Not Controlled Action	Completed
Ocean Reef Marina Development, City of Joondalup, WA	2014/7237	Not Controlled Action	Completed
Oman Australia Cable Installation, WA	2021/8922	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Oman Australia Cable - Marine Route Survey	2020/8731	Not Controlled Action	Completed
Palm Beach Caravan Park Redevelopment, Rockingham, WA	2013/6853	Not Controlled Action	Completed
Perth Desalination Plant 2	2019/8454	Not Controlled Action	Completed
Quinns Main sewer extension, Clarkson - Neerabup, WA	2018/8215	Not Controlled Action	Completed
Reid Highway duplication project(Erindale Rd - Duffy Rd)WA	2013/7073	Not Controlled Action	Completed
Residential development, Lots 9010 and 9031, Yanchep Beach Rd, Yanchep	2016/7642	Not Controlled Action	Completed
Residential Development Eglinton West, Lot 5000 & part Lot 5001, Pipidinny Road, Eglinton	2014/7137	Not Controlled Action	Completed
residential subdivision	2005/1965	Not Controlled Action	Completed
Re-zoning of Land for Future Residential Development Purposes	2009/4908	Not Controlled Action	Completed
Rottnest Lodge Redevelopment	2019/8565	Not Controlled Action	Completed
Scientific Sonar Trial	2002/680	Not Controlled Action	Completed
Seismic Survey, Bremer Basin, Mentelle Basin and Zeewyck Sub-basin	2004/1700	Not Controlled Action	Completed
Sepia Depression Ocean Outlet Landline Duplication	2012/6248	Not Controlled Action	Completed
WA-286-P Exploration Drilling Programme	2007/3863	Not Controlled Action	Completed
Warders' Cottages Block 2 'W2'	2022/9148	Not Controlled Action	Completed
Warders' Cottages W2 minor works, Fremantle, WA	2018/8185	Not Controlled Action	Completed
Yellowfin Tuna Aquaculture Trial	2003/1115	Not Controlled Action	Completed
Yngling-1 exploration well for WA-368-P	2007/3523	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
2D Marine Seismic Survey in Permit Area WA-337-P	2003/1158	Not Controlled Action (Particular Manner)	Post-Approval
2D seismic survey	2008/4493	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey	2007/3800	Not Controlled Action (Particular Manner)	Post-Approval
Australian Square Kilometre Array Pathfinder telescope & infrastructure	2009/4891	Not Controlled Action (Particular Manner)	Post-Approval
Australia to Singapore Fibre Optic Submarine Cable System	2011/6127	Not Controlled Action (Particular Manner)	Post-Approval
CETO 6 Garden Island Project, offshore WA	2016/7635	Not Controlled Action (Particular Manner)	Post-Approval
CETO 6 Geophysical and Geotechnical Surveys	2014/7408	Not Controlled Action (Particular Manner)	Post-Approval
City of Cockburn Sporting Facilties	2005/2139	Not Controlled Action (Particular Manner)	Post-Approval
Coodanup residential development	2006/3073	Not Controlled Action (Particular Manner)	Post-Approval
develop and operate a new deepwater port	2010/5760	Not Controlled Action (Particular Manner)	Post-Approval
Grand Southern Margin 2D Marine Seismic Survey	2008/4599	Not Controlled Action (Particular Manner)	Post-Approval
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Lake Richmond Boardwalk installation, Rockingham, WA	2013/6977	Not Controlled Action (Particular Manner)	Post-Approval
Laying a submarine optical fibre telecommunications cable, Perth to Singapore and Jakarta	2014/7332	Not Controlled Action (Particular Manner)	Post-Approval
Marine Environmental Survey	2012/6275	Not Controlled Action (Particular Manner)	Post-Approval
Marine reconnaissance survey	2008/4466	Not Controlled Action (Particular Manner)	Post-Approval
Marine Seismic Survey for oil and gas in Commonwealth waters off the WA coast.	2004/1802	Not Controlled Action (Particular Manner)	Post-Approval
Marine Seismic Survey in Permit WA-481P	2012/6626	Not Controlled Action (Particular Manner)	Post-Approval
Multipurpose development stage 1 within 340ha	2004/1913	Not Controlled Action (Particular Manner)	Post-Approval
Nexus Energy Seismic survey WA	2006/2569	Not Controlled Action (Particular Manner)	Post-Approval
North Perth Marine Survey	2011/6067	Not Controlled Action (Particular Manner)	Post-Approval
South West Metropolitan Railway Project	2003/1175	Not Controlled Action (Particular Manner)	Post-Approval
Study of behavioural responses of Austn Humpback Whales to seismic surveys, offshore Dongara, WA	2013/6927	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Wastewater Treatment Plant	2009/4970	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
3D Marine Seismic survey	2007/3729	Referral Decision	Completed
3D Seismic Survey	2012/6245	Referral Decision	Completed
CO2 3D Seismic Survey Vlaming Sub-Basin	2012/6343	Referral Decision	Completed
Exploration Drilling 2014/2015 WA-481-P	2013/7043	Referral Decision	Completed
Grand Southern Margin 2D Marine Seismic Survey	2008/4573	Referral Decision	Completed
Kennedy Bay Urban Development,PortKennedy,Rockingh	2013/7022	Referral Decision	Completed
Lots 1-5 Bluerise Cove & Lots 801 & 124 Pleasant Grove Rezoning and Subdivision	2008/4295	Referral Decision	Completed
Narelle 3D Marine Seismic Survey	2008/4575	Referral Decision	Completed
Proposed exploration drilling activities, Abrolhos Commonwealth Marine Reserve	2013/6949	Referral Decision	Completed
Residential Subdivision Lot 801 Pleasant Grove Circle, Falcon, WA	2012/6507	Referral Decision	Referral Publication
Residential Subdivision of 60ha, Swan Location 2424	2004/1928	Referral Decision	Completed
Sonar Trials and Acoustic Trials	2001/538	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

Name	Region
Ancient coastline at 90-120m depth	South-west
Cape Mentelle upwelling	South-west
Commonwealth marine environment surrounding the Houtman Abrolhos Islands	South-west
Commonwealth marine environment within and adjacent to the west coast inshore lagoons	South-west
Perth Canyon and adjacent shelf break, and other west coast canyons	South-west
Western demersal slope and associated fish communities	South-west
Western rock lobster	South-west

Biologically Important Areas

[Resource Information]

Scientific Name	Behaviour	Presence
Seabirds		
Anous stolidus Common Noddy [825]	Foraging	Known to occur
Anous stolidus Common Noddy [825]	Foraging (provisioning young)	Known to occur
Anous tenuirorstris melanops Australian Lesser Noddy [26000]	Foraging (provisioning young)	Known to occur
Ardenna carneipes Flesh-footed Shearwater [82404]	Aggregation	Known to occur
Ardenna pacifica Wedge-tailed Shearwater [84292]	Foraging (in high numbers)	Known to occur
Eudyptula minor Little Penguin [1085]	Foraging (provisioning young)	Known to occur
Hydroprogne caspia Caspian Tern [808]	Foraging (provisioning young)	Known to occur

Scientific Name	Behaviour	Presence
Larus pacificus Pacific Gull [811]	Foraging (in high numbers)	Former Range
Larus pacificus Pacific Gull [811]	Foraging (in high numbers)	Known to occur
Onychoprion anaethetus Bridled Tern [82845]	Foraging (in high numbers)	Known to occur
Onychoprion fuscata Sooty Tern [82847]	Foraging	Known to occur
Pelagodroma marina White-faced Storm-petrel [1016]	Foraging (in high numbers)	Known to occur
Pterodroma macroptera macroptera Great-winged Petrel (macroptera race) [1035]	Foraging (provisioning young)	Known to occur
Pterodroma mollis Soft-plumaged Petrel [1036]	Foraging (in high numbers)	Known to occur
Puffinus assimilis tunneyi Little Shearwater [59363]	Foraging (in high numbers)	Known to occur
Sterna dougallii Roseate Tern [817]	Foraging	Known to occur
Sterna dougallii Roseate Tern [817]	Foraging (provisioning young)	Known to occur
Sternula nereis Fairy Tern [82949]	Foraging (in high numbers)	Known to occur
Seals		
Neophoca cinerea Australian Sea Lion [22]	Foraging (male)	Likely to occur

Scientific Name	Behaviour	Presence
Neophoca cinerea Australian Sea Lion [22]	Foraging (male and female)	Known to occur
Sharks		
Carcharodon carcharias White Shark [64470]	Foraging	Known to occur
Whales		
Balaenoptera musculus Blue and Pygmy Blue Whale [36]	Foraging (abundant food source)	Known to occur
Balaenoptera musculus Blue and Pygmy Blue Whale [36]	Foraging (high density)	Known to occur
Balaenoptera musculus Blue and Pygmy Blue Whale [36]	Foraging (on migration)	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Foraging Area (annual high use area)	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Known Foraging Area	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north)	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north and south)	Known to occur
Physeter macrocephalus Sperm Whale [59]	Foraging (abundant food source)	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.

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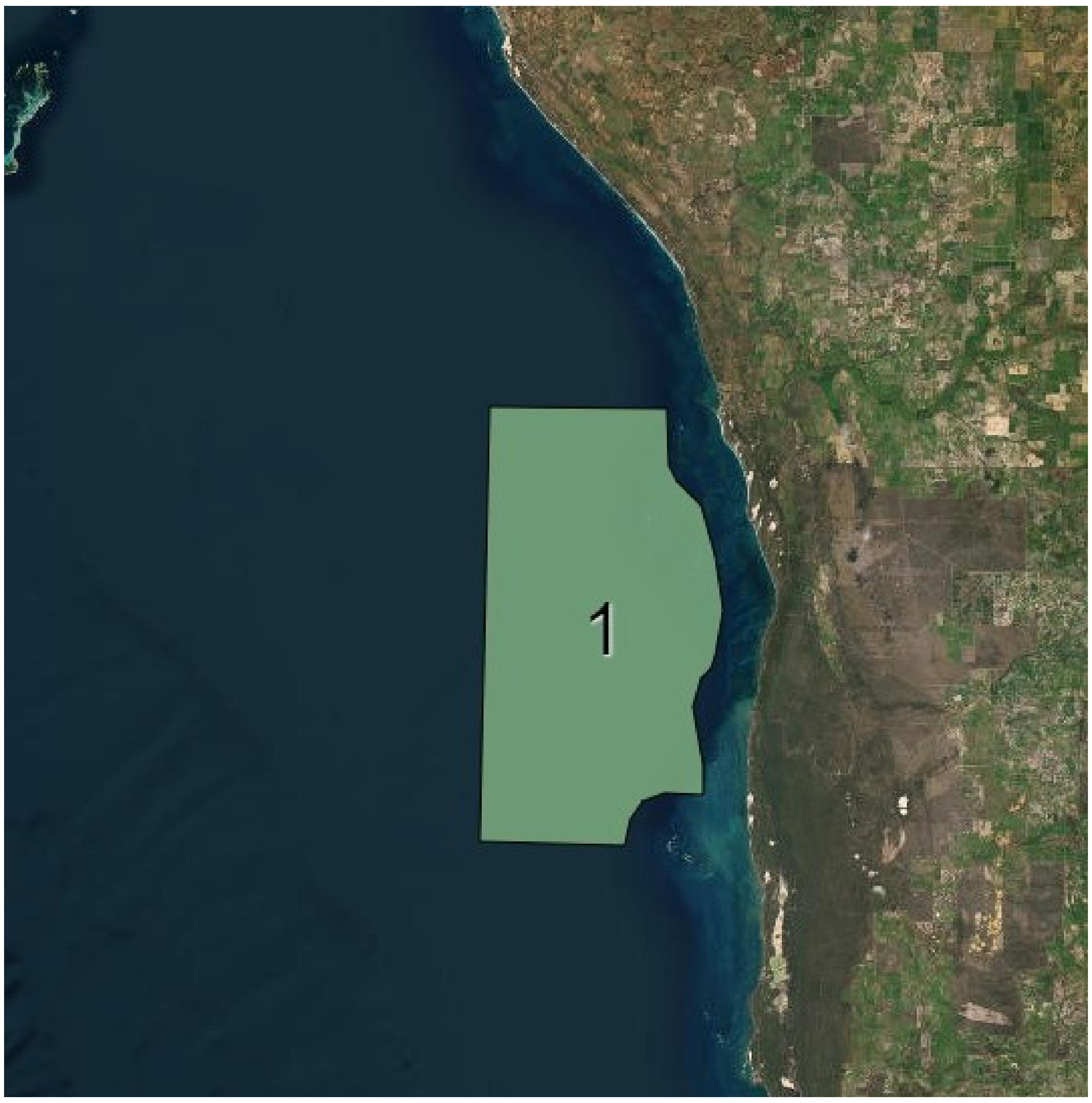
EPBC Act Protected Matters Report

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: 02-Oct-2024



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:	32
Listed Migratory Species:	43

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/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:	56
Whales and Other Cetaceans:	14
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None
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:	12
Key Ecological Features (Marine):	2
Biologically Important Areas:	15
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
Commonwealth Marine Areas (EPBC Act)
Commonwealth Marine Areas (EPBC Act)

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	Foraging, feeding or related behaviour likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Vulnerable	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat may occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	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 rubricauda westralis Red-tailed Tropicbird (Indian Ocean), Indian Ocean Red-tailed Tropicbird [91824]	Endangered	Species or species habitat may occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Species or species habitat may occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
MAMMAL		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Neophoca cinerea Australian Sea-lion, Australian Sea Lion [22]	Endangered	Species or species habitat known to occur within area
REPTILE		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat known to occur within area
SHARK		

Scientific Name	Threatened Category	Presence Text
Carcharias taurus (west coast population)		
Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat likely to occur within area
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Foraging, feeding or related behaviour known to 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
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Species or species habitat may 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
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna carneipes		
Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Species or species habitat likely to occur within area
Diomedea amsterdamensis		
Amsterdam Albatross [64405]	Endangered	Species or species habitat may occur within area
Diomedea epomophora		
Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within area
Hydroprogne caspia Caspian Tern [808]		Foraging, feeding or related behaviour known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Onychoprion anaethetus Bridled Tern [82845]		Foraging, feeding or related behaviour likely to occur within area
Sterna dougallii Roseate Tern [817]		Foraging, feeding or related behaviour likely to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Migratory Marine Species		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat likely to occur within area
Carcharias taurus Grey Nurse Shark [64469]		Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Eubalaena australis as Balaena glacialis australis		
Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Isurus oxyrinchus		
Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus		
Longfin Mako [82947]		Species or species habitat likely to occur within area
Lamna nasus		
Porbeagle, Mackerel Shark [83288]		Species or species habitat may 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
Mobula birostris as Manta birostris		
Giant Manta Ray [90034]		Species or species habitat may occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Species or species habitat known to occur within area
Orcinus orca		
Killer Whale, Orca [46]		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
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area

Migratory Wetlands Species

Scientific Name	Threatened Category	Presence Text
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Vulnerable	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	Foraging, feeding or related behaviour likely to occur within area

Scientific Name	Threatened Category	Presence Text
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area
Ardenna carneipes as Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Species or species habitat likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Vulnerable	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
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat may occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within area
Hydroprogne caspia as Sterna caspia Caspian Tern [808]		Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Larus pacificus Pacific Gull [811]		Foraging, feeding or related behaviour known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	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
Onychoprion anaethetus as Sterna anaethetus Bridled Tern [82845]		Foraging, feeding or related behaviour likely to occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Species or species habitat may occur within area
Puffinus assimilis Little Shearwater [59363]		Foraging, feeding or related behaviour known to occur within area
Stercorarius antarcticus as Catharacta skua Brown Skua [85039]		Species or species habitat may occur within area
Sterna dougallii Roseate Tern [817]		Foraging, feeding or related behaviour likely to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Thalassarche cauta Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Fish		
Acentronura australe Southern Pygmy Pipehorse [66185]		Species or species habitat may occur within area
Campichthys galei Gale's Pipefish [66191]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus breviceps Short-head Seahorse, Short-snouted Seahorse [66235]		Species or species habitat may occur within area
Hippocampus subelongatus West Australian Seahorse [66722]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Lissocampus fatiloquus Prophet's Pipefish [66250]		Species or species habitat may occur within area
Maroubra perserrata Sawtooth Pipefish [66252]		Species or species habitat may occur within area
Mitotichthys meraculus Western Crested Pipefish [66259]		Species or species habitat may occur within area
Nannocampus subosseus Bonyhead Pipefish, Bony-headed Pipefish [66264]		Species or species habitat may occur within area
Phycodurus eques Leafy Seadragon [66267]		Species or species habitat may occur within area
Phyllopteryx taeniolatus Common Seadragon, Weedy Seadragon [66268]		Species or species habitat may occur within area
Pugnaso curtirostris Pugnose Pipefish, Pug-nosed Pipefish [66269]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Stigmatopora argus Spotted Pipefish, Gulf Pipefish, Peacock Pipefish [66276]		Species or species habitat may occur within area
Stigmatopora nigra Widebody Pipefish, Wide-bodied Pipefish, Black Pipefish [66277]		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

Scientific Name	Threatened Category	Presence Text
Urocampus carinirostris Hairy Pipefish [66282]		Species or species habitat may occur within area
Vanacampus margaritifer Mother-of-pearl Pipefish [66283]		Species or species habitat may occur within area
Mammal		
Arctocephalus forsteri Long-nosed Fur-seal, New Zealand Fur-seal [20]		Species or species habitat may occur within area
Neophoca cinerea Australian Sea-lion, Australian Sea Lion [22]	Endangered	Species or species habitat known to occur within area
Reptile		
Aipysurus pooleorum Shark Bay Sea Snake [66061]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat known to occur within area
Hydrophis kingii as Disteira kingii Spectacled Sea Snake [93511]		Species or species habitat may occur within area
Hydrophis platura as Pelamis platurus Yellow-bellied Sea Snake [93746]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat known to occur within area

Whales and Other Cetaceans		[Resource Information]
Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area

Extra Information

EPBC Act Referrals

[Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
construction and operation of a unmanned platform at the Cliff Head oil field, a	2003/1300	Controlled Action	Post-Approval
Not controlled action			
Cliff Head 6 appraisal well	2004/1702	Not Controlled Action	Completed
Cliff Head Appraisal Wells	2003/938	Not Controlled Action	Completed
Drilling between Kalbarri and Cliff Head	2005/2185	Not Controlled Action	Completed
Exploration drilling program located in exploration permits WA-286-P and TP/15	2002/676	Not Controlled Action	Completed
INDIGO West Submarine Telecommunications Cable, WA	2017/8126	Not Controlled Action	Completed
Not controlled action (particular manner)			
2D seismic survey	2008/4493	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
3D Marine Seismic Survey	2007/3800	Not Controlled Action (Particular Manner)	Post-Approval
Marine Seismic Survey for oil and gas in Commonwealth waters off the WA coast.	2004/1802	Not Controlled Action (Particular Manner)	Post-Approval
Marine Seismic Survey in Permit WA-481P	2012/6626	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
3D Marine Seismic survey	2007/3729	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
Commonwealth marine environment within and adjacent to the west coast inshore lagoons	South-west
Western rock lobster	South-west

Biologically Important Areas [Resource Information]

Scientific Name	Behaviour	Presence
Seabirds		
Ardenna pacifica Wedge-tailed Shearwater [84292]	Foraging (in high numbers)	Known to occur
Hydroprogne caspia Caspian Tern [808]	Foraging (provisioning young)	Known to occur
Larus pacificus Pacific Gull [811]	Foraging (in high numbers)	Known to occur

Scientific Name	Behaviour	Presence
Onychoprion anaethetus Bridled Tern [82845]	Foraging (in high numbers)	Known to occur
Pelagodroma marina White-faced Storm-petrel [1016]	Foraging (in high numbers)	Known to occur
Puffinus assimilis tunneyi Little Shearwater [59363]	Foraging (in high numbers)	Known to occur
Sterna dougallii Roseate Tern [817]	Foraging	Known to occur
Sternula nereis Fairy Tern [82949]	Foraging (in high numbers)	Known to occur
Seals		
Neophoca cinerea Australian Sea Lion [22]	Foraging (male)	Likely to occur
Neophoca cinerea Australian Sea Lion [22]	Foraging (male and female)	Known to occur
Sharks		
Carcharodon carcharias White Shark [64470]	Foraging	Known to occur
Whales		
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Known Foraging Area	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north)	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north and south)	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.

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APPENDIX C: EUREKA MARINE SEISMIC SURVEY COMMERCIAL FISHER COMPENSATION PROTOCOL

EUREKA 3D MARINE SEISMIC SURVEY

COMMERCIAL FISHER COMPENSATION PROTOCOL

SEPTEMBER 2025

Loss of catch | Displacement | Fishing Gear Loss or Damage

Pilot Energy Ltd

Contents Table

1. Compensation Protocol Overview

1.1. Purpose

This protocol establishes a baseline standard to underpin Seismic Survey adjustment for loss of catch, Displacement and Fishing Gear loss or damage, between the petroleum Titleholders and commercial marine operators including fishers.

The purpose of this protocol is to provide a practical, evidence-based process and reasonable monetary adjustment to a Commercial Fisher for loss of catch, Displacement, and Fishing Gear loss or damage. Adjustment is available during a Seismic Survey and as appropriate, for a specified period of time after the completion of a Seismic Survey conducted under an Environment Plan (**EP**) that references and is therefore subject to this protocol.

This protocol also serves as the mechanism for other marine operators (e.g. fishing co-operatives, fishing charters, dive schools) to initiate discussions with Titleholders on evidence-based monetary adjustment if they could potentially be impacted by the Seismic Survey.

1.2. Background

In 2018, National Energy Resources Australia (**NERA**), in consultation with an industry consortium, established the Collaborative Seismic Environment Plan (**CSEP**) Project, to seek approval from the National Offshore Petroleum Safety and Environmental Management Authority (**NOPSEMA**) for Seismic Survey activities in an area in Commonwealth waters off Western Australia (WA) and the Northern Territory (NT) from 2021 and beyond. The CSEP Project was aimed at achieving fundamental and long-term improvements to the way that seismic activities are planned with consideration for commercial fishing activities.

As part of this CSEP project, an adjustment protocol (the NERA compensation Protocol) was developed by the CSEP Project Steering committee in consultation with State, Territory and Commonwealth commercial fishing license holders as well as relevant fishing associations, regulators, and petroleum industry associations.

In recent years, the NERA Protocol has become a petroleum industry standard for all types of activities and has been used as the basis of this Eureka Marine Seismic Survey Commercial Fisher Compensation Protocol (**EMSSCFCP**).

1.3. Commitment

Recognising the collaborative benefits the NERA Protocol has provided where it has been adopted, Pilot Energy (refer Appendix 1) commit to minimising impacts on commercial marine operators, including commercial fishing and the fish stocks that support the industry primarily through avoidance of other activities.

However, Pilot Energy recognise that their activities may, from time-to-time, take place in the same area and at the same time as commercial operations of others who have a history of using that area. Minimising interference with each other's rights and interests is also reflected in primary petroleum and fishing legislation[1].

Best endeavours will be made to avoid, minimise and mitigate potential impacts on the commercial fishing industry before the adjustment processes contained in this protocol are applied.

[1] For relevant statutory information refer to section 280 *Offshore Petroleum and Greenhouse Gas Storage Act 2006*, section 124 *Petroleum (Submerged Lands) Act 1982* (WA), section 124 *Petroleum (Submerged Lands) Act 1981* (NT), and section 171 *Fish Resources Management Act 1994*.

1.4. Scope

This EMSSCFCP is intended to apply to commercial users of the marine environment who are directly affected by the Seismic Survey, where interference is unavoidable.

This protocol covers:

- A Commercial Fisher who fishes as a normal part of their commercial fishing activity within an Acquisition & Adjustment Area, during and/or for a specified period after a Seismic Survey, conducted under an accepted EP that references and is therefore subject to this EMSSCFCP. Adjustment is also available for fishing outside of an Adjustment Area, in some circumstances, if agreed in advance with the Titleholder.
- Other Commercial Marine Operators who identified they could be potentially impacted by the Seismic Survey during relevant persons consultation, who utilise an area as a normal part of their commercial activity within an Adjustment Area during a Seismic Survey conducted under an accepted EP that references and is therefore subject to this EMSSCFCP.

This protocol applies to fishers with one or more Western Australia, or Commonwealth fishing licences.

1.5. Consultation

This protocol has been founded by Pilot Energy and developed by Klarite Sustainable Ventures (**KSV**) building on the NERA CSEP Commercial Fishing Industry Adjustment Protocol. While preparing an EP for the Seismic Survey in the Offshore North Perth basin, Pilot Energy consulted with fishers, fishing license holders, and fishing associations, to confirm a model for compensation that takes into account all fishing methods. Subsequently, on the request of the Titleholder, KSV has undertaken additional consultation with Western Rock Lobster Council (**WRLC**) and Western Australian Fishing Industry Council (**WAFIC**) prior to publishing this protocol for a review of updates that were necessary to the original NERA adjustment protocol to make it applicable to pot fishing. As well as disclosing Pilot Energy's intent to revise the NERA compensation protocol, allowing each Commercial Fisher and other commercial marine users identified during relevant persons consultation, as relevant persons, to provide input.

The Titleholder will continue to consult as per the requirements of the regulations with each relevant person. Consultation on this protocol has been carried out by KSV on behalf of the Titleholder. All records of consultation will be treated as confidential in accordance with Section 25(4) of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2023.

1.6. Definitions

- **Adjustment Area** – An area extending 10 kilometres around the perimeter of a Seismic Survey Acquisition Area[2] (refer Figure 1 for explanatory diagram)[3].
- **Acquisition Area -** The primary target area for a Seismic Survey in which seismic data will be recorded.
- **Active Source Area** - An area including and around the Acquisition Area in which the seismic energy source (airgun array) can be active. This includes survey line run-ins and run outs.
- **Catch Per Unit of Effort (CPUE)** - For the purposes of this protocol the catch will be defined in kilograms of landed catch and the unit of effort will be defined in hours (decimal hours where available) fished for trawl, hours fished or kilometres of line set or number of hooks per kilometre for line fishing, or number of trap lifts, resulting in the landed catch e.g. CPUE=kilograms per (trawl/line) hour or trap lift.
- **Claim Period (Loss of Catch Adjustment) -** The period during and after a Seismic Survey for which a claim can be made for loss of catch adjustment which will be compensated by Titleholder. Period starting from the notified start date of a Seismic Survey and no more than 30 days after the notified end date of a Seismic Survey (45 days for Western Rock Lobster fishers). This Claim Period (Loss of catch Adjustment) is extended for any fisher participating in the Western Rock Lobster Before-After-Control-Impact (BACI) scientific study, for the duration of time that the study remains active in the field. Compensation for CPUE adjustment for 6 fishing trips as part of the WRL BACI study will be allowed.
- **Claim Period (Displacement) -** The period during and after a Seismic Survey for which a claim can be made for displacement which will be compensated by Titleholder. Period starting from the notified start date of a Seismic Survey up to the notified end date of a seismic. This Claim Period (Displacement) is extended for any fisher participating in the Western Rock Lobster Before-After-Control-Impact (BACI) scientific study, for the duration of time that the study remains active in the field. Compensation for Displacement for 6 fishing trips as part of the WRL BACI study will be allowed.
- **Claim Period (Loss/damage of Fishing Gear)** – The period during and after a Seismic Survey for which a claim can be made for loss/damage of gear which will be compensated by the Titleholder. Period starting from the notified start date of a Seismic Survey up to the notified end date of a Seismic Survey.
- **Commercial Fisher** – for the purpose of this protocol, a Commercial Fisher is the entity, person, licence holder, company or affected business who would have received the revenue from the landed catch that is the subject of a claim under this protocol, or who can show they have incurred the cost of lost or damaged Fishing Gear or Displacement.
- **Displacement** – the relocation of commercial fishing activity or other commercial marine operations from an area into other area(s) as a result of a Seismic Survey.
- **Displacement Area** – an alternative fishing ground that is within 50 kilometres of the Adjustment Area (for Western Rock Lobster Commercial Fishers within the same fishing zone).
- **Fishing Gear** - Fishing equipment deployed in the water by a vessel engaged in commercial fishing activity.

[2] 10 kilometres is proposed as a reasonable distance around the Acquisition Area of a Seismic Survey and consistent with existing industry standards.

[3] Spatial parameters of an Adjustment Area for a 2D survey will require case-by- case specification due to the differing survey layout.

- **Historical Fishing Activity** – Commercial fishing operations within a statistical fishing block, or fishing event location (latitude/longitude) plotted within the 10x10nm grid system, with fishing activity data detailed in Government catch and effort information or as recorded in a statutory Catch and Disposal Record for at least two out of the previous five years prior to a relevant Seismic Survey conducted under this protocol. New fishing entrants need to prove that they have entered the fishery less than 5 years before and have historical catch data for at least one of those years, in accordance with the provisions of clause 2.2.6.

- **Historical Fishing Area** – An area within which historical fishing activities have been completed by a Commercial Fisher which in reference to this protocol, overlaps with the Seismic Survey's Acquisition and/or Adjustment Area.

- **Historical Fishing Block** - A statistical fishing block, or fishing event location (latitude/longitude) plotted within the 10x10nm grid system, used to capture fishing activity detailed in Government catch and effort information or recorded in a statutory Catch and Disposal Record.

- **Landed Catch** - The whole landed weight as detailed in Government catch and effort information provided for the purpose of this protocol, or as recorded in statutory Catch and Disposal Records. Fish that is processed in any way before landing, for example gutted and gilled or headed, should be converted back to whole weight for the purpose of this protocol.

- **Lodgement Period (Loss of catch adjustment)** – The period during and after a Seismic Survey within which a claim can be made, which is from the notified start date of a Seismic Survey and no longer than 12 months after the notified end date of a Seismic Survey.

- **Lodgement Period (Displacement)** – The period during and after a Seismic Survey within which a claim can be made, which is from the notified start date of a Seismic Survey and no longer than 183 days after the notified end date of a Seismic Survey.

- **Lodgement Period (Loss/damage of Fishing Gear)** – The period during and after a Seismic Survey within which a claim can be made, which is from the notified start date of a Seismic Survey and no longer than 183 days after the notified end date of a Seismic Survey.

- **Market Price** – The price received by a Commercial Fisher at the point of first landing, excluding any price margins for marketing, transport, sales commissions, value adding or packaging. In respect to a claim under this protocol, the market price should reflect the price at the time the loss of catch was incurred by the claimant.

- **Other Commercial Marine Operator** – means a commercial marine operator who identified they could potentially be impacted by the Seismic Survey during relevant persons consultation in preparation of the relevant EP.

- **Seismic Survey** – an offshore geophysical operation that includes the use of a seismic vessel transiting through a marine area, discharging sounds from a towed airgun array. The seismic vessel commonly towing streamers hosting hydrophones that collect reflected sound waves from subsurface layers. The survey includes the use of support and chaser vessels in addition to the main seismic vessel, to support the survey operations, and enforce environmental and safety standards. An operation undertaken for the purpose of exercising a right conferred on a Titleholder under the OPGGSA by a petroleum title or discharging an obligation imposed on a petroleum Titleholder by the OPGGSA.

- **Statistical Fishing Block** - Government statistical grid/block numbering system used to record commercial fishing activity data and referred to in this protocol as a block.

- **Titleholder** – The registered holder of the Access Authority, Special Prospecting Authority, Exploration Permit, Retention Lease or Petroleum Production Licence over which the Seismic Survey will be acquired, as detailed in the environment plan for the Seismic Survey subject to this protocol.

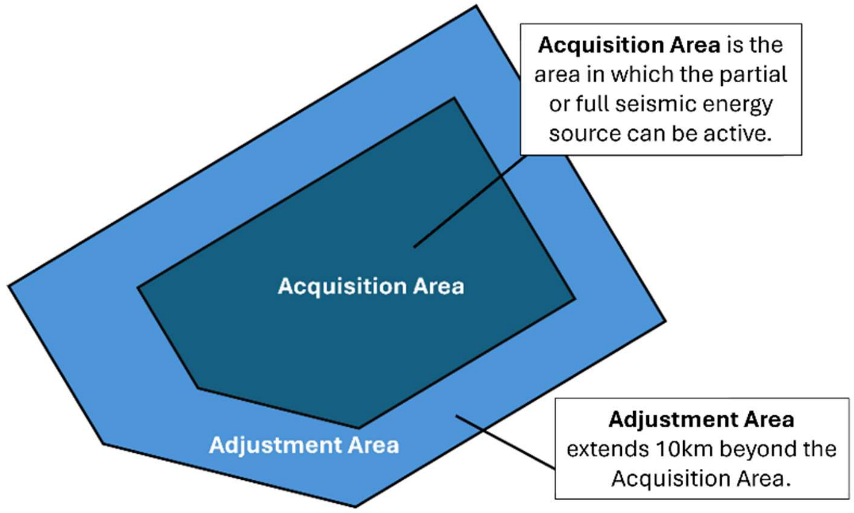


Figure 1 - Representation of defined terms for Acquisition Area and Adjustment Area

1.7. Operation of the protocol

Notification of the establishment of an Adjustment Area will be provided to relevant commercial fishing licence holders in writing no less than 28 days before a Seismic Survey starts. Notification is to be provided in the form of a map (nautical and/or bathymetric) plus digital files in formats such as KML, GPX or shapefiles.

Commercial Fishers (the fishing vessel/licence) must have established previous fishing history, at a minimum of two out of the previous five years, for all block(s) or fishing event(s) for which they wish to make a claim for loss of catch or Displacement adjustment under this protocol.

To receive adjustment under this protocol, a Commercial Fisher must be able to show that they would have received the revenue from the landed catch that is the subject of a claim or show that they have incurred the cost of lost or damaged Fishing Gear.

Adjustment under this protocol is dependent on a Commercial Fisher or Other Commercial Marine Operator continuing to carry out their activities to the best of their ability and to mitigate and limit financial loss despite the occurrence of a Seismic Survey. The Titleholder reserves the right to refuse a claim if fishers interfere with a Seismic Survey deliberately operating in properly notified areas, noting that such interference may also be in breach of Section 603 of the Offshore Petroleum and Greenhouse Gas Storage Act 2006 (See Appendix 7).

Note that this protocol may be referred to in the EP developed by the Titleholder as a control measure to manage potential impacts to commercial fishing licence holders and other marine users, where identified during consultation, and will therefore be subject to inspection under NOPSEMA's environmental inspection program.

2. Commercial Fishing Adjustment Available Under This Protocol

2.1. Displacement

If a Commercial Fisher is unable to fish in their Historical Fishing Area or within an Adjustment Area during a Seismic Survey and incurs costs over and above the normal running costs for a fishing trip while relocating to another Historical Fishing Area, then additional costs associated with increased distance/transit time, fuel and crewing will be considered under this protocol for monetary adjustment. For Displacement, an alternative fishing ground must be within 50 kilometres of the Adjustment Area (Western Rock Lobster Fishers Displacement must occur within the same fishing zone).

For fishers, Displacement will be assessed based on a comparison of the running costs per day at sea against the previous yearly average. A Commercial Fisher who decides it is necessary to relocate to another fishing ground because of a Seismic Survey subject to this protocol and wants to be considered for Displacement adjustment must notify the Titleholder of the Seismic Survey, where possible, prior to undertaking the relocation. When making a claim, evidence must also be provided to substantiate Fishing Gear in use at the claim time.

For Other Commercial Marine Operators, Displacement will be assessed on a case-by-case basis through prior agreement with a Titleholder on the method of calculation.

Timeframes related to the Claim Period (Displacement) and Lodgement Period (Displacement) can be found in Appendix 6.

2.2. Loss of catch adjustment

Evidence-based loss of catch adjustment under this protocol relates to fish lawfully caught and retained by a fishing vessel under a Western Australian or Commonwealth fishing licence. The adjustment process applies to Historical Fishing Activity over established fishing grounds, and not to speculative fishing activity.

The loss of catch adjustment process applies to commercial fishing activity conducted by a licensed fishing vessel within an Adjustment Area, and other fished areas during a month. For each month where adjustment is claimed, the licensed fishing vessel must have conducted fishing within an Adjustment Area, unless a fishing trip spans two months where each month will be considered to have satisfied this requirement.

Timeframes related to the Claim Period (Loss of Catch Adjustment) and Lodgement Period (Loss of catch adjustment) can be found in Appendix 6. This adjustment process assumes that any loss of catch experienced will be evident in a reduced CPUE for that fishing vessel (or license if subject to boat replacement) compared to previous years for the same eligible claim block/fishing event location by species by month.

Loss of catch assessments will be conducted using the Seismic Survey period catch and effort data per month plus the previous 10 years (by same block/fishing event location & month) where available (5 years for Western Rock Lobster fishers).

2.2.1. Method of Assessing Loss of Catch Adjustment

Treatment of catch and effort data to determine eligible fishing events to be included in the adjustment assessment process.

As detailed in this protocol, adjustment is available for fishing activity where it can be shown there is a minimum of two out of the prior five years where fishing activity has taken place in the same block or fishing event location that is the subject of a claim.

This requirement applies to the Adjustment Area and for any other block/fishing event location/area for which adjustment is being claimed.

The first step in conducting a loss of catch adjustment assessment will be to determine which fishing activity is eligible for adjustment under this protocol.

Where catch and effort data are provided in 10 x 10 nm statistical grid format, the same block by month will be checked for the five years preceding the survey year to ascertain the minimum requirement of a minimum of two years fishing activity within the previous five years. Where catch and effort data are provided in larger than 10x10nm statistical grid format, applicants may be asked for additional positional information for blocks that partially overlap the Adjustment Area, or are outside of the Adjustment Area, to assess the minimum fishing history requirement.

Timeframes related to the Claim Period (Loss of Catch Adjustment) can be found in Appendix 6.

10 x 10nm statistical grid format, applicants may be asked for additional positional information for blocks that partially overlap the Adjustment Area, or are outside of the Adjustment Area, to assess the minimum fishing history requirement.

Where catch and effort data are provided by the location of each fishing event by latitude and longitude coordinates the existing Western Australian 10x10nm statistical grid system will be used to assess the minimum fishing history requirement. The start point of each fishing event will be plotted within the 10 nm grid system to aid the assessment of previous fishing history by allocating each event to a 10 nm block to determine fishing events eligible to be included in the adjustment assessment process. Note that assessors have the flexibility to make judgements that will enhance the statistical accuracy of an assessment and/or provide balanced practical assessment outcomes.

2.2.2. Calculating an average CPUE

Catch and effort history covering the prior 10 years is required to provide an average CPUE value that is subject to minimal influence from fish stock recruitment and environmental fluctuations. 5 years of historical data for Western Rock Lobster and Octopus fishers.

CPUE will be defined in kilograms of landed catch and the unit of effort will be defined in hours (decimal hours where available) fished for trawl, hours fished, or kilometres of line set or number of hooks per kilometre for line fishing or number of trap lifts, resulting in the landed catch, for example CPUE = kilograms per trawl/line hour or trap lift. Average CPUE will be based on the mean catch and effort values of all eligible fishing events per claim month.

It is recognised that in some cases, 10 years of catch history data may not be available and where this occurs an assessor should determine an appropriate historical average CPUE based on the information available in the application and any other information that an assessor deems appropriate. Western Rock Lobster Fishery and the Octopus Interim Managed Fishery will use 5 years of catch history data for CPUE assessment calculations.

The use of 10 years prior catch history and the intention of this protocol is that assessments are conducted based on the available catch and effort information. However, an assessor may also consider significant catch trends within a fishery and/or management changes if they are thought to materially affect resulting catch rates or landed catch volumes.

2.2.3. Loss of Catch Adjustment Assessment Method

1. Claim Period (Loss of Catch Adjustment) must contain fishing activity within the Acquisition and/or Adjustment Area.
2. A claimant must have Historical Fishing Activity for each block or fishing event location subject to a claim.
3. Yearly historical average CPUEs (up to 10 years) will be calculated for all eligible fishing events fished in the claim month, by species, and then averaged to provide a baseline historical average CPUE for the claim month. Western Rock Lobster and Octopus fishers to use a 5-year window of historical fishing data.
4. The claim month actual average CPUE will be calculated for eligible fishing events by species by month.
5. The CPUE for the month/s and block/s being claimed for will then be compared to the baseline historical average CPUE calculated for the same block/fishing events and month/s, and where a shortfall is established, an adjustment will be calculated.
6. The shortfall in CPUE will be multiplied by the unit of effort (hours, kilometres of line set/number of hooks per kilometre, number of trap/pot lifts) fished for that claim month, and then the grouped species Market Price, to provide the amount of monetary adjustment due for that month.
7. Adjustment can be calculated for individual species or combined as appropriate.

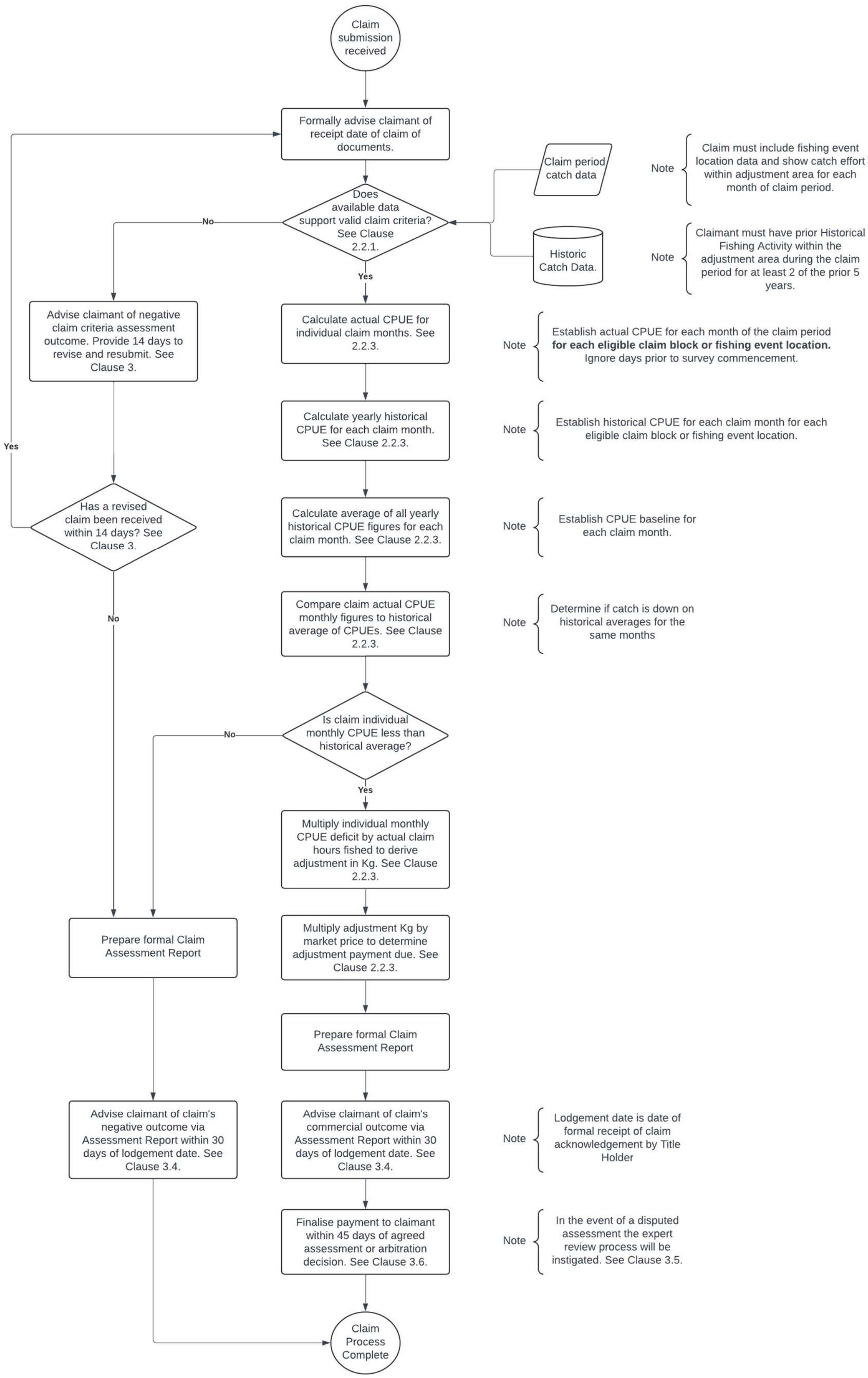
2.2.4. Adjustment method loss of catch adjustment calculation example

Claim month April 2020	Species - Narrow Barred Mackerel. Troll hours fished 100. Market price $17 per kg. Total catch 8,200kgs.
Claimant has Historical Fishing Activity within Adjustment Area prior to April 2020	Condition met
Claimant fished in Adjustment Area during April 2020	Condition met
April historical baseline CPUE	100 kgs per hour
April 2020 CPUE	82 kgs per hour
Shortfall in CPUE	18 kgs per hour
Shortfall multiplied by 100 hours fished in April 2020	1,800 kgs
1,800 kgs multiplied by market price of $17 per kg	$30,600
Monetary adjustment due for April 2020	$30,600

Claim month February 2025	Species – Western Rock Lobster. Pot lifts in February 2025, 2000. Market price $40 per kg. Total catch 4000kg
Claimant has Historical Fishing Activity within the Adjustment Area prior to February 2025	Condition met
Claimant fished in Adjustment Area during February 2025	Condition met
February historical baseline Effort	Average 2500 pot lifts
February historical baseline CPUE	Average 2.8kg/pot lift
February historical catch	7000 kg
February 2025 Effort	2000 pot lifts
February 2025 CPUE	2kg/pot lift
February 2025 Catch	4000kg
Shortfall in Effort	500 pot lifts
Shortfall in CPUE	0.8kg/potlift
Shortfall in Catch	3000kg
Catch Shortfall in February 2025	X = 3000kg
X multiplied by Market Price of $40* per kg	Y = $120,000
(less) Marginal Costs of fishing at $25/potlift	Z = - $12,500
Y - Z = Monetary adjustment due for February 2025	$107,500

The full loss of catch assessment process is detailed in the flow chart on the following page.

2.2.5. Loss of Catch Assessment Flow Chart



2.2.6. Exceptions to loss-of-catch assessment method information requirements.

Where a fisher is unable to provide 10 years prior catch and effort data due to Government confidentiality requirements or other reason, an assessment may still be conducted subject to the claim assessor being satisfied that an accurate assessment can still be conducted using the volume of data available.

If the fisher is a late entrant to the region and does not have data to back up their claim that they have historically fished in the Operational Area for 5+ years, the new entrant must demonstrate that they have less than five years' experience with the fishery but have fished in the Acquisition Area at least once. In this instance the claims assessor may use an average of other fishers catch-and-effort data to determine probable catch numbers.

If requested by the claimant, an assessment may be conducted using a fisher's own catch and effort data where a claim assessor forms the view that the data is consistent with Government data accuracy and formatting and that the data is suitable to conduct an accurate assessment.

The loss of catch adjustment process under this protocol does not cover circumstances where there may be discussions and/or agreement reached between a Seismic Survey Titleholder and a Commercial Fisher prior to a survey taking place, that it is not appropriate for fishing to occur within the area of a Seismic Survey. Likewise, if a Commercial Fisher feels that they will be disadvantaged by a Seismic Survey due to alternative suitable fishing grounds not being available to them during the Seismic Survey, then they should engage with the Titleholder ahead of a survey commencing.

A Commercial Fisher wishing to lodge a claim for adjustment should notify the Titleholder of their intention to lodge a claim as soon as possible after the conclusion of operations of a Seismic Survey and timeframes relating to Claim Period (Loss of Catch Adjustment) and Lodgement Period (Loss of Catch Adjustment) can be found in Appendix 6.

2.3. Fishing gear loss or damage

A Commercial Fisher may lodge a claim in accordance with this protocol if they experience accidental loss or damage of deployed Fishing Gear from physical contact with a Seismic Survey vessel and/or it's in-water equipment or supporting vessels during a Seismic Survey subject to this protocol.

Through pre-survey notifications and communications, Titleholders and Commercial Fishers should have an awareness of survey and fishing activities and make all reasonable efforts to avoid direct interaction and Fishing Gear loss or damage. It should be noted that Seismic Survey vessels carrying out seismic acquisition identify as 'vessel restricted in her ability to manoeuvre' under international marine navigation laws. The Titleholder reserves the right to refuse a claim if fishers interfere with a Seismic Survey deliberately operating in properly notified areas, noting that such interference may also be in breach of Section 603 of the Offshore Petroleum and Greenhouse Gas Storage Act 2006 (See Appendix 7). If a Commercial Fisher has prior awareness of their Fishing Gear being within the Operational Area during the Seismic Survey, Pilot Energy must be informed of the exact location(s) of the Fishing Gear prior to the activity commencing and seek agreement from Pilot Energy that the vessel has capability of navigating around Fishing Gear, alternatively, enter into a cooperative agreement allowing Pilot to lift and redrop Fishing Gear, to entitle the fisher to claim compensation for Fishing Gear loss or damage in this circumstance.

If Fishing Gear loss or damage occurs, the Commercial Fisher should immediately notify the Titleholder.

When lodging a claim, the claimant should clearly document when, where and how the gear damage or loss occurred and where possible, the name and details of vessel(s) involved in the incident. A claim should include a quote (two where possible) with costs associated with repairing or replacing the lost or damaged Fishing Gear.

As a result of assessing the claim, by mutual agreement with the claimant, the Titleholder may offer to cover the cost of repairing or replacing the damaged Fishing Gear or providing like-for-like replacement equipment.

Fishers making a claim for lost or damaged gear may also make a CPUE based claim for the lost catch associated with the lost or damaged gear for time damaged/lost gear spent in the water. Compensation will not be covered for lost time out of the water where Fishing Gear is under repair, unless under exceptional circumstances where 10+ pots have been affected. The Titleholder can discuss this issue on an individual bases with the claimant.

In the event a claim for forgone catch has been submitted, the Titleholder may (at their sole expense) enlist the services of an independent person or organisation to assess the claim. If agreement cannot be reached between the claimant and Titleholder, then refer to the independent expert review provisions in the *How long will it take to deal with my claim and independent expert review process section of this protocol*.

Timeframes for the Claim Period (Loss/damage of Fishing Gear) and Lodgement Period (Loss/damage of Fishing Gear) can be found in Appendix 6.

3. Claim Information and Assessment Process

Titleholders conducting a Seismic Survey in accordance with an EP subject to this protocol will provide a centralised contact point and online portal to relevant Commercial Fishers/marine operators relating to lodging a claim or notification regarding Displacement, loss of catch, or Fishing Gear loss or damage, as relevant. Contact information will also be provided to relevant fishing associations as the respective peak commercial fishing industry bodies.

All information provided in an application under this protocol must be kept confidential by the Titleholder, an assessor or expert reviewer of a claim and any other person who has access to the information.

Provided a claimant can demonstrate the required previous fishing history within an Adjustment Area, if all the remaining information requirements set out in this protocol are not available to a claimant, then such claims will be considered on a case-by-case basis, in consultation with the nominated competent assessor. For example, if a Commercial Fisher, whose regular fishing grounds are within the Displacement Area, believes they are indirectly affected by another Commercial Fisher who has been displaced and has moved into the first fishers regular fishing grounds they may qualify as a claimant under the CPUE adjustment process detailed above.

An option for applicants lodging a claim is to authorise an assessor to access the relevant fishing catch and effort information directly with the appropriate Government Department. Alternatively, applicants may provide the required Government catch and effort information with their claim application.

Applicants will receive confirmation of a claim being lodged with the Titleholder. If an assessor forms the view that the information lodged with a claim is not sufficient to conduct a meaningful assessment or support the application, then the claimant will be advised in writing and given 14 days to respond to the assessor. If no response is received within 14 days, then the assessment will be completed, and the claimant advised of the outcome.

Claims will be assessed by separate monthly fishing activity, with each month assessment outcome not influencing or impacting on any other month's assessment outcome. This protocol outlines the adjustment processes in a manner to provide consistent assessments over time. However, assessors have the flexibility to make judgements that will enhance the statistical accuracy of an assessment and/or provide balanced practical assessment outcomes.

For fully documented claims that meet the Adjustment Area historical fishing/usage activity requirement, whether successful or not, clerical costs relating to preparing, submitting, and engaging in the adjustment process under this protocol, up to a value of $2,000 per claim, will be reimbursed by the survey Titleholder as part of the claim process. A statement outlining time and resource costs to support an amount up to $2,000 should be included with a claim. Clerical costs that exceed $2,000 may also be included with a claim and reimbursed under this protocol if evidenced by documentation.

3.1. Who can lodge a claim and when?

A Commercial Fisher who is an affected person who has suffered Displacement, a loss of catch, or gear loss or damage whilst operating in and around a Seismic Survey Adjustment Area subject to this protocol, can lodge an adjustment claim during the lodgement.

Other Commercial Marine Operators, identified during relevant persons consultation during the preparation of the relevant EPs, who suffers Displacement whilst operating in and around a Seismic Survey Adjustment Area, subject to this protocol can lodge an adjustment claim.

A person so authorised may lodge a claim on behalf of a Commercial Fisher/marine operator. Claims may be lodged by a person, company, or association on behalf of more than one Commercial Fisher/marine operator, provided that the required individual usage/catch history is provided and there is evidence of the authority to lodge the claim on behalf of others.

Timeframes related to Claim Period (Loss of Catch Adjustment) can be found in Appendix 6.

3.2. What information is needed to lodge a claim?

Claimants will need to be able to identify the relevant vessel and licence(s) that are involved in the claim, and to provide evidence of the entity that would have received the revenue that is the subject of a claim. For Commercial Fishers, a key information requirement when lodging a loss of catch claim will be to either authorise access to the relevant Government catch and effort data or provide the catch and effort data with the application. For Other Commercial Marine Operators, the information needed for lodging a claim will have been agreed between the Titleholder and the entity that would have received the revenue that is the subject of a claim.

Full details on the information required to be lodged with a claim are contained in the application forms at:

- Appendix 2 – Consent and Confidentiality Form
- Appendix 3 – Displacement Application Form
- Appendix 4 – Claim for Loss-of-catch Application Form
- Appendix 5 – Fishing Gear Loss or Damage Application Form

Each claim should relate to only one Seismic Survey and associated Titleholder.

3.3. Who will assess the claims and what information will be in the report?

Subject to a claim being lodged, the Titleholder of a Seismic Survey (at their expense) in consultation with the claimant, will engage a suitably experienced/qualified independent person or organisation as the assessor of the claim. The selection will be predicated on a nominated individual put forward by the relevant fishery bodies, as having extensive, documented experience with the commercial fishing industry and verifiable ability to quantify catches. Any conflicts of interest must be disclosed as a condition of engagement.

The Titleholder is to provide the assessor with a letter of instruction/project brief, which is to be provided to the claimant as part of the assessment report.

An assessment report prepared by an assessor should include the following information:

- a copy of the letter of instruction/project brief received by an assessor when engaged to carry out the independent assessment,
- confirmation (or otherwise) that the information provided in the claim is sufficient to conduct a meaningful assessment,
- a summary of the claim details (survey, applicant, vessel, month(s)),
- for a loss of catch claim, monthly CPUE assessments as outlined in this protocol including an estimation of any loss of catch (in kilograms) and its Market Price, and

- any other information, comments, or views relevant to the assessment that the assessor may wish to include.

Upon receiving and considering the assessment report, the Titleholder will provide a copy of the report to the claimant and offer to meet with the claimant to discuss/address the claim. The claim assessment will be transparent, auditable and appealable.

3.4. How long will it take to deal with a claim?

An appropriately documented claim (including relevant catch and effort information) should be assessed, and a report provided to the claimant within 30 days of the lodgement date of the claim. If an assessor is authorised to access catch and effort data, then the 30-day period begins upon receipt of the necessary catch-and-effort data. If an appropriately documented claim report cannot be made available to the claimant within 60 days of a claim being lodged or receipt of catch and effort information as appropriate, and no mutual agreement to extend the time period has been entered into, then the Titleholder (at their expense) in consultation with the claimant, shall appoint a suitably experienced/qualified independent person or organisation to provide an expert review of the claim.

Included as part of the settlement of each claim, will be a binding agreement that summarises the claim outcomes and an agreement by the claimant that acceptance of the settlement negates any further claims for the same species and month(s) of that Seismic Survey.

3.5. Independent expert review of a claim

If a claimant disagrees with a claim assessment outcome and cannot reach agreement with the Titleholder, they may opt to go to an independent expert review (funded by the Titleholder of the survey).

If a claim is subject to independent expert review, then as part of that process, both the claimant and the Titleholder shall be given the opportunity to address the assessor to state their position, prior to an independent expert review decision being reached.

An independent expert reviewer must provide a view as to whether the claim assessment process has been conducted in line with the requirements of the protocol. The independent expert reviewer may also consider any additional information deemed appropriate by themselves, including information provided by either the claimant or the Titleholder. An independent expert review decision is binding on the claimant and the Titleholder and may differ from the initial assessment report. A timeline diagram setting out the relevant time frames under this protocol can be found at Appendix 6.

3.6. How long will it take to be paid adjustment?

Once a claimant and Titleholder agree with a claim outcome, or an expert reviewer has issued a report, the Titleholder will provide monetary adjustment to the claimant as soon as possible or within a maximum of 45 days.

4. Protocol Review and Maintenance

This protocol will remain in force for the validity period of any accepted EP for Pilot Energy. The protocol will be subject to review and update by KSV and Pilot Energy at least once in each 12-month period. Changes will be considered in consultation with relevant fishing associations (and other stakeholders as appropriate) and subject to agreement by the Titleholder members.

The forms in the Appendices will be made available for download through the Eureka website, or online forms may be used to submit a claim.

Appendix 1: Eureka Compensation Protocol Members

Founding Members

- Pilot Energy Ltd
- Klarite Sustainable Ventures Pty Ltd

Appendix 2: Consent and Confidentiality Form

CATCH & EFFORT and CATCH DISPOSAL RECORDS CONSENT

Records from this year and previous years are needed to support your claim. Please complete the following consent form for lodgement with the appropriate fisheries management agency.

I, (insert name) .... give permission to the Klarite Sustainable Ventures nominee to have access to my (insert fishery) .... catch and effort records at (fisheries management agency) ....

I affirm that the fishing cooperatives listed below (leave blank if not applicable):

(insert fishing cooperative) .... receive (insert percentage) ....% of my landed catch.

(insert fishing cooperative) .... receive (insert percentage) ....% of my landed catch.

(insert fishing cooperative) .... receive (insert percentage) ....% of my landed catch.

I, (insert name) .... do:

a. Certify that the details and particulars in this application are true to the best of my knowledge, information, and belief; and

b. Acknowledge that the making of a false statement is unlawful and open to prosecution.

c. Understand that my data will be kept confidential and only used for the purposes of assessing a compensation claim by an authorised assessor as a result of Eureka 3D Marine Seismic Survey operations.

Signed: .... Date: ....

Appendix 3: Displacement Application Form

Commercial Fishing Industry Adjustment Protocol - Application Form for Displacement Claim

Application Form - Commercial Marine Operator Adjustment Protocol - Displacement 1 of 2	
Survey Details	
Seismic Survey name	
Seismic Survey Titleholder	
Claimant Details	
Name of person/company making claim	
Address	
Email	
Contact number	
I am the entity that would have received the revenue from the catch that is the subject of this claim. Please include evidence of above statement	Yes or No
Relevant authorisation holder details (if different from claimant)	
Name	
Address	
Email	
Contact number	
Authorisation/licence(s) name and number	
Claim details	
Evidence of the additional distance, fuel and crew costs incurred by the relocation of the fishing/other marine operation.	Attach receipts/evidence of costs for claim month. Include vessel track data, fuel receipts, transit time, distance travelled etc.
Evidence of previous year daily (at sea) average distance, fuel and crew costs	Attach receipts/evidence of costs for previous year.

Application Form - Commercial Marine Operator Adjustment Protocol – Displacement 2 of 2
Include five years catch data preceding the year of the claim in the following form: • Vessel • Year • Month • Fishery • Fishing event location/blocks fished provided at the highest available block resolution. • Whole weight calculated based on the reported landed weight and listing any relevant conversion factor(s). For Other Commercial Marine Operators, include five years Historical Fishing Area usage data preceding the year of the claim in the following form: • Vessel • Year • Month • Location provided at the highest available resolution. Note 5 years of data is required for Displacement purposes to show recent operational history has occurred within an Adjustment Area. If less than 5 years data available, then claim assessor should evaluate appropriate method of assessment.
Please list the documents provided with your application
1.
2.
3.
4.

Appendix 4: Loss of Catch Application Form

Commercial Fishing Industry Adjustment Protocol - Application Form for Loss of Catch claim

Application Form - Commercial Marine Operators Adjustment Protocol - Loss of Catch 1 of 2	
Seismic Survey Details	
Seismic Survey name	
Seismic Survey Titleholder	
Claimant Details	
Name of person/company making claim	
Address	
Email	
Contact number	
I am the entity that would have received the revenue from the catch that is the subject of this claim. Please include evidence of above statement	Yes or No
I wish to authorise direct access to my catch and effort history relevant to this application.	Yes/No (If yes then authorisation holder to sign here)
Relevant authorisation holder details (if different from claimant)	
Name	
Address	
Email	
Contact number	
Authorisation/licence(s) name and number	
Claim details	
Months for which loss of catch adjustment is being claimed	

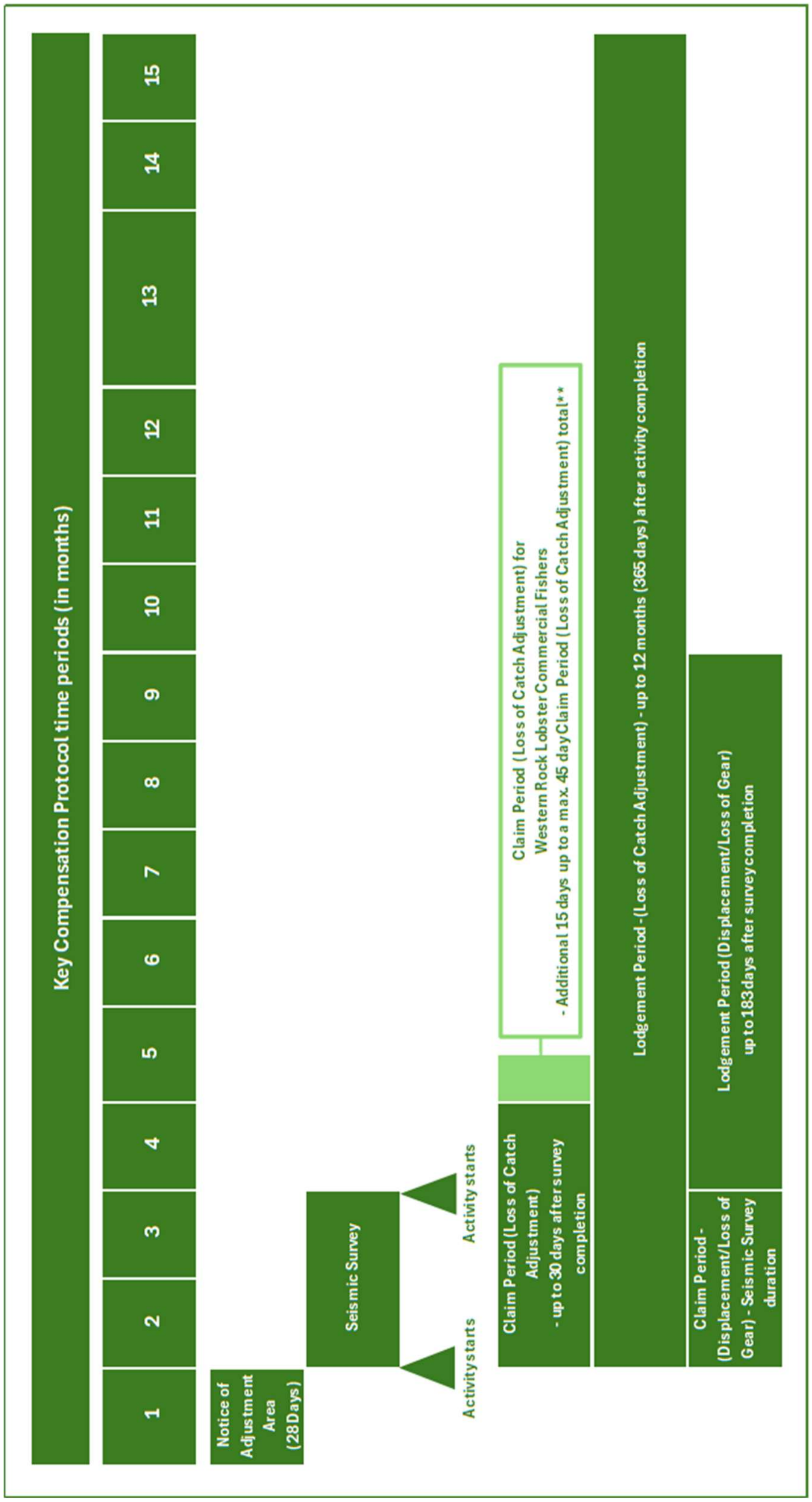
Application Form - Commercial Marine Operators Adjustment Protocol - Loss of Catch 2 of 2	
Market Price information – please include documentary evidence of price received from normal buyer/processor for catch relevant to loss of catch claim.	
Catch and effort information for blocks/area by month by species for which loss of catch is being claimed plus previous 10 years (5 years for Western Rock Lobster fishers). If 10 years Government catch history is not available and/or or you wish to provide your own validated catch history, please indicate here.	Indicate whether Government or own catch and effort data is being provided and number of previous years of data available.
NOTE: If any information is not available from Government and fishers own catch data is being submitted, then copies of the relevant statutory catch and effort fishing returns should be submitted with the claim.	
Catch and effort information should be provided in the form of: • Vessel • Year • Month • Fishery • Blocks fished provided at the highest (e.g., 10x10nm) available block resolution, or fishing event locations (by latitude and longitude). • Block days including fishing events in identified area/blocks per month. • Fishing hours (in decimal hours) showing the duration of each fishing event at highest available block/fishing event resolution. • Whole weight calculated based on the reported landed weight and listing the relevant conversion factor(s) if applicable.	
Other relevant information may be submitted with a claim and will be assessed on a case-by-case basis. Questions regarding the claim process may be directed to a person nominated by the Titleholder.	
Please list the documents provided with your application	
1.	
2.	
3.	
4.	

Appendix 5: Fishing Gear Loss or Damage Application Form

Application Form - Commercial Marine Operators Adjustment Protocol – Fishing Gear loss or damage	
Seismic Survey details	
Seismic Survey name	
Seismic Survey Titleholder	
Claimant Details	
Name of person/company making claim	
Address	
Email	
Contact number	
I am the entity that has incurred the costs of the lost or damaged Fishing Gear that is the subject of this claim. If claiming for loss of catch, I am the entity that would have received the revenue from the catch that is the subject of this claim. Please include evidence of above statements.	Yes or No and supporting information.
I wish to authorise direct access to my catch and effort history relevant to this application.	Yes/No (If yes then authorisation holder to sign here)
Relevant authorisation holder details (if different from claimant)	
Name	
Address	
Email	
Contact number	
Authorisation/licence(s) name and number	
Claim details	
Evidence of notification to the Titleholder of the gear loss and/or damage incident.	
Information describing when, where, and how the gear damage and/or loss occurred.	

Where possible, the name and details of vessel(s) involved in the incident.	
A claim should include a quote (two where possible) with costs associated with repairing or replacing the lost or damaged Fishing Gear.	
Estimate of any proportionate loss of catch including Market Price, plus catch and effort information sufficient to calculate CPUE for claim month or same month in previous year.	
Please list the documents provided with your application	
1.	
2.	
3.	
4.	

Appendix 6: Eureka Commercial Fisher Compensation Protocol Timeframes



** This Claim Period (Loss of catch Adjustment) and Claim Period (Displacement) are extended for any fisher participating in the Western Rock Lobster Before-After-Control-Impact (BACI) scientific study, for the duration of time that the study remains active in the field. Compensation for CPUE adjustment for 6 fishing trips as part of the WRL BACI study will be allowed.

Timeframes for making a claim:

1. Titleholder to provide 28-day notice of a future Adjustment Area including a map and coordinates.

2. Titleholder to provide notice of Seismic Survey start and Seismic Survey end through the Eureka website.

3. Time periods for claims and lodgements:
    1. Claim Period (Loss of Catch Adjustment) – up to 30 days after Seismic Survey completion.
    2. Claim Period (Displacement) – For the duration of the Seismic Survey.
    3. Claim Period (Loss/damage of Fishing Gear) – for the duration of the Seismic Survey.
    4. Lodgement Period (Loss of Catch Adjustment) – up to 12 months (365 days) after Seismic Survey completion.
    5. Lodgement Period (Displacement) – up to 183 days after Seismic Survey completion.
    6. Lodgement Period (Loss/damage to Fishing Gear) – up to 183 days after Seismic Survey completion.

4. Any fisher participating in the Western Rock Lobster Before-After-Control-Impact (BACI) study will be subject to an extended Claim Period (Loss of catch Adjustment) and Claim Period (Displacement) for the duration of time that the study remains active in the field. Compensation for CPUE adjustment for 6 fishing trips as part of the WRL BACI study will be allowed.

Timeframes for processing a claim:

1. Claims to be finalised within 30 days of being lodged, or receipt of catch and effort information, unless mutual agreement reached between claimant and Titleholder to extend time frame.

2. If agreement cannot be reached between the Titleholder and claimant within the prescribed times above then the Titleholder, in consultation with the claimant, must appoint an independent expert reviewer to decide the claim.

3. Subject to an independent expert review decision, the Titleholder shall settle the claim in accordance with the decision within 60 days.

Appendix 7: Legislation Section 603

Offshore Petroleum and Greenhouse Gas Storage Act 2006

No. 14, 2006

Compilation No. 54

Compilation date: 18 October 2023

Includes amendments up to: Act No. 74, 2023

Registered: 21 October 2023

603 Interfering with offshore petroleum installations or operations

(1) A person commits an offence if:

(a) the person engages in conduct; and

(b) the person's conduct results in:

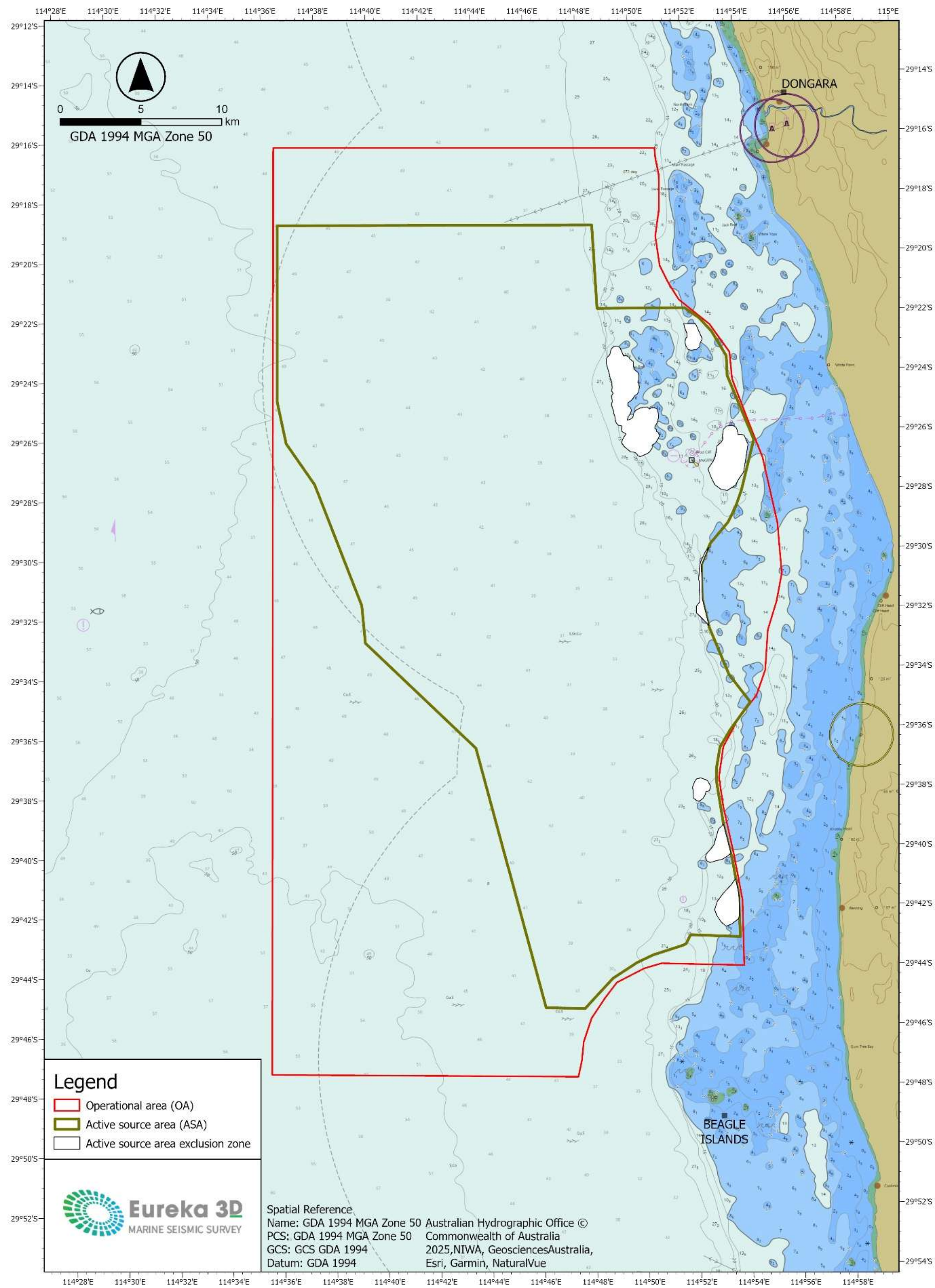
(i) damage to, or interference with, any structure or vessel that is in an offshore area and that is, or is to be, used in exploring for, recovering, processing, storing, preparing for transport, or transporting, petroleum; or

(ii) damage to, or interference with, any equipment on, or attached to, such a structure or vessel; or

(iii) interference with any operations or activities being carried out, or any works being executed, on, by means of, or in connection with, such a structure or vessel.

Penalty: Imprisonment for 10 years.

Appendix 8: Eureka 3D MSS Nautical Map & Coordinates



Coordinates of Eureka seismic survey GDA94:

Operational area		Active source area	
Latitude	Longitude	Latitude	Longitude
-29.270842	114.606743	-29.7548	114.7702
-29.274973	114.849632	-29.6088	114.7284
-29.30962	114.851687	-29.5489	114.6592
-29.350656	114.856948	-29.5278	114.6573
-29.389779	114.895096	-29.4597	114.6288
-29.449083	114.915039	-29.4364	114.6111
-29.514094	114.92597	-29.4131	114.606
-29.568026	114.914272	-29.3145	114.6083
-29.596011	114.895846	-29.3174	114.8087
-29.627502	114.883474	-29.3641	114.8112
-29.696458	114.897106	-29.3646	114.8668
-29.733026	114.89746	-29.3919	114.893
-29.731198	114.844435	-29.4029	114.8934
-29.741452	114.815726	-29.439	114.9096
-29.761163	114.799096	-29.485	114.8922
-29.793673	114.790001	-29.4968	114.8806
-29.789274	114.593941	-29.5437	114.879
-29.270842	114.606743	-29.5857	114.9044
		-29.6228	114.8819
		-29.7171	114.8953
		-29.7155	114.8635
		-29.7205	114.8605
		-29.7391	114.8133
		-29.7557	114.7951
		-29.7548	114.7702

APPENDIX E: OIL POLLUTION EMERGENCY PLAN

Pilot Energy

Eureka 3D Marine Seismic Survey

Revision	Date	Reason for issue	Reviewers	Approvers
A	13/03/2023	Internal Review		
B	26/07/2023	Internal Review		
0	06/12/2023	Issued for Use	RPS	RPS

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Terms

Term/Acronym	Definition
3D	Three dimensional
ADIOS2	Automated Data Inquiry for Oil Spills 2.0
AFMA	Australian Fisheries Management Authority
AMOSC	Australian Marine Oil Spill Centre
AMSA	Australian Marine Safety Authority
BAOAC	Bonn Agreement Oil Appearance Codes
CEO	Chief Executive Officer
CMT	Crisis Management Team
DBCA	WA Department of Biodiversity Conservation and Attractions
DCCEEW	Cwth Department of Climate Change, Energy, the Environment and Water
DWER	WA Department of Water and Environmental Regulation
DFAT	Cwth Department of Foreign Affairs and Trade
DISR	Cwth Department of Industry, Science And Resources
DMIRS	WA Department of Mines, Industry Regulation and Safety
DoT	WA Department of Transport
DPIRD	WA Department of Primary Industries and Resource Development
EMBA	Environment that May Be Affected
EMSA	European Maritime Safety Authority
EP	Environment Plan
ERT	Emergency Response Team
ESC	Environmental Scientific Coordinator
FOB	Forward Operating Base
GIS	Geographic Information System
GPS	Global Positioning System
HMA	Hazard Management Authority
IAP	Incident Action Planning
ICC	Incident Command Centre
IMT	Incident Management Team
IPIECA-IOGP	International Petroleum Industry Environmental Conservation Association - International Association of Oil & Gas Producers
ITOPF	International Tanker Owners Pollution Federation
JSA	Job Safety Analysis
MARPOL	International Convention for the Prevention of Pollution from Ships
MDO	Marine Diesel Oil
MEE	Maritime Environmental Emergencies
MEECC	Maritime Environmental Emergency Coordination Centre (DoT)
MEER	Maritime Environmental Emergency Response (unit) (DoT)
MGO	Marine Gas Oil

Term/Acronym	Definition
MNES	Matters of National Environmental Significance
MSS	Marine Seismic Survey
NEBA	Net Environmental Benefit Analysis
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NOPTA	National Offshore Petroleum Titles Administrator
OMP	Operational Monitoring Plan
OPEP	Oil Pollution Emergency Plan
OPGGS (Env)	Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (OPGGS (Env) Regulations)
OPGGS Act	*Offshore Petroleum and Greenhouse Gas Storage Act 2006*
OPICC	Offshore Petroleum Incident Coordination Committee
OSC	On Scene Commander
OSCP	Oil Spill Contingency Plan
OSM-BIP	Operational and Scientific Monitoring – Bridging Implementation Plan
OSTM	Oil Spill Trajectory Modelling
OWR	Oiled Wildlife Response
POLREP	Pollution Report
PPE	Personal Protective Equipment
RCC	Rescue Coordination Centre (AMSA)
SEMC	State Emergency Management Committee
SHP-MEE	Western Australian State Hazard Plan for Maritime Environmental Emergencies
SIMA	Spill Impact Mitigation Assessment
SIMAP	Spill Impact Mapping and Analysis Program
SMP	Scientific Monitoring Plan
SMPC	State Marine Pollution Coordinator (DoT)
SMPEP	Shipboard Marine Pollution Emergency Plan
SOPEP	Shipboard Oil Pollution Emergency Plan
WA	Western Australia
WAOWRP	Western Australian Oiled Wildlife Response Plan

First strike activations

The initial response to an oil spill incident will be undertaken by the 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, which will include notification to the relevant Control Agency (refer to Section 2.2 and 2.3).

Table A-1 outlines the first strike response actions that need to be followed in the event of a spill.

Table A-1: First strike actions

Responsibility	Actions
Observer	❑ Provide details of the incident to the Vessel Master.
Vessel Master/On-Scene Commander (OSC)[1]	❑ Monitor the safety of all personnel. ❑ Take immediate actions to control the source of the spill, in accordance with the vessel-specific SOPEP. ❑ If source control is not possible, ensure vessel safety by clearing the immediate vicinity of the spill, if possible. ❑ Conduct risk assessment and assess safe approach routes. ❑ Contact relevant Jurisdictional Authority and Control Agency, as soon as practicable, to inform them of the incident, providing as much information as possible via POLREP (Refer to Table 2-2 for a description of Jurisdictional Authorities and Control Agencies). ❑ Notify Pilot Energy Survey Representative of the spill.
Pilot Energy Survey Representative on vessel	❑ Notify the Pilot Energy Duty Manager of the incident and ensure source control measures being implemented. ❑ Aid the Vessel Master/OSC in preparing the POLREP[2] and provide as much information[3] to the Incident Management Team (IMT) as soon as practicable, including: – Name and details of vessel – Location and coordinates – Date and time the release occurred or was first reported – How it was detected – Names of any witnesses – Hydrocarbon type (e.g. Marine Diesel Oil (MDO)), any Material Safety Data Sheets – Vessel's Oil Record Book (contains information on volumes and contents in each tank) – Cause of the spill (e.g. collision) – Source of spill (e.g. fuel tank) – Approximate volume of spill (better to overestimate) – If the spill is controlled or continuous – Weather, tide and current details – Trajectory of the spill (what direction is the slick spreading) – If any fauna has been observed nearby (e.g. whales, dolphins, seabirds)

1 The Vessel Master may act as the OSC or nominate a delegate for this role.

2 This information will also be required when completing incident reports and reports to external agencies.

3 Some details may be limited in the initial POLREP. Aim to get the initial report submitted as soon as possible and follow up with more detail as it becomes available.

Responsibility	Actions
	– Notifications undertaken. ❑ Provide updated POLREPs to the IMT as required. ❑ Use personal Incident Log to record events. ❑ Take photos and send to the IMT, if possible.
Duty Manager/ IMT Operations Section Chief Note: Duty Manager may take on the role of IMT Operations Section Chief or handover command to the IMT Operations Section Chief	❑ Notify Incident Commander as soon as practicable that an incident has occurred and determine if IMT activation is required. ❑ Ensure IMT has been activated (if required). ❑ Confirm incident report and capture key details relating to the incident (obtain POLREP). ❑ Undertake external notifications and reporting (Refer to Section 4). ❑ Remain as the sole liaison and communication interface between the IMT Incident Commander and the Pilot Energy Survey Representative on the vessel.
IMT Incident Commander	❑ Evaluate initial incident report. ❑ Maintain contact with Control Agency to confirm actions (Australian Marine Safety Authority (AMSA) or Western Australian Department of Transport (WA DoT) IMT) (see Section 2.2). ❑ Confirm level of the incident in consultation with Control Agency. ❑ Activate IMT in consultation with Duty Manager/Operations Section Chief. ❑ Notify Crisis Duty Manager Leader of incident (if level 2 or 3). ❑ Remain as the decision-making interface between the IMT and the Crisis Management Team (CMT) Leader.

Once first strike actions are completed and initial notifications to the Control Agency are made, Pilot Energy shall maintain direct contact with the Control Agency and act as a Supporting Agency throughout the response. This includes providing essential services, personnel, material or advice in support of the Control Agency. In addition, Pilot Energy will implement monitoring activities as outlined in the Eureka 3D Marine Seismic Survey Operational and Scientific Monitoring Bridging Implementation Plan (OSM-BIP) (Appendix H).

1. Introduction

1.1 Purpose

This Oil Pollution Emergency Plan (OPEP) outlines oil spill response arrangements for spill scenarios that may occur from a three dimensional (3D) seismic survey undertaken within the Operational Area for the Eureka 3D Marine Seismic Survey (MSS) Environment Plan (EP) (**Error! Reference source not found.**). It describes the spill response management arrangements, protection priorities and the process for selecting suitable oil spill response strategies.

This OPEP addresses the requirements of the Offshore Petroleum and Greenhouse Gas Storage (OPGGS) (Environment) Regulations 2009 and forms a supporting document to the Eureka 3D MSS EP. It is also consistent with the National Plan for Maritime Environmental Emergencies (National Plan) (AMSA, 2020) managed by AMSA and the Western Australian (WA) State Hazard Plan for Maritime Environmental Emergencies (SHP-MEE) (DoT, 2021).

1.2 Scope

This OPEP only applies to acquisition of the proposed Eureka 3D MSS. It excludes all other petroleum related activities. It also excludes marine hydrocarbon spills originating from vessels outside of the Eureka 3D MSS EP Operational Area, which will be addressed by the vessel's SOPEP or Shipboard Marine Pollution Emergency Plan (SMPEP), as applicable to vessel class.

Refer to Section 3 of the Eureka 3D MSS EP for further details on the activity.

1.3 Location

This OPEP applies to a hydrocarbon spill originating within the Eureka 3D MSS Operational Area, which is located within Commonwealth waters off the mid-west coast of Western Australia (WA) (**Error! Reference source not found.**), within the northern Perth Basin, in exploration permit area WA-481-P and associated AA and SPA areas.

1.4 Objectives

The objectives of this OPEP are to:

- Meet the requirements of the OPGGS (E) Regulations.
- Provide alignment with arrangements in the WA State Emergency Management Plan (SEMC, 2022), specifically the WA SHP-MEE and the National Plan.
- Define the oil spill response arrangements that are in place for the credible spill scenarios.
- Provide guidance to the IMT in relation to spill response selection and response implementation.
- Provide procedures for identifying appropriate resources to support a marine hydrocarbon spill response associated with a seismic survey.

1.5 Interface with internal documents

In addition to this OPEP, a number of other Pilot Energy documents provide guidance and instruction relevant to the spill response, including:

- Pilot Energy Emergency Response Procedure (PE-05-PRO-003)
- Pilot Energy Incident Management Procedure (PE-07-PRO-001)
- Eureka 3D MSS OSM-BIP (Appendix H).

Other documents, including an emergency contact form, will be generated to meet the specific requirements of the survey. These will be finalised in the pre-mobilisation phase for up to date information.

1.6 Document review

This OPEP is required to be reviewed, and if applicable updated, to ensure that all relevant information is accurate, and that new information or improved technology is evaluated and used to adapt and improve the management of spills.

Reviews and revisions to this OPEP will be undertaken as per the Eureka 3D MSS EP review and revision process detailed in Section 10 of the Eureka 3D MSS EP.

This could include changes required in response to one or more of the following:

- When major changes have occurred, which affect oil spill response coordination or capabilities.
- Changes to the Eureka 3D MSS EP that affect oil spill response coordination or capabilities (e.g. a significant increase in spill risk, inclusion of new activity).
- Following routine testing of the OPEP if improvements are identified.
- After a Level 2/3 spill incident.

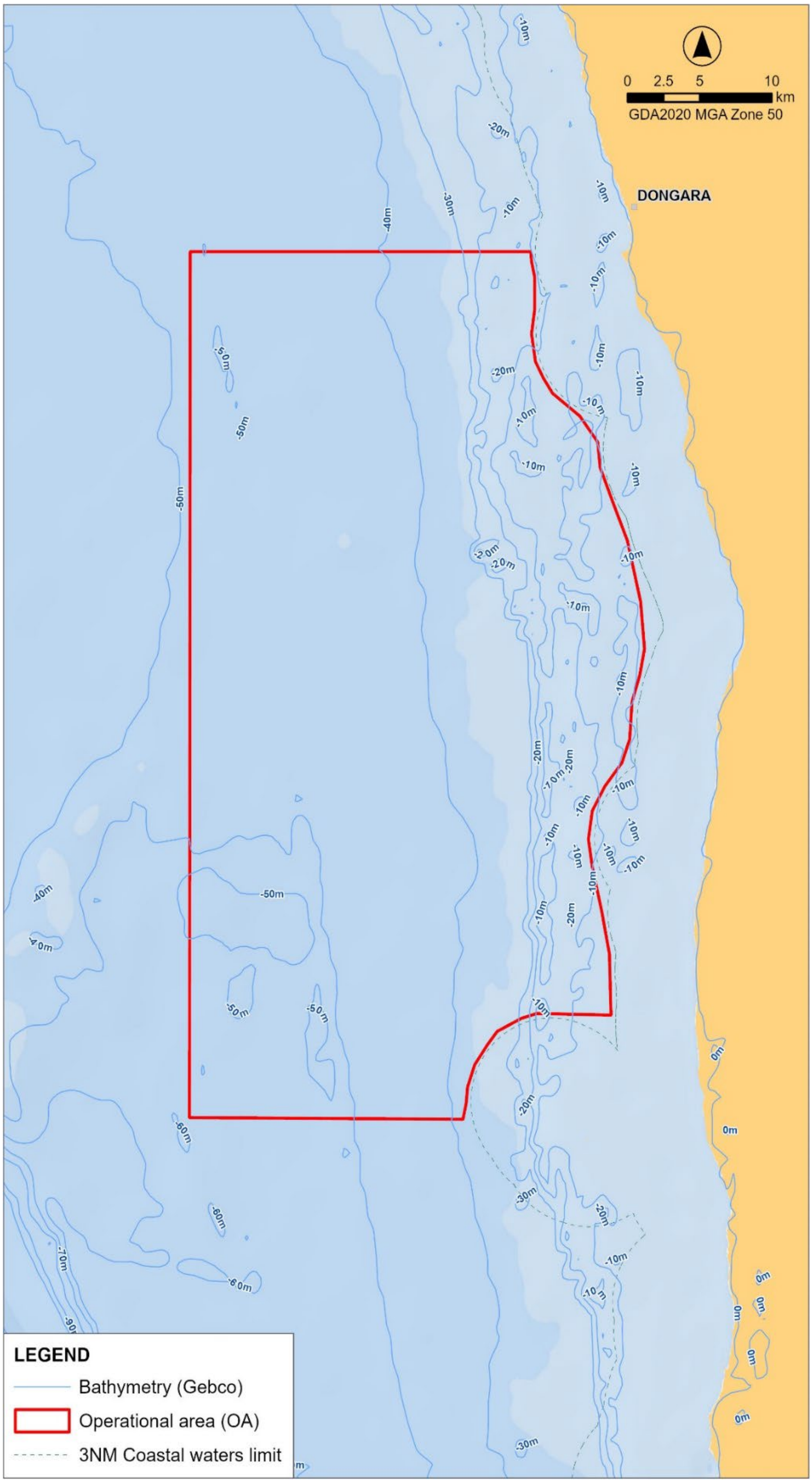

Figure 1-1: Eureka 3D MSS Operational Area

2. Spill Management Arrangements

2.1 Response levels and escalation criteria

The National Plan and the WA SHP-MEE identify three levels of incidents, which are consistently applied by Pilot Energy.

An incident level (also referred to as 'tier') will determine where the resources will be drawn from to respond to the spill and the level of incident management that is required to manage the response effort.

In the event of a spill occurring where effective response is considered beyond the capabilities within a level, the response will be escalated immediately to the next level. The decision to escalate a response to a higher level (as defined in Table 2-1) will be made by the responsible Control Agency.

If the response level is undetermined, then a worst-case scenario should be assumed when activating resources, as it is always possible to scale down the response effort.

Table 2-1: Pilot Energy Incident Level Guidance

	Incident management response level		
Characteristic	**Level 1**	**Level 2**	**Level 3**
General description and escalation criteria	An incident that has not caused severe injury to personnel or damage to assets or the environment Incident does not threaten the safety of a vessel/facility and can be managed by the local response team and its resources	An incident that exceeds Level 1 capability and requires the assistance of the IMT and external support services/agencies If no external support is required, an incident may be classified in a higher tier if there is potential for escalation or damaging public image or government relations	An incident that exceeds Level 2 capabilities and resources and requires the assistance of the CMT Incident may attract media coverage or create public outrage and has the potential to cause, or does cause, a major impact
AMSA National Plan Levels and escalation criteria	Level 1 Generally able to be resolved by Responsible Party through the application of local or initial response resources (first strike response)	Level 2 Typically, more complex in size, duration, resource management and risk than Level 1 incidents. May require deployment of resources beyond the first strike response	Level 3 Characterised by a high degree of complexity, require strategic leadership and response coordination. May require national and international response resources
IMT activation	Vessel or Facility's local response team activated	IMT activated	IMT activated
Resources at risk			
Human	Potential for serious injuries	Potential for loss of life	Potential for multiple loss of life
Environment	Isolated impacts or with natural recovery expected within weeks.	Significant impacts and recovery may take months. Monitoring and remediation may be required.	Significant area and recovery may take months or years. Monitoring and remediation will be required.

Characteristic	Incident management response level Level 1	Level 2	Level 3
Wildlife	Individuals of a small number of fauna species affected	Groups of fauna species or multiple numbers of individuals affected	Large numbers of fauna (individuals and species) affected
Economy	Business level disruption	Business failure	Disruption to a sector
Social	Reduced services	Ongoing reduced services	Reduced quality of life
Infrastructure	Short term failure Non-safety/operational critical failure	Medium term failure Potentially safety/operational critical failure	Severe impairment Safety/operational critical system failure
Public affairs	Local and regional media coverage	National media coverage	International media coverage

2.2 Control agencies and jurisdictional authorities

The responsibility for responding to an oil spill is dependent on location and spill origin. The National Plan sets out the divisions of responsibility for an oil spill response. Definitions of Jurisdictional Authority and Control Agency are as follows:

- Control Agencies: the organisation assigned by legislation, administrative arrangements or within the relevant contingency plan, to control response activities to a maritime environmental emergency. Control Agencies have the operational responsibility of response activities but may have arrangements in place with other parties to provide response assistance under their direction.
- Jurisdictional Authority: the agency which has responsibility to verify that an adequate spill response plan is prepared and, in the event of an incident, that a satisfactory response is implemented. The Jurisdictional Authority is also responsible for initiating prosecutions and the recovery of clean-up costs on behalf of all participating agencies.

Table 2-2 provides guidance on the designated Control Agency and Jurisdictional Authority for Commonwealth and State waters and for vessel and petroleum activity spills.

It should be noted that in Commonwealth waters, vessels involved in seismic surveys are considered to be ‘vessels’ and not ‘petroleum activities’. However, in WA waters marine seismic surveys are a petroleum activity where they are associated with exploration for hydrocarbon reservoirs or evaluation of these resources.

2.3 Seismic survey spills in Commonwealth waters

AMSA manages the National Plan and is the Control Agency for all vessel-based spills in the Commonwealth jurisdiction. This includes vessels undertaking seismic surveys and associated supply or support vessels.

The Vessel Master is responsible for implementing source control arrangements detailed in the vessel specific SOPEP. Once initial notifications to the Control Agency are made, Pilot Energy shall maintain direct contact with the Control Agency and act as a Supporting Agency throughout the response. This includes providing essential services, personnel, material or advice in support of the Control Agency. In addition, Pilot Energy will implement monitoring activities as outlined in the Eureka 3D MSS OSM-BIP.

2.4 Seismic survey spills in WA waters

Although the National Plan defines seismic survey spills to be 'vessel-based' spills, this definition does not apply to WA waters, or to cross jurisdictional arrangements involving WA. As seismic survey spills are petroleum activity spills in WA waters, if a Marine Oil Pollution incident occurs enters, or has the potential to enter, State waters, the DoT is the Hazard Management Agency (HMA) (DoT CEO or proxy). The Assistant Executive Director (or proxy) has been nominated by the HMA to perform the role of State Marine Pollution Coordinator (SMPC) (as prescribed in Section 1.3 of the SHP–MEE) and DoT will take on the role as a Control Agency. The role of the SMPC is to provide strategic management of the incident response on behalf of the HMA.

Where DoT has assumed the role of Control Agency, Pilot Energy will provide all necessary resources to assist DoT.

2.5 Cross jurisdiction vessel spills

If a Level 2/3 vessel spill crosses jurisdictions between Commonwealth and State waters, two Jurisdictional Authorities will exist (AMSA for Commonwealth waters and DoT for WA State waters). The Control Agency will remain with the original nominated agency or organisation unless otherwise appointed through agreement between the HMA / Jurisdictional Authority of both waters. Pilot Energy will continue to provide all necessary resources (including personnel and equipment) as a Supporting Agency.

AMSA may request that DoT manage a vessel incident in Australian Commonwealth waters (DoT, 2021).

2.6 Pilot Energy Incident Management

For the period of a seismic survey Pilot Energy will maintain an IMT that is commensurate to the response level (Section 2.1) for the survey oil spill risk and impacts. The IMT structure, roles and responsibilities are outlined in Section 10 of the Eureka 3D MSS EP. IMT competencies and training schedule is outlined in Section 10 of the Eureka 3D MSS EP.

Table 2-2: Jurisdictional and Control Agencies for Hydrocarbon Spills

Jurisdictional boundary	Spill source	Jurisdictional authority	Control agency		Relevant documentation
			Level 1	Level 2/3	
Commonwealth waters (three to 200 nautical miles from Territorial/State sea baseline)	Vessel [4]	AMSA	AMSA		Vessel SOPEP National Plan Eureka 3D MSS OPEP (this document)
	Petroleum activities[5]	National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA)	Titleholder		Activity OPEP
Western Australian (WA) State waters (State waters to three nautical miles and some areas around offshore atolls and islands)	Vessel	WA Department of Transport (DoT)	DoT	DoT	Vessel SOPEP SHP-MEE Incident Management Plan – Marine Pollution (DoT, 2023)
	Petroleum activities	DoT	Titleholder	DoT	Eureka 3D MSS OPEP (this document) SHP-MEE

[4] Vessels are defined by Australian Government Coordination Arrangements for Maritime Environmental Emergencies (AMSA, 2017a) as a seismic vessel, supply or support vessel, or offtake tanker. Note: this definition does not apply to WA State waters.

[5] Includes a 'Facility', such as a fixed platform, FPSO/FSO, MODU, subsea infrastructure, or a construction, decommissioning and pipelay vessel. As defined by Schedule 3, Part 1, Clause 4 of the OPGGS Act.

2.7 Integration with other organisations

2.7.1 Western Australia – Department of Transport

Pilot Energy will notify the DoT Maritime Environmental Emergency Response (MEER) unit as soon as reasonably practicable (within 2 hours of spill occurring) if an actual or impending spill may impact WA State waters. On notification, the SMPC will activate their Maritime Environmental Emergency Coordination Centre (MEECC) and the DoT IMT. Titleholders will work in partnership with DoT during such instances, as outlined within the DoT's Offshore Petroleum Industry Guidance Note – Marine Oil Pollution: Response and Consultation Arrangements (DoT, 2020).

Pilot Energy will conduct initial response actions in State waters as necessary in accordance with this OPEP and the Eureka 3D MSS OSMP-BIP and continue to manage those operations until formal handover of incident control is completed. Appendix 1 in the Offshore Petroleum Industry Guidance Note provides a checklist for formal handover. Beyond formal handover, Pilot Energy will continue to provide all necessary resources, including personnel and equipment, to assist the DoT in performing duties as the Control Agency.

For a cross-jurisdictional response, there will be a Lead IMT (DoT or AMSA) for each spill response activity, with DoT's control resting primarily for State waters activities. Appendix 2 in the Offshore Petroleum Industry Guidance Note provides guidance on the allocation of a Lead IMT to response activities for a cross-jurisdictional spill.

To facilitate coordination between DoT and AMSA during a cross-jurisdictional response, a Joint Strategic Coordination Committee will be established. The Joint Strategic Coordination Committee will be jointly chaired between the SMPC and a nominated representative of AMSA and will ensure alignment of objectives and provide a mechanism for de-conflicting priorities and resourcing requests.

For a cross-jurisdictional response, Pilot Energy will be responsible for ensuring adequate resources are provided to DoT as Control Agency, initially 11 personnel to fill roles in the DoT IMT or Forward Operating Base (FOB) (DoT, 2020) and operational personnel to assist with those response strategies where DoT is the Lead IMT. Concurrently, DoT will also provide two of their personnel to the Pilot Energy IMT as described in the Offshore Petroleum Industry Guidance Note. Pilot Energy's Representative is to attend the DoT Fremantle Incident Command Centre (ICC) as soon as possible after the formal request has been made by the SMPC. It is an expectation that the remaining initial cohort will attend the DoT Fremantle ICC no later than 8 am on the day following the request being formally made to Pilot Energy by the SMPC. Pilot Energy delegated personnel designated to serve in DoT's FOB will arrive no later than 24 hours after receipt of formal request from the SMPC.

Figure 2-1 shows the overall cross-jurisdictional organisational structure referenced from the SHP-MEE.

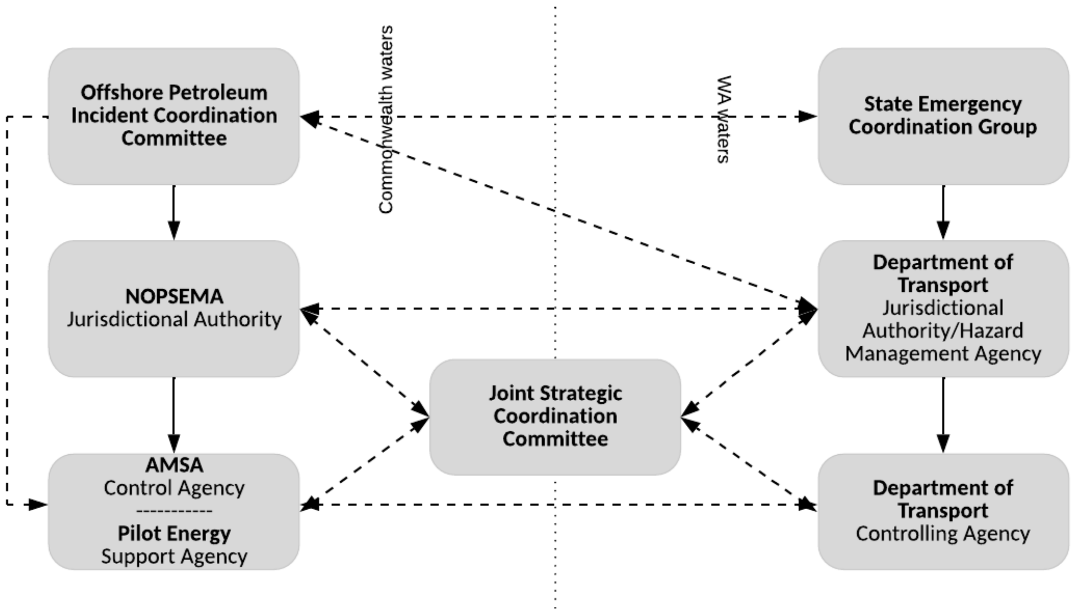

Figure 2-1: Cross-Jurisdictional Organisational Structure

2.7.2 AMSA

AMSA is the designated Control Agency for vessel spills in Commonwealth waters. Therefore, should a vessel spill enter Commonwealth waters, AMSA may also become a (or the) Control Agency. Arrangements for coordination and potential transfer of Control Agency status are outlined in AMSA Guidance Note NP-GUI-023: Coordination of Cross-Border Incidents (AMSA, 2017b).

AMSA is to be notified immediately of all ship-source incidents through the AMSA Rescue Coordination Centre (RCC) Australia (refer to project emergency contacts register).

AMSA manages the National Plan, Australia's key maritime emergency contingency and response plan (AMSA, 2020). AMSA also has a range of National Plan supporting documents containing related policies, guidance and advisory information.

2.7.3 Western Australian Department of Biodiversity, Conservation and Attractions

The Western Australian Department of Biodiversity, Conservation and Attractions (DBCA) has responsibilities associated with wildlife and activities in national parks, reserves and State marine parks. The *Biodiversity Conservation Act 2016* (WA) is the legislation that provides DBCA with the responsibility and Statutory Authority to treat, protect, and destroy wildlife. In State waters, DBCA is the Jurisdictional Authority for Oiled Wildlife Response (OWR), providing advice to the Control Agency (DoT). The role of DBCA in an OWR is outlined in the Western Australian Oiled Wildlife Response Plan (WAOWRP) (DBCA, 2022a).

For a Level 2/3 petroleum spill that originates within or moves into State waters, DoT will be the Control Agency responsible for overall command of an oiled wildlife response. Pilot Energy will provide all necessary resources (equipment and personnel) to DoT to facilitate this response.

For matters relating to environmental sensitivities and scientific advice in State waters DBCA may provide an Environmental Scientific Coordinator (ESC) to support the SMPC and/or DoT Incident Controller.

This may include advice on priorities for environmental protection, appropriateness of proposed response strategies and the planning and coordination of scientific monitoring for impact and recovery assessment.

2.7.4 Department of Industry, Science and Resources

The Commonwealth Department of Industry, Science and Resources (DISR) will be the lead Commonwealth Agency for the provision of strategic oversight and Commonwealth government support to a significant offshore petroleum incident (including oil spill incidents). DISR will be notified by NOPSEMA of a significant oil pollution incident and under the Offshore Petroleum Incident Coordination Framework will stand up the Offshore Petroleum Incident Coordination Committee (OPICC) as the mechanism to provide Commonwealth strategic advice and support to the incident. To facilitate information between the petroleum titleholder IMT and Offshore Petroleum Incident Coordination Committee, Liaison Officer/s will be deployed from DISR to the Pilot Energy IMT.

For incidents that are classified at a greater level than level 3 (See section 2.1), a whole of government crisis committee will be formed under the Australian Government Crisis Management Framework to provide strategic advice and support and the Offshore Petroleum Incident Coordination Committee will not be convened, although DISR will remain as the lead agency.

2.8 Incident Action Planning

The incident action planning (IAP) process is built on the following phases:

1. Understand the situation.
2. Establish incident objectives.
3. Develop the plan.
4. Prepare and disseminate the plan.
5. Execute, evaluate and revise the plan.

The Control Agency will use the IAP process to determine and document the appropriate strategies as more information becomes available during an incident response. The Control Agency IMT will use an IAP for each operational period following the initial first-strike assessments, notifications, and activations undertaken by the Pilot Energy.

As Support Agency, Pilot Energy may be requested by the Control Agency to develop, or support the development of an IAP to help guide the incident response.

The DoT have a suite of Incident Management System templates to assist with the preparation of an IAP. These can be found under the Incident Management System drop down list here

3. Response Strategy Selection

3.1 Strategic spill impact mitigation assessment

Titleholders typically use a Spill Impact Mitigation Assessment (SIMA) or Net Environmental Benefit Analysis (NEBA) as their decision support tool to consider available information that helps them select the most suitable response strategies or combination of strategies that would minimise impacts to ecological, cultural, economic and social values (hereafter referred to as receptors). Different response strategies provide varying levels of effectiveness and protection under different environmental conditions, depending on the individual spill (Coelho et al., 2014).

Conducting a SIMA is an important step in the oil spill planning and preparedness process and is often called a Strategic SIMA. An overview of this assessment process is provided in Figure 3-1. To complete a Strategic SIMA, all available information on a potential spill is considered (e.g. oil type, volume, duration of release), together with any vector mapping or spill trajectory modelling to consider potential impacts to sensitive receptors.

A list of possible response strategies are considered from a ‘response toolbox’, as detailed in Section 3.3.1.

A detailed assessment of the benefits and drawbacks of each response strategy is completed to help determine the combination of strategies that would be most suited to each maximum credible spill scenario. This includes ‘primary response strategies’ and ‘secondary response strategies’, with the former typically being more reliable and effective in reducing impacts from an individual spill.

Table 3-6 details the Strategic SIMA for the Eureka 3D MSS spill scenario of an MGO spill from a vessel collision. It details the response strategies applicable or not applicable for an MGO spill.

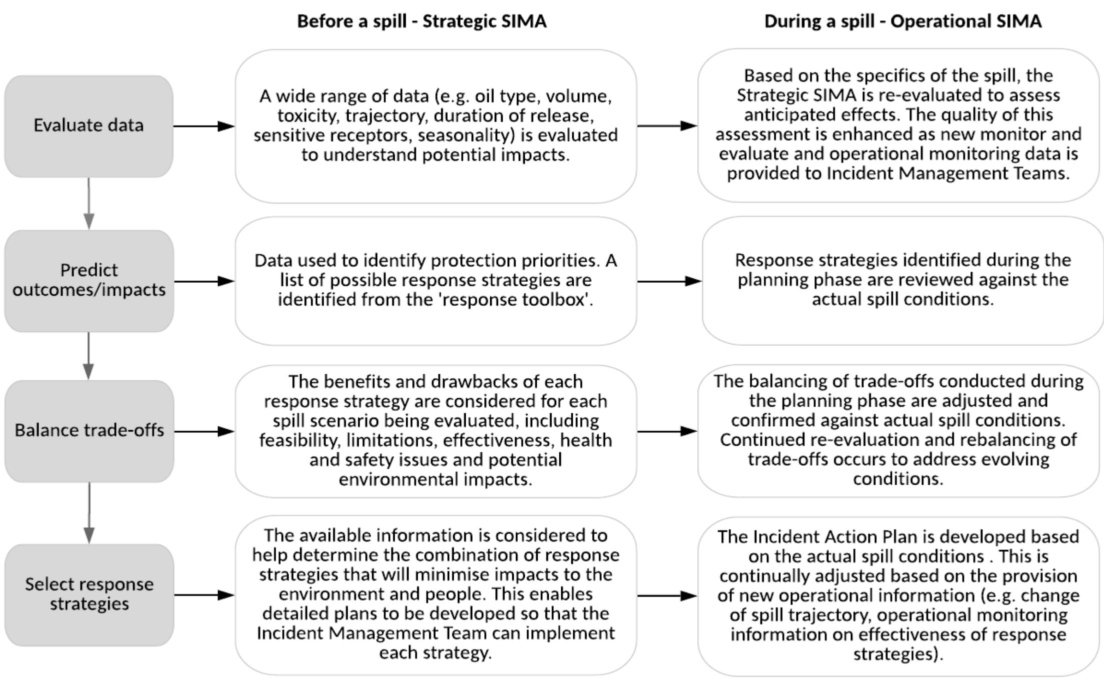

Figure 3-1: Spill Impact Mitigation Assessment Overview

3.2 Evaluate data

3.2.1 Spill scenario

The worst-case spill scenario in the Eureka 3D MSS EP (as presented in Table 3-1) is an MGO spill from a vessel collision in the south-east corner of the Operational Area, at a location that is approximately 12 km from the mainland coastline and approximately 5 km from the Beagle Islands.

Table 3-1: Worst-Case Credible Spill Scenario – Eureka 3D MSS

Spill scenario	Hydrocarbon type	Maximum credible volume released (m^3)	Release duration
Vessel collision	MGO	320	6 hours

3.2.2 Hydrocarbon properties

MGO is a product that contain a mixture of volatile and persistent hydrocarbons. Table 3-2 shows the approximate physical properties and boiling point range of MGO.

When released to the marine environment, MGO will spread quickly and thin out to low thickness levels, thereby increasing the rate of evaporation. Due to its chemical composition, up to 65% will generally evaporate over the first two days depending upon the prevailing conditions and spill volume.

MGO has a strong tendency to entrain into the upper water column (0 m–10 m) (and consequently reduce evaporative loss) in the presence of moderate winds (> 10 knots) and breaking waves. However, MGO can re-surface when the conditions calm.

Table 3-2: MGO Representative Characteristics

Hydrocarbon type	Density (kg/m^3)	Viscosity (cP)	Component	Volatile (%)	Semi-volatile (%)	Low volatility (%)	Residual (%)
			BP (ºC)	<180	180–265	265–380	>380
MGO	820–860 (at 15 °C)	2–4.5 (at 40 °C)	% of total	16.4	49	31.9	2.7

3.2.3 Spill Modelling Results

The worst-case credible spill scenario shown in Table 3-1 was used as the basis for modelling, which was performed using a three-dimensional spill trajectory and weathering model, SIMAP (Spill Impact Mapping and Analysis Program). The SIMAP model calculates the transport, spreading, entrainment, evaporation and decay of surface hydrocarbon slicks as well as the entrained and dissolved oil components in the water column.

A total of 100 spill trajectories were simulated for the time of year that the survey might be conducted (February and March) using a number of unique environmental conditions sampled from historical metocean data. The scenario was tracked for 28 days.

The modelling outputs do not represent the potential behaviour of a single spill (which would have a much smaller area of influence) but provides an indication of the probability of any given area of the sea surface being contacted by hydrocarbons above impact thresholds. For the purpose of spill response preparedness, outputs relating to floating oil and oil accumulated on the shoreline are most relevant (i.e. oil that can be diverted, contained, collected or dispersed through the use of spill response strategies) for the allocation and mobilisation of spill response resources.

Table 3-3 presents the stochastic modelling results for floating concentrations and shoreline accumulation volumes for the vessel collision spill for February to March. Oil spill modelling did not predict any shoreline accumulation above the moderate exposure thresholds above 10% probability for either season.

Modelling results for dissolved and entrained oil for the worst-case scenario have not been included given there are limited response strategies that will reduce subsurface impacts. However, Pilot Energy uses the modelling results for entrained oil from the worst-case scenario for the purposes of identifying scientific monitoring priority areas as outlined in the Eureka 3D MSS OSM-BIP.

Table 3-3: Stochastic Modelling Results – Scenario 1 (February to March) - MGO spill (RPS, 2023)

Location	Probability (%) of floating oil exposure ≥10 g/m^2	Minimum time before floating oil exposure (hours) ≥10 g/m^2	Maximum probability (%) of shoreline loading ≥10 g/m^2	Minimum time before shoreline accumulation ≥10 g/m^2 (hours)	Maximum probability (%) of shoreline loading ≥100 g/m^2	Minimum time before shoreline accumulation ≥100 g/m^2 (hours)	Peak volume ashore (m^3) ≥100 g/m^2	Maximum length of shoreline contacted (km) ≥100 g/m^2
Bowes River – Broken Anchor Bay (B)	<1	NC	1	472	<1	NC	NC	NC
Glenfield Beach – Bowes River (C)	<1	NC	1	234	<1	NC	NC	NC
Green Head - Leeman	<1	NC	1	54	1	60	<1	<1
Illawong – Cliff Head	6	3	<1	NC	<1	NC	NC	NC
Leeman Coolimba	<1	NC	1	56	<1	NC	NC	NC
Thirsty Point – Booker Valley	<1	NC	1	491	<1	NC	NC	NC
Abrolhos Islands	<1	NC	1	234	<1	NC	NC	NC
Pelsaert Group	<1	NC	1	234	<1	NC	NC	NC
Wallabi Group	<1	NC	1	472	<1	NC	NC	NC
NC= No contact								

3.2.4 Sensitive Receptors and Protection Priorities

For any oil spill entering or within WA State waters/shorelines, the WA DoT is the Control Agency and ultimate decision-maker regarding identification and selection of protection priorities.

Spill modelling results were used to predict the Environment that may be Affected (EMBA) for Eureka 3D MSS (refer to section 8). The EMBA is the area in which activities associated with Eureka 3D MSS may result in environmental impacts – defined as the area potentially impacted by hydrocarbons from a spill event above impact concentration thresholds. Within the EMBA, priority protection areas have been identified. Priority protection areas are emergent features (i.e. coastal areas and islands) that are predicted to be contacted above moderate exposure values and would be targeted by nearshore spill response operations such as protection and deflection and shoreline clean-up.

Table 3-4 lists the priority protection areas for this activity.

Table 3-4: Priority Protection Area – Eureka 3D MSS

Protection Priority Areas	Key sensitivities	DoT Ranking (Floating oil)[6]	DoT Ranking (Dissolved oil)
Green Head – Leeman (DoT shoreline cell #193)	• Extensive meadows of seagrass that grow in shallow lagoons which provide an important nursery habitat for juvenile fish and western rock lobster (CALM, 2000) • Macroalgal communities • Abalone occur on intertidal reefs • Humpback whale and bottlenose dolphins (*Tursiops truncatus*) regularly seen in the area (CALM, 2000) • White shark foraging • Inshore islands between Cliff Head and Grey are important breeding areas for seabirds (Dunlop and Wooller, 1990; CALM, 2004) • Seabird foraging • Only breeding area for Australian sea lions on the west coast of Australia: – Reside and breed on Buller Island, North Fisherman Island, East Island, Beagle Island (CALM, 2004) – Approximately 800 sea lions – Isolated genetically distinct sub-population • Sea lion foraging • Boullanger Island dunnart is only found on Boullanger Island (CALM, 2004) • Dibblers are found on Boullanger and Whitlock islands (CALM, 2004) • Cultural heritage- mainland areas have been identified as a significant area for Noongar people • The coast area between Green Head and Jurien has the largest number of midden deposits in the south-west of WA (CALM, 2004) • Coast dunes in the Jurien Bay region were used as burial sites (CALM, 2004) • Several shipwrecks have been recorded between Cliff Head and Grey (CALM, 2004)	4	3

[6] Provision of Western Australian Marine Oil Pollution Risk Assessment – Protection Priorities: Assessment for Zone 3: Midwest (Advisian, 2018).

3.3 Predict Outcomes

3.3.1 Response 'Toolbox'

Possible response strategies for a surface oil spill include:

- Monitor and evaluate
- Source control
- Containment and recovery
- (Mechanical) physical dispersion
- Chemical dispersion – surface application
- Shoreline protection
- Shoreline clean-up
- In-situ burning
- Oiled wildlife response

Support functions:

- Waste management
- Scientific monitoring

3.3.2 Response Planning Thresholds

In addition to the impact assessment thresholds described in the Eureka 3D MSS EP Section 8.6.3, response thresholds have been developed for response planning to determine the conditions that response strategies would be effective. These thresholds are provided as a guide for response planning based on case studies that have demonstrated some response strategies (e.g. chemical dispersant application) require certain oil spill thicknesses and conditions to be effective.

The thresholds assist with understanding worst-case spill scenario response strategy capability requirements when used in conjunction with oil spill trajectory modelling results. Modelling informs the predicted spatial extent of the spill at certain response thresholds, which in turn can inform response strategy capability.

Response planning thresholds are provided in Table 3-5.

Table 3-5: Surface and Shoreline Hydrocarbon Thresholds for Response Planning

Hydrocarbon (g/m^2)	Description	Justification
≥ 1	Estimated minimum threshold for commencing some monitoring components (e.g. water quality monitoring) and monitoring and evaluation tactics (e.g. aerial surveillance)	This thickness approximates the range of socio-economic effects and helps to establish the spatial extent for scientific monitoring (NOPSEMA, 2019).
≥ 10	Estimated minimum threshold for commencing all triggered monitoring components	This approximates the lower limit for harmful exposures to birds and marine mammals (NOPSEMA, 2019) so assists with planning for related scientific monitoring components.
≥ 50	Estimated minimum floating hydrocarbon threshold for on water response strategies	Surface chemical dispersants are most effective on hydrocarbons that are at a thickness of 50–100 g/m^2 on the sea surface. EMSA (2010) recommends thin layers of spilled hydrocarbons should not be treated with dispersant. This includes Bonn Agreement Oil Appearance Codes (BAOAC) 1–3 (EMSA, 2010). However, this may not always be practical in the field, as the actual thickness of a slick can vary greatly over even short distances (IPIECA-IOPG, 2015). Hence, this threshold is applied for planning purposes but should be judged according to real-time conditions in the event of a spill. McKinney and Caplis (2017) tested the effectiveness of various oil skimmers at different oil thicknesses. Their results showed that the oil recovery rate of skimmers dropped significantly when oil thickness was less than 50 g/m2.
≥ 100	Estimated floating hydrocarbon threshold for on water response strategies Estimated minimum shoreline accumulation threshold for shoreline clean-up (if required) and subsequent waste management	This threshold is often used as the minimum thickness for effective shoreline clean-up (Owens and Sergy, 2000; French-McCay, 2009).

3.4 Balance trade-offs and select response strategies

Selecting which response strategies to use often involves making trade-offs (e.g. risk, feasibility, flexibility, effectiveness), based on which environmental receptors should receive priority for protection. A Strategic SIMA is presented in Table 3-6 and indicates the applicability of each possible response strategy (Section 3.3.1) for the worst case spill scenario of a MGO spill from a vessel collision (Section 3.2.1).

Table 3-6: Strategic SIMA for Eureka 3D MSS vessel collision MGO spill

Response strategy	Evaluation	Recommendation
Source control	In the event of a vessel spill, the Vessel Master would revert to the Ship Oil Pollution Emergency Plan (SOPEP), which is a MARPOL requirement for applicable vessels and not addressed by this SIMA.	n/a
Monitor and evaluate	The requirement for situational awareness is critical to implement a coordinated, focussed and effective spill response. This strategy has several tactics (e.g. tracking buoys, aerial surveillance) and is scalable according to the nature and scale of the spill. SIMA will always support the implementation of ‘Monitor and Evaluate’ given the clear benefits in maintaining situational awareness throughout the duration of a spill event and little or no environmental impact associated with its implementation. Therefore, the benefits of undertaking this response are considered to significantly outweigh the potential environmental risks/impacts.	Primary response strategy
Natural recovery	Natural recovery is often the most effective response for light hydrocarbons (Group 1-3), including MGO. MGO products lose a large percentage of their volume via natural weathering and fate processes in the first 24 hours following a spill. It is unlikely that significant response resources would be able to be deployed within this time, so much of the spill volume will weather and evaporate prior to the arrival of additional response resources. Allowing the product to weather naturally can often create less overall impact than intrusive methods of clean-up and response (e.g. the net impact of allowing small volumes of product to naturally degrade on sensitive offshore islands may be less than sending in shoreline clean-up teams and equipment, which may damage nesting locations, disturb fauna and create significant waste volumes).	Primary response strategy
Containment and recovery	Unlikely to be effective as MGO products will rapidly degrade in the open ocean environment. For containment and recovery to be effective, a sufficient oil thickness is required be achieved by the containment booms (minimum of 50 g/m^2). This strategy is often limited to heavier and more persistent Group 3 and 4 (ITOPF) hydrocarbons.	Not recommended
In-situ burning	To conduct in-situ burning, meteorological conditions and sea-state must allow the deployment of especially designed fire-retardant booms, which are required to corral hydrocarbons to a sufficient thickness to permit ignition and ongoing combustion. MGO is a rapidly evaporating and spreading hydrocarbon and is not expected to be available at sufficient thicknesses for ignition.	Not recommended
(Mechanical) physical dispersion	The benefits of undertaking this response are not considered to significantly outweigh the potential risk to human health due to the volatility of the hydrocarbon products. Mechanical dispersion is not considered a suitable response strategy for MGO scenarios.	Not recommended
Chemical dispersion – surface application	MGO has high natural spreading, dispersion and evaporation rates in the marine environment and would be too thin to enable effective use of chemical dispersants. Chemical dispersants have a window of opportunity, after which effectiveness decreases. This includes a workable area for dispersant application, adequate surface thickness and presence of dispersible components of oil. These characteristics typically exist in the initial hours following a release. Dispersant use is not considered to be effective	Not recommended

Response strategy	Evaluation	Recommendation
	on the spill scenarios given they are not continuous releases and slick characteristics amenable to dispersant operations will unlikely be present by the time dispersant operations are mobilised. Adding chemical dispersants would introduce more chemicals into the marine environment, for little to no benefit.	
Shoreline protection and deflection	Shoreline protection and deflection activities involve mobilising personnel and equipment to remote coastal environments, which can result in physical disturbance to intertidal and shoreline habitats. It would also require small inshore vessels and calm weather to be effective and temporary staging areas for waste that would be generated from the recovery of floating oil. The effectiveness of this response will be dependent on local bathymetry, sea state, currents, tidal variations and wind conditions at the time of implementation. It is typically more effective in areas with low to moderate tidal ranges on low energy coastline types such as sandy beaches. Moderate to high tidal ranges generally include stronger currents and larger/longer intertidal areas that make it less effective and more difficult to keep booms in place. Activities would focus on areas of high protection value in low energy environments based upon real-time operational surveillance, provided the environmental and metocean conditions are favourable for an effective implementation. An Operational SIMA should demonstrate that protection would result in an overall benefit to receptors. Consequently, this option may not be applicable across all areas or receptors identified as having priority for protection.	Secondary response strategy – to be deployed if operational SIMA indicates it would result in a net benefit.
Shoreline clean-up	Shoreline clean-up activities involve mobilising personnel and equipment to remote coastal environments, which can result in physical disturbance to intertidal and shoreline habitats. This may cause more impacts than leaving the hydrocarbon to degrade naturally, especially if the oiling is light. Intrusive activities such as physical removal of waste using manual labour or mechanical aids requires careful site-specific planning to reduce secondary impacts of habitat disturbance, erosion and spreading oil beyond shorelines. Secondary impacts can be minimised using trained personnel to lead operations. Logistically, clean-up operations will require site access, decontamination, waste storage, PPE, catering and transport services to support personnel working on shorelines. Given the relatively small volumes predicted to come ashore for most locations, and the high rates of natural biodegradation of diesel, it would be better to focus on high priority areas for clean-up. This strategy is considered to be a secondary response strategy where it is safe and practical to implement and where an Operational SIMA demonstrates that clean-up would result in an overall benefit to receptors.	Secondary response strategy - to be deployed if operational SIMA indicates it would result in a net benefit.
Oiled wildlife response	Oiled wildlife response (OWR) includes wildlife surveillance/reconnaissance, wildlife hazing, pre-emptive capture and the capture, cleaning, treatment, and rehabilitation of animals that have been oiled. In addition, it includes the collection, post-mortem examination, and disposal of deceased animals that have succumbed to the effects of oiling.	Primary response strategy

Response strategy	Evaluation	Recommendation
	Wildlife surveillance/reconnaissance will likely form the main component of an OWR associated with the MGO scenarios.	

3.5 Operational SIMA

An Operational SIMA is an iterative process that is used to help guide an IMT during a response. An outline of an Operational SIMA process is provided in Figure 3-1 and considerations to help refine the Operational SIMA are provided in Table 3-7. Real-time data from monitor and evaluate and operational monitoring activities should be incorporated into the Operational SIMA, so that the IMT can adjust the response according to the effectiveness of tactics during each operational period.

Following implementation of the initial (first strike) response, the Strategic SIMA (Table 3-6) will form the basis for the initial Operational SIMA.

The initial Operational SIMA should be a priority action for the Planning Section once they are activated but may be based on limited information. However, the overall response effort should not be delayed due to a lack of some information. The Operational SIMA can always be revised when more information is available.

The Planning Section is responsible for completing the Operational SIMA and to determine if outputs from the Strategic SIMA are still appropriate. The Operational SIMA should be revised during each new Operational Period and should incorporate post-spill trajectory modelling data, surveillance data, operational monitoring data and should be incorporated into the IAP.

Table 3-7: Operational SIMA Considerations

Response strategy	Considerations
Monitor and evaluate	• Which monitor and evaluate tactics will provide reliable and accurate data for the individual spill? • What sensitive receptors are in the current or anticipated trajectory? • What is the assessed volume and size of the spill? • Is the product weathering as anticipated? • What data is being returned from operational monitoring and how can this be used to aid decision making? • How do the response options and tactics seem to be influencing the spill? Shoreline assessment (only): • Will access to remote shorelines be safe and feasible? • Will assessment teams disturb sensitive seasonal nesting species?
Protection and deflection	• Have the protection priorities been ground-truthed and are there seasonal receptors that should be prioritised for protection? • Are conditions (e.g. tides, current, sea state) favourable for this strategy to be effective in open ocean environments immediately surrounding the emergent sensitivities (reefs)? • Can tactics be deployed in time? • Will access to the shallow intertidal areas on top of emergent sensitivities be safe and feasible? • Can the IMT access suitable shallow draft vessels to safely establish booming arrangements (e.g. does vessel have ability to transfer anchors and booms; does it have adequate tie-points?). • Is there potential that reefs could be damaged from anchor drag?
Shoreline clean-up	• What volumes and/or concentrations of hydrocarbons are present or expected on the shoreline and what would be the impact to leave the product to weather naturally (taking into consideration the effects of MGO as a lighter hydrocarbon type – high evaporation rates but more toxic and greater ability to penetrate sediments)? • Have the protection priorities been ground-truthed and are there seasonal receptors that should be prioritised for protection?

Response strategy	Considerations
	• Will access to remote shorelines be safe and feasible? • Will responders disturb sensitive seasonal nesting species? • Would it reduce overall impacts to send small teams of clean-up personnel?
Oiled wildlife response	• Is there adequate monitoring for wildlife, taking into consideration temporal and spatial species-specific considerations? • Are known species breeding or nesting? • What level of wildlife impact has occurred or is expected to occur? • What wildlife response strategies are feasible and safe?

4. External Notifications and Reporting Requirements

Pilot Energy is responsible for making external notifications and reporting. Table 4-1 outlines external notification and reporting requirements required for Level 2-3 incidents, noting that regulatory reporting may apply to smaller Level 1 spills.

Contact details for the regulatory agencies outlined in Table 4-1 are provided with the project emergency contacts register.

Table 4-1: External Notifications and Reporting

Agency or Authority	Type of Notification / Timing	Legislation/ Guidance	Reporting Requirements	Responsible Person/Group	Forms
AMSA **(Rescue Coordination Centre)**	Verbal notification without delay to include: • name of ship/s involved • time, type and location of incident • quantity and type of harmful substance • assistance and salvage measures • any other relevant information Written POLREP form, within 24 hours of request from AMSA	National Plan for Maritime Environmental Emergencies MARPOL	All slicks trailing from a vessel All spills to the marine environment (notwithstanding the size or amount of oil or sheen) All spills where National Plan equipment is used in a response	Vessel Master	Incident reporting requirements: https://www.amsa.gov.au/marine-environment/marine-pollution/mandatory-marpol-pollution-reporting Online POLREP – https://amsa-forms.nogginoca.com/public/
NOPSEMA **(Incident Notification Office)**	Verbal notification within 2 hours after Pilot Energy becomes aware of the incident Written report as soon as practicable, but no later than 3 days	*Offshore Petroleum and Greenhouse Gas Storage Act 2006* Offshore Petroleum Greenhouse Gas Storage (Environment) Regulations 2009 (as amended 2014)	A spill associated with the activity that has caused, or has the potential to cause, moderate to significant environmental damage: Vessel loss of containment (MDO/MGO)	Notification by Pilot Energy IMT	Incident reporting requirements: https://www.nopsema.gov.au/environmental-management/notification-and-reporting/
National Offshore Petroleum Titles	Written report to NOPTA within 7 days of the initial	Guidance Note (N-03000-GN0926) Notification and Reporting of Environmental	Spill in Commonwealth waters that is	Notification by Pilot Energy IMT	Provide same written report as provided to NOPSEMA

Agency or Authority	Type of Notification / Timing	Legislation/ Guidance	Reporting Requirements	Responsible Person/Group	Forms
Administrator (NOPTA) **(Titles Administrator)**	report being submitted to NOPSEMA	Incidents - https://www.nopsema.gov.au/assets/Guidance-notes/A198752.pdf	reportable to NOPSEMA		
Commonwealth Department of Climate Change, Energy, the Environment and Water (DCCEEW) **(Director of monitoring and audit section)**	Email notification as soon as practicable	*Environment Protection and Biodiversity Conservation Act 1999*	If Matters of National Environmental Significance (MNES) are considered at risk from a spill or response strategy, or where there is death or injury to a protected species	Notification by Pilot Energy IMT	Not applicable
Parks Australia **(24-hour Marine Compliance Duty Officer)**	Verbal notification as soon as practicable	*Environment Protection and Biodiversity Conservation Act 1999*	All actual or impending spills which occur within a marine park or are likely to impact on an Australian marine park	Notification by Pilot Energy IMT	No forms, but the following information should be provided: • Pilot Energy's details • Time and location of the incident (including name of marine park likely to be affected) • Proposed response arrangements as per the OPEP • Details of the relevant contact person in the IMT
Australian Fisheries Management Authority (AFMA)	Verbal phone call notification as soon as practicable (within 24 hours)		Fisheries within the environment that may be affected (EMBA) Consider a courtesy call if not in exposure zone	Notification by Pilot Energy IMT	Not applicable

Agency or Authority	Type of Notification / Timing	Legislation/ Guidance	Reporting Requirements	Responsible Person/Group	Forms
If spill is heading towards WA waters					
WA DoT **(WA Maritime Environmental Emergency Response (MEER) unit)**	Immediate notification to the MEER Duty Officer Follow up with written POLREP, as soon as practicable Written Situation Report (SITREP) submitted within 24 hours of being directed by DoT	State Hazard Plan – Maritime Environmental Emergencies	All actual or impending spills in WA waters, regardless of source or quantity	Immediate notification by Pilot Energy IMT POLREP to be submitted by Pilot Energy IMT SITREP to be submitted by Pilot Energy IMT	DoT POLREP: http://www.transport.wa.gov.au/mediaFiles/marine/MAC-F-PollutionReport.pdf SITREP: http://www.transport.wa.gov.au/mediaFiles/marine/MAC-F-SituationReport.pdf
Department of Mines, Industry Regulation and Safety (DMIRS) **(Petroleum Environment Duty Officer)**	Verbal notification within 2 hours Notification report within 3 days	Guidance Note on Environmental Non-compliances and Incidents	All actual or impending spills in WA waters	Notification by Pilot Energy IMT	Environmental and Reportable Incident/ Non-compliance Reporting Form http://www.dmp.wa.gov.au/Documents/Environment/ENV-PEB-189.docx
Department of Biodiversity Conservation and Attractions (DBCA) **(State Duty Officer)**	Verbal notification as soon as practicable	WA Oiled Wildlife Response Plan	Notify if spill has the potential to impact or has impacted wildlife in State waters (to activate the Oiled Wildlife Advisor)	Notification by Pilot Energy IMT	Not applicable
Department of Water and Environmental Regulation (DWER)	Initial verbal or electronic notification of the discharge as soon as practicable Written notification of the incident to the CEO of the DWER, copied to the local DWER Industry Regulation Office, as soon as practicable	*Environmental Protection Act 1986* (Section 72) Environmental Protection (Unauthorised Discharge) Regulations 2004	Call DWER 24 hour Pollution Watch hotline *Environmental Protection Act 1986* (WA): Spill or discharge of hydrocarbons to the environment	Notification by Pilot Energy IMT	Reporting requirements: https://www.dwer.wa.gov.au/your-environment/51-reporting-pollution/110-reporting-a-life-threatening-incident-or-pollution-emergency

Agency or Authority	Type of Notification / Timing	Legislation/ Guidance	Reporting Requirements	Responsible Person/Group	Forms
			that has caused, or is likely to cause pollution, or material or serious environmental harm (Level 2 / 3 spills) Environmental Protection (Unauthorised Discharge) Regs.: Unauthorised discharge (where there is potential for significant impact or public interest) to environment of Schedule 1 material		
Department of Primary Industries and Resource Development (DPIRD) **Fisheries**	Verbal notification as soon as practicable (within 24 hours)	Agreed consultation	Notify if spill has the potential to impact or has impacted fisheries in State waters	Notification by Pilot Energy IMT	Not applicable
If spill is heading towards international waters					
Department of Foreign Affairs and Trade (DFAT) **(24-hour consular emergency centre)**	Verbal phone call notification within 8 hours, if the spill is likely to extend into international waters	Not applicable	Notify DFAT that a spill has occurred and is likely to extend into international waters Inform DFAT of the measures	Notification by Pilot Energy IMT	Not applicable

Agency or Authority	Type of Notification / Timing	Legislation/ Guidance	Reporting Requirements	Responsible Person/Group	Forms
			being undertaken to manage the spill		

5. Source Control

Source control involves stopping the discharge of hydrocarbons from the source of the spill. If the source of the spill is a vessel, then the vessel owner is responsible for undertaking source control, although the titleholder may be requested to provide support.

Vessel based source control includes measures that can be undertaken aboard the vessel (e.g. shutoff valves, diversion to unaffected tanks) and support from other vessels (e.g. magnetic patches, salvage, transfer of hydrocarbons to alternate vessel) to control the source, reduce the loss of hydrocarbons and prevent escalation of the incident. This information is detailed in the relevant Ship Oil Pollution Emergency Plan (SOPEP).

6. Monitor and Evaluate

Monitor and evaluate involves the collection and evaluation of information to provide and maintain situational awareness in the event of a spill. Monitor and evaluate activities should be conducted throughout the spill response, as it provides the IMT with ongoing information on sensitive receptors at risk of impact from the spill and the effectiveness of spill response operations. This information should be used by the IMT when updating response (operational) SIMAs and in the development of IAPs.

The monitor and evaluate response strategy includes a range of tactics which may be suitable for the spill scenarios covered by this OPEP. The relevance and suitability of individual tactics will need to be considered when preparing the Operational SIMA for individual spills. Initiation of suitable tactics (with the exception of tracking buoys and fate/weathering modelling) will need to be confirmed by the Control Agency, prior to deployment.

- Deployment of tracking buoy(s) – requires a buoy to be deployed to the water at the leading edge of the spill to track the movement of the spill.
- Fate and weathering modelling – uses computer modelling (e.g.ADIOS2) to estimate the weathering of an oil spill.
- Oil spill trajectory modelling – uses computer modelling (e.g. SIMAP) to estimate the movement, fate and weathering of spills.
- Visual observation (via aerial and/or vessel surveillance) – requires trained observers to identify and characterise spills. Survey platforms typically include aircraft and/or vessels. Is also used to ground truth oil spill trajectory modelling and monitor the effectiveness of response options.
- Satellite surveillance and data capture – uses satellite technology to identify and track oil spills.

6.1 Initiation and termination criteria

Tactic	Initiation criteria	Termination criteria
Tracking buoy	Notification of a Level 2/3 spill	Tracking buoy deployment will continue for 24 hours after the source is under control and a surface sheen is no longer observable; or As directed by the relevant Control Agency
Fate and weathering modelling (e.g. ADIOS2)	Notification of a Level 2/3 spill - may be deployed in a Level-1 incident (to be determined by On-Scene Commander)	Spill fate and weathering modelling will continue for 24 hours after the source is under control and a surface sheen is no longer observable; or As directed by the relevant Control Agency
Oil Spill Trajectory Modelling (OSTM)	Notification of a Level 2/3 spill; and Requested by the relevant Control Agency	OSTM will continue for 24 hours after the source is under control and a surface sheen is no longer observable; or As directed by the relevant Control Agency
Vessel surveillance	Notification of a Level 2/3 spill - may be deployed in a Level-1 incident (to be determined by On-Scene Commander); and Requested by the relevant Control Agency	Vessel surveillance will continue for 24 hours after the source is under control and a surface sheen is no longer observable; or As directed by the relevant Control Agency
Aerial surveillance	Notification of a Level 2/3 spill; and	Aerial surveillance will continue for 24 hours after the source is under control and a surface sheen is no longer observable; or

Tactic	Initiation criteria	Termination criteria
	Requested by the relevant Control Agency	As directed by the relevant Control Agency
Satellite surveillance and data capture	Notification of a Level 2/3 spill; and Requested by the relevant Control Agency	Satellite surveillance will continue for 24 hours after the source is under control and a surface sheen is no longer observable; or Satellite surveillance is no longer required to provide situational awareness; or Agreement has been reached with the Jurisdictional Authority relevant to the spill to terminate the tactic

6.2 Implementation guide

Table 6-1 provides guidance on tasks and responsibilities that the IMT should consider to support the Control Agency if they implement this response strategy. The Control Agency is responsible for the implementation of the response and therefore, depending on the circumstances of the spill, may determine that some tasks be varied, should not be undertaken or should be reassigned.

Table 6-1: Monitor and evaluate implementation guide

Responsibility		Task	Consideration	Complete
Tracking buoy (if selected)				
Initial Actions	Pilot Energy Representative/Operations Section	Request onsite vessel to deploy tracking buoy		❑
	Vessel Master	Direct personnel to deploy buoy from the vessel: • Remove buoy from packaging; • Remove On/Off magnet and place in safe location (back in the box); and • Deploy buoy into the water from height not greater than 10 m unless the buoy design is robust to do so from a greater height'	Buoy should be deployed as close as possible to the leading edge of the spill (personnel and vessel safety is priority and must be considered by Vessel Master prior to selecting this tactic)	❑
	Pilot Energy Representative	Inform IMT that buoy has been deployed and provide IMT with current weather conditions	Note deployment details in incident log	❑
	Planning Section	Verify deployment of tracking buoy using tracking buoy login details	Tracking buoy login details located in the Project Emergency Contacts Directory	❑
Ongoing Actions	Planning Section	Use tracking buoy data to regularly update Common Operating Picture/Situation Boards in IMT		❑
	Planning Section	Provide tracking buoy data to Control Agency as soon as possible	Control Agency could provide data to spill trajectory provider improve the accuracy of spill model	❑
	Planning Section	Liaise with Control Agency to seek direction regarding any additional deployments of tracking buoys		❑
Trajectory and fate/weathering modelling (if selected)				
Initial Actions	Planning Section	Conduct hydrocarbon distribution, fate and weathering assessment using Automated Data Inquiry for Oil Spills (ADIOS2) using information available on oil type and provide information to Control Agency		❑

Responsibility		Task	Consideration	Complete
	Planning Section	Use information to regularly update Common Operating Picture/Situation Boards in IMT		❑
	Planning Section	Provide tracking buoy data to Control Agency as soon as possible		❑
ACTIONS BELOW ARE INDICATIVE ONLY AND ARE AT THE FINAL DETERMINATION OF THE CONTROL AGENCY				
Initial Actions	Planning Section	Contact Control Agency to request modelling through AMSA National Plan arrangements Complete Spill Trajectory Modelling Request form and provide to Control Agency	Complete Spill Trajectory Modelling Request form can be found here - https://www.amsa.gov.au/forms/national-plan-spill-trajectory-modelling-request Modelling should be undertaken within 4 hours of the request being sent to OSTM Service Provider, then every operational day during the spill response. Note all actions in incident log	❑
Ongoing Actions	Planning Section	Request trajectory modelling be provided daily throughout the duration of the response and integrate data into Common Operating Picture/Situation Boards		❑
	Planning Section	Use results from monitor and evaluate activities, and/or operational monitoring data (where available) to improve spill trajectory model accuracy	Provide available data to OSTM Service Provider at the end of each operational period	❑
Vessel surveillance (if selected)				
Initial Actions	Pilot Energy Representative/Operations Section	Determine if there are any nearby vessels available to follow spills and aid surveillance activities	Support vessels may be able to provide surveillance	❑
	Operations Section	Obtain approval from Control Agency to commence vessel surveillance in the vicinity		❑
	Vessel Master	Provide IMT initial report on estimated spill volumes and movement based on visual observation (if possible)	Preliminary observations are intended to provide initial projections of spill trajectory and scale prior to more detailed modelling and surveillance. These observations should be immediately verified by more detailed surveillance A Vessel Surveillance Observation Log is provided in Visual Surveillance Logs.	❑

Responsibility		Task	Consideration	Complete
Ongoing Actions	Planning Section	If vessel surveillance is feasible, ensure surveillance data is regularly incorporated into the Common Operating Picture/Situation Boards		❑
Aerial surveillance (if selected)				
Initial Actions	Operations Section	Contact AMSA to initiate aerial surveillance (via National Plan arrangements)	Trained observers should be familiar with the Bonn Agreement Aerial Operations Handbook (Part III) (Bonn Agreement, 2016). An Aerial Surveillance Observation Log is provided in Visual Surveillance Logs. Trained aerial observers are available from AMSA National Response Team (via the National Plan)	❑
	Operations Section	Once approval obtained, confirm availability of aerial surveillance platform to conduct initial surveillance flight	If aviation asset available near spill location, utilise where possible to gather as much information about the spill. If aviation asset not available at spill location, IMT is to seek available resources. It is possible that the initial surveillance flight will not include a trained aerial surveillance observer. Initial flights can be conducted using a standard crew and initial surveillance should not be delayed waiting for trained personnel. Ensure all safety requirements are met prior to deployment. There should be an attempt to obtain the following data during initial surveillance: • name of observer, date, time, aircraft type, speed and altitude of aircraft • location of slick or plume (GPS positions, if possible) • spill source • size of the spill, including approximate length and width of the slick or plume • visual appearance of the slick (e.g. colour) • edge description (clear or blurred) • general description (windrows, patches etc.) • wildlife, habitat or other sensitive receptors observed	❑

Responsibility		Task	Consideration	Complete
			• basic metocean conditions (e.g. sea state, wind, current) • photographic/video images	
	Operations Section	Obtain approval from Control Agency to commence surveillance flights in the vicinity of the spill	Operations Section is to assume primary coordination for all flights if approved by Control Agency	❑
	Operations Section	Once initial flight is complete, IMT in consultation with the Control Agency to determine if additional flights are required		❑
	Operations Section	In addition to arranging initial flight, mobilise aircraft and trained observers to the spill location to undertake surveillance activities if approved by the Control Agency (these can be cancelled if initial flight determines no additional surveillance is required)	Aerial platform should be capable of providing the following: • immediate accessibility from a designated airport • capability to fly at 150 feet • provision of aircraft crew for 1 x aircraft and space for at least one trained aerial observer	❑
	Operations Section	All records to be relayed to IMT and Control Agency when aircraft returns from observation flight	Visual observations from aircraft have inherent subjectivity due to the effect of the angle of insolation on the surface of the ocean. Optical techniques are also dependent on cloud cover and daylight. Where possible, a verbal report via radio/telephone en-route providing relevant information should be considered if the aircraft has long transits from the spill location to base	❑
Ongoing Actions	Operations Section	In consultation with the Control Agency, develop a flight schedule for ongoing aerial surveillance	Frequency of flights should consider information needs of IMT to help maintain the Common Operating Picture and determine ongoing response operations	❑
Satellite imagery (if selected)				
Initial Actions	Intelligence/Planning Section	Contact AMSA to initiate satellite services		❑
	Intelligence/Planning Section	Combine satellite data with other optical imagery (aerial surveillance, vessel-based observations) to mitigate issues of angle of insolation, thick cloud cover and night	Satellite derived data can be used to broaden aerial survey data in terms of both spatial and temporal scale and provide images	❑

Responsibility		Task	Consideration	Complete
Ongoing Actions	Intelligence/Planning Section	Request satellite imagery be provided every 48 hours throughout the duration of the response and integrate data into Common Operating Picture/Situation Boards		❑
General Actions (to be coordinated between Pilot Energy IMT and Control Agency)				
Surveillance Team		Record relevant data e.g. equipment used, time deployed, weather conditions, Job Safety Analysis (JSA) for all tasks		❑
Surveillance Team		Hold pre-mobilisation survey team meeting, including communication of field survey schedules (provision for field personnel rotation)		❑
IMT		Obtain weather and tidal information from the Bureau of Metrology and on-scene observers		❑
IMT		Assemble competent field team(s) (if required), including required personal protective equipment (PPE). Arrange any required inductions and/or permits		❑
IMT		Arrange transportation (e.g. flights, vehicles), accommodation and food/equipment for field teams		❑
IMT		Activate Geographic Information Systems (GIS) personnel to develop maps that can overlay surveillance data to enhance situational awareness of the spill		❑
IMT		Review fate and weathering, tracking buoy, oil spill modelling data and satellite data with field surveillance data (aerial and vessel surveillance) to validate spill fate and trajectory	Use available data to conduct Operational SIMA and confirm that pre-identified response options are still appropriate	❑
IMT		Use monitor and evaluate data to periodically reassess the spill and modify the response (through the IAP), as required		❑

6.4 Monitor and evaluate - environmental performance

Table 6-2 indicates the environmental performance standards and measurement criteria for the following Environmental Performance Outcome:

- Support implementation of monitor and evaluate tactics in order to provide situational awareness to inform Control Agency decision making.

Table 6-2: Environmental Performance – Monitor and Evaluate

Performance Standard	Measurement Criteria
Response Preparedness	
Tracking buoy available on seismic vessel and maintained according to manufacturer specifications for duration of the titleholder survey	Records demonstrate that tracking buoys are available on vessels and maintained according to manufacturer specifications for the duration of the seismic survey
Response Implementation	
Offer support to the Control Agency in the selection and initiation of suitable monitor and evaluate tactics within 2 hours of notifying Control Agency of spill	Records demonstrate that IMT offered support to Control Agency in the selection and initiation of monitor and evaluate tactics within 2 hours of notifying Control Agency of spill
Deploy tracking buoys close to leading edge of spill (providing it is safe to do so) within 2 hours of Vessel Master being made aware of the spill	Records indicate that tracking buoys deployed close to leading edge of spill within 2 hours of Vessel Master being made aware of the spill
Initiate hydrocarbon distribution, fate and weathering assessment using ADIOS2 within 2 hours of IMT being made aware of the spill	Records indicate IMT initiated hydrocarbon distribution, fate and weathering assessment within 2 hours of spill notification
Provide available data from monitor and evaluate activities to modelling provider at the end of each operational period to help improve spill model accuracy	Records indicate that at the end of each operational period available data from monitor and evaluate activities was submitted to service provider to help improve spill model accuracy
Provide available monitoring data to Control Agency at the end of each operational period for inclusion into the Common Operating Picture and Operational SIMA to aid in response decision making	Incident Log shows available monitoring data provided to Control Agency at the end of each operational period

7. Natural Recovery

Natural recovery is a no impact response. There are no initiation or termination criteria, nor capability required to implement it apart from supporting strategies such as monitor and evaluate and oil spill monitoring.

Natural recovery is the process of letting hydrocarbons degrade naturally in the environment, either offshore or onshore. This section addresses offshore natural recovery, including degradation on or in the water column.

Oil on the ocean disperses and breaks up via several processes. Natural processes acting on the oil such as evaporation, dissolution, dispersion into the water column, biodegradation and photo oxidisation reduce the volume of oil over time. Evaporation can be the most important mechanism to reduce the volume of oil, especially in the short term. Approximately 65-80% of an MGO spill will generally evaporate over the first two days, depending upon the prevailing conditions and spill volume.

Whilst offshore natural recovery involves no direct response activities to mitigate the spill, it may be an appropriate response strategy to complement other intervention-based response strategies; or as a primary response strategy if other strategies are likely to cause a greater impact than leaving the oil to degrade naturally. It may also be the only viable response strategy during inclement weather (e.g. tropical cyclones), as responding could place personnel at risk.

Table 7-1 provides guidance on when natural recovery may be a suitable response option.

There is no implementation guide provided for this response option, as no direct tasks are required. However, if natural recovery is selected as a suitable response strategy, the Operational SIMA would need to confirm that natural recovery remains a suitable response strategy throughout the spill response.

Table 7-1: Natural Recovery Application Guidance

Recommended	Not Recommended
• For light, non-persistent hydrocarbons, such as ITOPF Group 1-2 hydrocarbons (e.g. MGO, condensate, hydraulic oil) • Product is weathering rapidly due to environmental conditions (e.g. high energy coastline, wave action) • Product is too thin for effective use of dispersants or containment and recovery • If responding during inclement weather conditions would place response personnel at risk	• For persistent hydrocarbons, such as ITOPF Group 3-4 hydrocarbons (Crude oil, Intermediate Fuel Oil, Heavy Fuel Oil) • Environmental conditions are not favourable for rapid degradation (e.g. calm seas) • Slick is continuous enough and thick enough to treat with dispersants or via containment and recovery methods

8. Shoreline Protection and Deflection

Spill modelling predicts if a worst-case vessel collision spill (refer to Section 3.2.1) were to occur during Eureka 3D MSS activities, there is a low probability of minimal shoreline contact (<1 m^3). Shoreline protection and deflection has been included as a secondary response strategy for the worst-case scenario, and would only be implemented if an operational SIMA demonstrated it would result in an overall benefit to receptors.

Protection and deflection tactics are utilised to divert hydrocarbons away from sensitive shoreline receptors and are more effective if they are deployed ahead of spill contact. They are typically used to protect smaller, high priority sections of shoreline. The relevant Control Agency has operational responsibility for the implementation of shoreline protection activities. Protection priorities are identified in

Table 3-4 but will need to be confirmed by the relevant Control Agency when the Operational SIMA is prepared.

The relevance and suitability of individual tactics (or combination of tactics) will need to be considered when preparing the Operational SIMA for individual spills. Initiation of suitable tactics will need to be confirmed by the Control Agency, prior to deployment.

- Shoreline booming – involves the use of a variety of booming techniques to exclude oil (exclusion booming), divert oil to a collection point where it can be removed from the environment (diversion booming) and redirecting flow of oil away from a priority area (deflection booming).
- Berms, dams and dikes – uses sandbags or embankments to exclude oil from sensitive areas
- Shoreside recovery – uses nearshore skimmers to collect oil corralled by nearshore booms (also used during shoreline clean-up).
- Passive recovery - uses sorbent booms or pads to collect oil and remove it from the environment. This can be used as a pre-impact tactic where sorbents are laid ahead of the spill making contact with the shoreline.
- Non-oiled debris removal – involves the removal of debris (e.g. seaweed) from the shoreline to prevent it being oiled, which in turn reduces impacts to wildlife and the volumes of waste produced during shoreline clean-up activities.

The effectiveness of shoreline protection and deflection tactics will be dependent upon metocean and wind conditions. Protection booms should only be installed in areas where tidal currents are below 0.75 knots.

8.1 Initiation and termination criteria

Initiation criteria	Termination criteria
Level 2 or 3 spills where shorelines with protection priorities will potentially be impacted; or SIMA demonstrates that the response strategy and selected tactics are likely to result in a net environmental benefit; and Requested by the relevant Control Agency	SIMA has determined that this strategy is unlikely to result in an overall benefit to the affected shoreline/s; and Control Agency decides to terminate the response strategy

8.2 Implementation guide

The locations for nearshore protection and deflection operations will be evaluated by the relevant Control Agency throughout the incident response and will consider monitor and evaluate data and the protection priorities. In addition, the information obtained from monitor and evaluate activities will be used by the IMT in the development of the Operational SIMA to inform the most effective protection tactics (if any) to apply to individual sites. This will also consider the feasibility and effectiveness of selected tactics.

Deployment of equipment and personnel is to be at the direction of the WA DoT as the Control Agency in State waters.

Table 8-1 provides guidance to the IMT on the actions and responsibilities that should be considered to support the Control Agency if they implement this response strategy. The Control Agency is responsible for the implementation of the response and therefore, depending on the circumstances of the spill, may determine that some tasks be varied, should not be undertaken or should be reassigned.

Table 8-1: Shoreline Protection and Deflection Implementation Guide

Responsibility		Task	Consideration	Complete
Initial Actions	Planning Section	Notify relevant authorities if there are likely to be any impacts on shorelines. See Table 4-1 for details on notifications. See Table 2-2 for details on Control Agency responsibilities.		❑
	Planning Section	Collect and provide spill trajectory modelling, other operational monitoring data and existing sensitivity information/mapping to Control Agency for confirmation of priority protection areas and Operational SIMA.		❑
ACTIONS BELOW ARE INDICATIVE ONLY AND ARE AT THE FINAL DETERMINATION OF THE CONTROL AGENCY				
Initial Actions	Planning Section	In conjunction with Control Agency conduct Operational SIMA to determine if protection and deflection is likely to result in a net environmental benefit using information from shoreline assessments and any tactical response plans for the area. See Section 3.5 for guidance on Operational SIMA.	Shoreline Clean-up Assessment Teams are responsible for preparing field maps and forms detailing the area surveyed and making specific clean-up recommendations (Refer to the Pilot Energy OSM-BIP for information on OMP: Shoreline Clean-up Assessment). The condition of affected shorelines will be constantly changing. Results of shoreline surveys should be reported as quickly as possible to the IMT and Control Agency to help inform real-time decision making. In consultation with Control Agency, engage a Heritage Advisor if spill response activities overlap with potential areas of cultural significance.	❑
Initial Actions	Planning Section	If Operational SIMA indicates that there is an overall environmental benefit, support Control Agency in the development of a Shoreline Protection Plan (IAP sub-plan) for each deployment area.	Shoreline Protection Plan may include (but not be limited to): • Priority nearshore and shoreline areas for protection • Locations to deploy protection and deflection equipment • Permits required (if applicable)	❑

Responsibility		Task	Consideration	Complete
			• Protection and deflection tactics to be employed for each location • List of resources (personnel and equipment) required • Logistical arrangements (e.g. staging areas, accommodation, transport of personnel) • Timeframes to undertake deployment • Access locations from land or sea • Frequency of equipment inspections and maintenance (noting tidal cycles) • Waste management information, including logistical information on temporary storage areas, segregation, decontamination zones and disposal routes • No access and demarcation zones for vehicle and personnel movement considering sensitive vegetation, bird nesting/roosting areas and turtle nesting habitat (utilise existing roads and tracks first).	
Ongoing Actions	Planning Section	In conjunction with Control Agency conduct regular Operational SIMA to confirm effectiveness of tactics and demonstrate benefit of continuing to implement shoreline protection and deflection activities.		❑
General (to be coordinated by Control Agency and Pilot Energy IMT to provide support)				
Emergency Response Team (ERT)		Record relevant data e.g. equipment used, time deployed, weather conditions, JSA for all tasks.		❑
ERT		Hold pre-mobilisation survey team meeting, including communication of field survey schedules (provision for field personnel rotation).		❑
IMT		Obtain weather and tidal information from the Bureau of Metrology and on-scene observers.		❑

Responsibility	Task	Consideration	Complete
IMT	Assemble competent field team(s) (if required), including required PPE. Arrange any required inductions and/or permits.		❑
IMT	Arrange transportation (e.g. flights, vehicles), accommodation and food/equipment for field teams.		❑
IMT	Establish staging areas.		❑
IMT	Establish decontamination facilities (as required) for all equipment, vessels and personnel.		❑
IMT	Prepare a communications plan for field personnel.		❑

8.3 Shoreline protection and deflection – environmental performance

Table 8-2 indicates the environmental performance standards and measurement criteria for the following Environmental Performance Outcome:

- Support implementation of shoreline protection and deflection tactics to protect prioritised receptors from contact with hydrocarbons.

Table 8-2: Environmental Performance – Shoreline Protection and Deflection

Performance Standard	Measurement Criteria
Response Implementation	
Support Control Agency in the preparation of the Operational SIMA to determine if shoreline protection is likely to result in a net environmental benefit.	Records demonstrate that support offered to Control Agency in the preparation of an Operational SIMA.
Locations for nearshore protect and deflect operations will be evaluated by the relevant Control Agency throughout the incident response and will consider monitor and evaluate data and protection priorities.	Incident log.
If Operational SIMA indicates that there is an overall environmental benefit, support Control Agency in the development of a Shoreline Protection Plan (IAP sub-plan).	Shoreline Protection Plan (IAP sub-plan) is dated and indicates preparation done in conjunction with Control Agency and prior to shoreline protection operations commencing.

Performance Standard	Measurement Criteria
Shoreline protection activities will be implemented under the direction of the Control Agency.	Records demonstrate that shoreline protection activities implemented under the direction of the Control Agency.

9. Shoreline Clean-up

Spill modelling predicts if a worst-case vessel collision spill were to occur during Eureka 3D MSS activities (refer to Section 3.2.1), there is a low probability of minimal shoreline contact. Out of 100 simulations only one simulation predicted shoreline accumulation above 100 g/m^2 which was at Green Head – Leeman, with a volume of less than 1 m^3 predicted over less than 1 km of shoreline (refer to Table 3-3). Shoreline clean-up has been included as a secondary response strategy for the worst-case scenario, and would only be implemented if an operational SIMA demonstrated it would result in an overall benefit to receptors.

The relevant Control Agency has operational responsibility for the implementation of shoreline clean-up activities. Protection priorities are identified in

Table 3-4 but will need to be confirmed by the relevant Control Agency when the Operational SIMA is prepared.

Shoreline clean-up aims to remove hydrocarbons from shorelines and intertidal habitat to achieve a net environmental benefit. Removal of these hydrocarbons helps reduce remobilisation and contamination of wildlife, habitat and other sensitive receptors. Shoreline clean-up is often a lengthy and cyclical process, requiring regular surveys (via OMP: Shoreline Clean-up Assessment) to monitor the effectiveness of clean-up activities and assess if they are resulting in any adverse impacts.

The locations for shoreline clean-up operations will continue to be evaluated by the relevant Control Agency throughout the incident response and will take into account monitor and evaluate data, operational monitoring data and the protection priorities identified.

The relevance and suitability of individual tactics (or tactics used in combination) will need to be considered when preparing the Operational SIMA for individual spills. Initiation of suitable tactics will need to be confirmed by the Control Agency, prior to deployment.

- Natural recovery – involves leaving the oil on the shoreline and allowing it to degrade naturally over time
- Manual and mechanical removal – requires the use of machinery, hand tools (or a combination) to remove hydrocarbons and oiled materials
- Washing, flooding and flushing – involves using water, steam, or sand to flush hydrocarbons from impacted shoreline areas
- Sediment reworking and surf washing – uses various methods to move oiled material into the intertidal zone where the hydrocarbons are washed out by wave action.

The information obtained from Shoreline Clean-up Assessment Teams should be used by the IMT and Control Agency in the development of the Operational SIMA to inform the most effective clean-up tactics (if any) to apply to individual sites. A minimum threshold of 100 g/m^2 (concentration of accumulated hydrocarbons on shorelines) is used to determine the lower limit for commencing clean-up operations (Table 3-5).

9.1 Initiation and termination criteria

Initiation criteria	Termination criteria
Level 2 or 3 spills where shorelines with protection priorities will potentially be impacted; or SIMA demonstrates that the response strategy and individual tactics are likely to result in a net environmental benefit; and Requested by the relevant Control Agency	SIMA has determined that this strategy is unlikely to result in an overall benefit to the affected shoreline/s; and Control Agency decides to terminate the response strategy

9.2 Operational considerations

Large scale operations involving large numbers of personnel may cause adverse environmental impacts at sensitive shoreline locations. The constant removal of hydrocarbons mixed with sand and debris, even via manual removal can result in a removal of large volumes of substrate (e.g. sand, pebbles). If intrusive clean-up is conducted frequently, over a long period of time and along contiguous lengths of coastline, this may result in geomorphological changes to the shoreline profile and adverse impacts to shoreline invertebrate communities which provide an array of ecosystem services (Michel et al., 2017).

An Operational SIMA should consider the safety constraints and ecological sensitivities of these shorelines (Refer to considerations presented in Table 3-7). If an Operational SIMA deems clean-up is likely to result in a net environmental benefit, it may be beneficial for operations to be conducted by smaller teams (max 10 people/team) over a longer period. Intermittent manual treatment (<20 visits/month) and use of passive recovery booms is likely to be more effective than intrusive methods (e.g. intrusive manual removal >20 visits/month). Although this may take longer to undertake the clean-up, the benefits often outweigh the impacts as smaller teams are more targeted, recover more hydrocarbons and less sand and debris, reducing trampling of hydrocarbons into the shore profile and will minimise ecological impacts on the shorelines and their sensitive species.

Clean-up endpoints should be established in consultation with key stakeholders (e.g. Parks Australia, WA DBCA) early in the clean-up process.

9.3 Implementation guide

The locations for shoreline clean-up operations will be evaluated by the relevant Control Agency throughout the incident response and will consider monitor and evaluate data and the protection priorities. In addition, the information obtained from monitor and evaluate activities will be used by the IMT in the development of the Operational SIMA to inform the most effective protection tactics (if any) to apply to individual sites. This will also consider the feasibility and effectiveness of selected tactics.

Table 9-1 provides guidance on tasks and responsibilities that Pilot Energy will undertake to support the Control Agency should they implement this response strategy. The Control Agency is responsible for the implementation of the response and therefore, depending on the circumstances of the spill, may determine that some tasks be varied, should not be undertaken or should be reassigned.

Table 9-1: Shoreline clean-up implementation guide

Responsibility		Task	Consideration	Complete
Initial Actions	Planning Section	Notify relevant authorities if there are likely to be any impacts on shorelines. Refer to Table 4-1 for details on notifications. Refer to Table 2-2 for details on Control Agency responsibilities.		❑
	Planning Section	Collect and provide spill trajectory modelling, other operational monitoring data and existing sensitivity information/mapping to Control Agency for confirmation of priority protection areas and Operational SIMA.		❑
	Planning Section	In conjunction with Control Agency, consult with Director of National Parks whilst preparing Operational SIMA for Designated Marine Parks.		❑
ACTIONS BELOW ARE INDICATIVE ONLY AND ARE AT THE FINAL DETERMINATION OF THE CONTROL AGENCY				
Natural recovery (if selected)				
Initial Actions	Planning Section	If Operational SIMA supports natural recovery, use monitor and evaluate data to periodically reassess the condition of the shoreline/s and modify tactics, if required by the Control Agency.		❑
Manual and mechanical removal; washing, flooding and flushing; and/or sediment reworking and surf washing (if selected)				
Initial Actions	Planning Section	If Operational SIMA supports shoreline clean-up, support Control Agency in the development of a Shoreline Clean-up Plan (IAP sub-plan) for inclusion in the IAP.	Shoreline Clean-up plan may include (but not be limited to): • Clean-up objectives • Clean-up end points • Clean-up priorities • Assessment and location of staging areas and worksites (including health and safety constraints, zoning) • Permits required (if applicable) • Chain of command for onsite personnel	❑

Responsibility		Task	Consideration	Complete
			• List of resources (personnel, equipment, PPE) • Details of accommodation and transport • Waste management information, including logistical information on temporary storage areas, segregation, decontamination zones and disposal routes • No access zones (to minimise disturbance to sensitive receptors) Refer to IPEICA-IOGP (2016) for additional guidance on shoreline clean-up planning and implementation.	
Ongoing Actions	Operations Section	Support Control Agency in monitoring the effectiveness of shoreline clean-up operations by continual implementation of Shoreline Clean-up Assessment.	Where possible, maintain same composition of Shoreline Clean-up Assessment Teams. If the same personnel are able to recommend clean-up techniques and then monitor their implementation, they will be better placed to adapt their recommendations as the clean-up progresses and judge when the agreed end-points have been met.	❑
General (to be coordinated by Control Agency and Pilot Energy IMT to provide support)				
IMT		Record relevant data e.g. equipment used, time deployed, weather conditions, JSA for all tasks.		❑
IMT		Hold pre-mobilisation survey team meeting, including communication of field survey schedules (provision for field personnel rotation).		❑
IMT		Obtain weather and tidal information from the Bureau of Metrology and on-scene observers.		❑
IMT		Assemble competent field team(s) (if required), including required PPE. Arrange any required inductions and/or permits.		❑
IMT		Arrange transportation (e.g. flights, vehicles), accommodation and food/equipment for field teams.		❑

Responsibility	Task	Consideration	Complete
IMT	Establish decontamination facilities (as required) for all equipment, vessels and personnel.		❑
IMT	Prepare a communications plan for field personnel.		❑
IMT	Consult with key stakeholders to develop clean-up end points for shorelines.		❑

9.4 Shoreline clean-up – environmental performance

Table 9-2 indicates the environmental performance standards and measurement criteria for the following Environmental Performance Outcome:

- Support implementation of shoreline clean-up tactics to remove stranded hydrocarbons from shorelines in order to reduce impact on coastal protection priorities and facilitate habitat recovery.

Table 9-2: Environmental Performance – Shoreline Clean-up

Performance Standard	Measurement Criteria
Response Implementation	
Support Control Agency in the preparation of the Operational SIMA to determine if shoreline clean-up is likely to result in a net environmental benefit.	Records demonstrate that support offered to Control Agency in the preparation of an Operational SIMA.
Control Agency and IMT consult with Director of National Parks whilst preparing Operational SIMA for Designated Marine Parks.	Records demonstrate that Director of National Parks consulted when preparing Operational SIMA for Designated Marine Parks.
Shoreline clean-up activities will be implemented under the direction of the Control Agency.	Records demonstrate that shoreline clean-up activities implemented under the direction of the Control Agency.
Locations for clean-up operations will be evaluated by the relevant Control Agency throughout the incident response and will consider monitor and evaluate data, operational monitoring data and protection priorities.	Incident log.
If Operational SIMA indicates that there is an overall environmental benefit, support Control Agency in the development of a Shoreline Protection Plan (IAP sub-plan).	Shoreline Protection Plan (IAP sub-plan) is dated and indicates preparation done in conjunction with Control Agency and prior to shoreline protection operations commencing.

10. Oiled Wildlife Response

The short-term effects of hydrocarbons on wildlife may be direct such as the external impacts from coating or internal effects from ingestion and inhalation. Oiled wildlife response (OWR) includes wildlife surveillance/reconnaissance, wildlife hazing, pre-emptive capture and the capture, cleaning, treatment, and rehabilitation of animals that have been oiled. In addition, it includes the collection, post-mortem examination, and disposal of deceased animals that have succumbed to the effects of oiling.

Long-term effects of a spill on wildlife may be associated with loss/degradation of habitat, impacts to food sources, and impacts to reproduction. An assessment of such impacts is covered under scientific monitoring.

The relevant Control Agency has operational responsibility for the implementation of an OWR as outlined in Sections 10.1 and 10.2. It is however also an expectation that Pilot Energy will conduct the initial first-strike response actions for wildlife and continue to manage those operations until the Control Agency takes over. Once the Control Agency takes over, the Pilot Energy will function as a Support Agency, and continue to provide planning and resourcing support.

10.1 Commonwealth waters

The Commonwealth of Climate Change, Energy, the Environment and Water (DCCEEW) is the Jurisdictional Authority for oiled wildlife in Commonwealth waters, although for vessel-based spills, the Control Agency function remains with AMSA. If an oiled wildlife response is required then this would be initiated through AMSA, who can access Australian Marine Oil Spill Centre (AMOSC) oiled wildlife resources.

10.2 Western Australian waters

If an OWR is required in WA State waters, the Department of Biodiversity, Conservation and Attractions (DBCA) will lead the OWR under the control of the WA DoT (as Control Agency). The key plan for OWR in WA is the WA Oiled Wildlife Response Plan (WAOWRP) (DBCA, 2022a) and the WA Oiled Wildlife Response Manual (WA OWR Manual) (DBCA, 2022b).

10.3 Magnitude of wildlife impact

Given the distribution and behaviour of wildlife in the marine environment, a spill which only impacts offshore waters is likely to result in limited opportunities to rescue wildlife. In such instances, continued wildlife reconnaissance, carcass recovery, sampling of carcasses that cannot be retrieved and scientific monitoring are more likely to be the focus of response efforts. In contrast, a spill which results in shoreline accumulation is likely to result in far greater wildlife impacts and opportunities to rescue wildlife.

Spill modelling predicts if a worst-case vessel collision spill (refer to Section 3.2.1) were to occur during Eureka 3D MSS activities, there is a low probability of minimal shoreline contact. Using the WAOWRP (DBCA, 2022a) *Guide for Rating the Wildlife Impact of an Oil Spill* (

Table 10-1) it is predicted that low wildlife impacts are likely associated with this scenario.

Table 10-1: WAOWRP Guide for rating the wildlife impact of an oil spill (DBCA, 2022a)

Wildlife Impact Rating	Low	Medium	High
What is the likely duration of the wildlife response?	< 3 days	3 – 10 days	> 10 days
What is the likely total intake of animals?	< 10	11 - 25	> 25
What is the likely daily intake of animals?	0 -2	2 – 5	> 5
Are threatened species, or species protected by treaty, likely to be impacted, either directly or by pollution of habitat or breeding areas?	No	Yes – possible	Yes - likely
Is there likely to be a requirement for building primary care facility for treatment, cleaning and rehabilitation?	No	Yes - possible	Yes - likely

10.4 Wildlife priority protection areas

For planning purposes, determination of wildlife priority protection areas is based on stochastic modelling of the worst-case spill scenario, the known presence of wildlife, and in consideration of the following:

- presence of high densities of wildlife, threatened species, and/or endemic species with high site fidelity
- greatest probability and level of contact from floating oil and/or shoreline accumulation
- shortest timeframe to contact.

The wildlife priority protection areas for a spill associated with Eureka 3D MSS activities are outlined in Table 10-2.

Depending on the timing of a potential hydrocarbon spill, certain species could be more impacted because of key seasonal biological activities such as breeding, mating, nesting, hatching or migrating.

Table 10-2: Wildlife priority protection areas

Wildlife priority protection area	Wildlife
Illawong – Cliff Head (DoT shoreline cell # 191)	• Inshore islands are important breeding areas for seabirds • Australian sea lion • Humpback whales and other inshore cetaceans
Green Head – Leeman (DoT shoreline cell # 193)	• Inshore islands are important breeding areas for seabirds • Australian sea lion • Humpback whales and other inshore cetaceans • Dunnart and dibbler found on Boullanger Island

10.5 Initiation criteria

Initiation criteria	Termination criteria
Notification of a Level 2/3 spill	When the SIMA for oiled wildlife response activities indicates no further action required; and Control Agency decides to terminate the response strategy

10.6 Implementation guide

Table 10-3 provides guidance to the IMT on the actions and responsibilities that should be considered when implementing an oiled wildlife first-strike plan. In State waters, Pilot Energy will conduct the initial first-strike response actions for wildlife and continue to manage these operations until DBCA is activated as the lead agency for wildlife response and formal handover occurs. Following formal hand over, Pilot Energy will function as a support organisation for the OWR and will be expected to continue to provide planning and resources as required.

Wildlife surveillance/reconnaissance is a critical component of an oiled wildlife first-strike. Wildlife reconnaissance should be undertaken in close consultation with personnel undertaking relevant operational monitoring activities. The information gathered from wildlife reconnaissance and all relevant pre-existing wildlife data/information should be used to inform decisions and aid the on-going development of the OWR portion of the IAP.

Table 10-3: OWR implementation guide

Responsibility		Task	Consideration	Complete
Initial Actions	Surveillance personnel	Personnel conducting monitor and evaluate activities shall report wildlife sightings in or near the spill trajectory (including those contacted with hydrocarbons or at risk of contact) and report them to the IMT within two hours of detection.	Record all reports of wildlife potentially impacted and impacted by spill. Record reports on: • Time / date • Location / GPS coordinates • Access to location • Numbers of individuals (estimate) • Species (if known) • Condition of implanted animals (if available) • Take phots of the affected wildlife and / or affected surrounds, if possible	❑
	Environment Unit Lead	If wildlife is sighted and are at risk of contact or have been contacted: In Commonwealth waters notify AMSA who can access AMOSC oiled wildlife resources In State waters notify DoT and DCBA State Duty Officer	Refer to Table 4-1 for reporting requirements.	❑
	Environment Unit Lead	Notify Department of Agriculture, Water and the Environment if there is a risk of death or injury to a protected species (including Matters of National Environmental Significance [MNES]).	Refer to Table 4-1 for reporting requirements.	❑
	Environment Unit Lead	Review all wildlife reports from surveillance or opportunistic activities and contact personnel who made the reports (if possible) to confirm information collected.		❑
ACTIONS BELOW ARE INDICATIVE ONLY AND ARE AT THE FINAL DETERMINATION OF THE CONTROL AGENCY				
Initial Actions	Planning Section	Support Control Agency in the development of an OWR Plan (IAP sub-plan) for inclusion in the IAP.	Targeted wildlife surveillance/reconnaissance needs to consider species known to occur in the impacted area, life-cycle stages, behaviour, and key risk periods. Wildlife reconnaissance should be undertaken in close consultation with personnel	❑

Responsibility		Task	Consideration	Complete
			undertaking relevant operational monitoring activities. Confirm best reconnaissance platform (e.g. vessel, aerial, shoreline). Consider ability to share resources (e.g. Monitor and Evaluate activities, Scientific Monitoring). Refer to the WA OWR Manual (DBCA, 2022b) for further information: • P1 OWR Procedure: Phase 1 Wildlife Reconnaissance • G-1: OWR Strategies by Fauna Group	
Ongoing Actions	Planning and Operations Section	Support Control Agency with any on-going OWR planning and resourcing support.		❑
General (to be coordinated by Control Agency and Pilot Energy IMT to provide support)				
IMT		Record relevant data e.g. equipment used, time deployed, weather conditions, JSA for all tasks.		❑
IMT		Hold pre-mobilisation team meeting, including communication of field schedules (provision for field personnel rotation).		❑
IMT		Obtain weather and tidal information from the Bureau of Metrology and on-scene observers.		❑
IMT		Assemble competent field team(s) (if required), including required PPE. Arrange any required inductions and/or permits.		❑
IMT		Arrange transportation (e.g. flights, vehicles), accommodation and food/equipment for field teams.		❑
IMT		Establish decontamination facilities (as required) for all equipment, vessels and personnel.		❑
IMT		Prepare a communications plan for field personnel.		❑

10.7 Oiled wildlife response – environmental performance

Table 10-4 indicates the environmental performance standards and measurement criteria for the following Environmental Performance Outcome:

- Support implementation of OWR tactics in accordance with relevant State Oiled Wildlife Response Plans to prevent or reduce impacts, and to humanely treat, house, and release or euthanise wildlife.

Table 10-4: Environmental Performance – Oiled wildlife response

Performance Standard	Measurement Criteria
Response Implementation	
OWR Plan developed and included in the IAP to provide oversight and management of OWR operations.	Records indicate IAP OWR Plan prepared prior to OWR operations commencing.

11. Scientific Monitoring

Pilot Energy has developed an OSM-BIP which describes a program of monitoring oil pollution that will be adopted in the event of a hydrocarbon spill incident (Level 2-3) to marine waters. It is aligned to the Joint Industry Operational and Scientific Monitoring Framework (APPEA, 2021) and describes how this Framework applies to the Eureka 3D MSS activities and spill risks in Australian waters.

The OSM-BIP is structured so that it can provide a flexible framework that can be adapted to individual spill incidents. A series of Operational Monitoring Plans (OMPs) and Scientific Monitoring Plans (SMPs) form part of the Joint Industry Framework and provide detail on monitoring design, standard operating procedures, data management and reporting. Details on personnel, resources, logistics and mobilisation times are outlined in the OSM-BIP. Table 11-1 lists the plans that are relevant to Pilot Energy's activities and the objective of each monitoring plan.

There are two types of monitoring that would occur following a Level 2-3 spill event:

- Operational Monitoring (OM) – which is undertaken during the course of the spill and includes any physical, chemical and biological assessments which may guide operational decisions such as selecting the appropriate response and mitigation methods and / or to determine when to terminate a response activity. The design of operational monitoring requires judgements to be made about scope, methods, data inputs and outputs that are specific to the individual spill incident, balancing the operational needs of the response with the logistical and time constraints of gathering and processing information. There is a need for information to be collected and processed rapidly to suit response needs, with a lower level of sampling and accuracy needed than for scientific purposes. For details on initiation and termination criteria for OM's refer to the OSM-BIP.
- Scientific Monitoring (SM) - which can extend well beyond the termination of response operations. Scientific monitoring has objectives relating to attributing cause-effect interactions of the spill or associated response with changes to the surrounding environment. The SMs will be conducted on a wider study area, extending beyond the spill footprint, will be more systematic and quantitative and aim to account for natural or sampling variation. For further details on the SM's refer to the OSM-BIP.
- Pilot Energy will review the initiation criteria for OMPs and SMPs (Provided in Table 5-1 (OMPs) and Table 6-1 (SMPs) of the Joint Industry Operational and Scientific Monitoring Framework (APPEA, 2021) during the preparation of the initial IAPs, and subsequent IAPs. If any initiation criteria are met, then that relevant OMP and/or SMP will be activated via the relevant Monitoring Service Provider.

Table 11-1: Operational and Scientific Monitoring Plans Relevant to Eureka 3D MSS

Monitoring Plan	Aim/Objective
Operational Monitoring	
Hydrocarbon properties and weathering behaviour at sea	To provide in field information on the hydrocarbon properties, behaviour and weathering of the spilled hydrocarbons to assist in determining suitability of spill response tactics and strategies
Shoreline clean-up assessment	Provide information on the physical and biological characteristics of shorelines within the predicted trajectory of the hydrocarbon spill or that have been exposed to the spill Conduct sectorisation of shorelines to aid in response planning and implementation of response activities Inform suitable pre-impact and post-impact response options/activities to minimise the threat posed to sensitive receptors from the spill, taking into account shoreline character Establish clean-up end points for the shoreline Monitor effectiveness of shoreline protection and/or clean-up activities Inform the IMT/EMT of any potential or actual impacts to sensitive receptors from response options/activities Inform the IMT/EMT of any sensitive receptors that may be relevant to scientific monitoring programs
Water quality assessment	To provide a rapid assessment of the presence, type, concentrations and character of hydrocarbons in marine water to assess the extent of spill contact and inform impact predictions for other monitoring plans
Sediment quality assessment	To provide a rapid assessment of the presence, type, concentrations and character of hydrocarbons in marine sediments to assess the extent of spill contact and inform impact predictions for other monitoring plans
Marine fauna assessment • Cetaceans (observational only) • Pinnipeds • Seabirds and shorebirds	To undertake a rapid assessment of marine fauna to understand the species, populations, habitats and geographical locations at greatest risk from potential spill impacts To provide the IMT/EMT with information that assists in deciding protection priorities and selecting response options that minimise the potential impact on marine fauna To provide the IMT/EMT with information on the effects of response activities on marine fauna Assess and document mortality of fauna during the spill event and response activities Establish the need for scientific monitoring of fauna affected by the spill event and/or response activities.
Marine fauna assessment • Fish	Identify, report and monitor potential impacts on fish, sharks and rays resulting from the hydrocarbon and/or response activities To provide the IMT/EMT with information that assists in deciding protection priorities and selecting response options that minimise the potential impact on fish Determine the extent and level of hydrocarbon contamination and tainting of fish Determine any mortality of fish species and document any fish-kills during the spill event

Monitoring Plan	Aim/Objective
	Determine if fish harvested from the spill area meets statutory limits for hydrocarbon residues and is marketable Provide regulatory agencies, fisheries managers and other spill responders with information to help them evaluate the likelihood that a hydrocarbon spill will contaminate seafood (fish) for commercial, aquaculture, recreational, traditional purposes Assist in the decision-making process to restrict, ban, close or re-open a fishery Establish the need for scientific monitoring of fish affected by the spill event and/or response activities.
Scientific Monitoring	
Water quality impact assessment	Detect and monitor the presence, concentration and persistence of hydrocarbons in marine waters following the spill and associated response activities. The specific objectives of this SMP are as follows: • Assess and document the temporal and spatial distribution of hydrocarbons and dispersants in marine waters of sensitive receptors; • Consider the potential sources of any identified hydrocarbons • Verify the presence and extent of hydrocarbons (both on water and in water) that may be directly linked to the source of the spill • Assess hydrocarbon/dispersant content of water samples against accepted environmental guidelines or benchmarks to predict potential areas of impact • Provide information that may be used to interpret potential cause and effect drivers for environmental impacts recorded for sensitive receptors monitored under other SMPs
Sediment quality impact assessment	Detect and monitor the presence, concentration and persistence of hydrocarbons in marine sediments following the spill and associated response activities. The specific objectives of this SMP are as follows: • Assess and document the temporal and spatial distribution of hydrocarbons and dispersants in marine sediments of sensitive receptors • Consider the potential sources of any identified hydrocarbons; and • Verify the presence and extent of hydrocarbons that may be directly linked to the source of the spill • Assess hydrocarbon content of sediment samples against accepted environmental guidelines or benchmarks to predict potential areas of impact
Intertidal and coastal habitat assessment	To assess the impact (extent, severity, and persistence) and subsequent recovery of intertidal and coastal habitats and associated biological communities in response to a hydrocarbon release and associated response activities. The specific objectives of this SMP are as follows: • Collect quantitative data to determine short-term and long-term (including direct and indirect) impacts of hydrocarbon (and implementation of response activities) on intertidal and coastal habitats and associated biological communities, post-spill and post-response recovery

Monitoring Plan	Aim/Objective
	• Monitor the subsequent recovery of intertidal and coastal habitats and associated biological communities from the impacts of the hydrocarbon release and response activities
Seabirds and shorebirds	Document and quantify shorebird and seabird presence; and any impacts and potential recovery from hydrocarbon exposure and response activities. The objectives are to: • Identify and quantify, if time allows the post-spill/pre-impact presence and status (e.g. foraging and/or nesting activity) of shorebirds and seabirds in the study area • Observe, and if possible quantify and assess, the impacts from exposure of shorebirds and seabirds to hydrocarbons (i.e. post-impact) and to the response activities, including abundance, oiling, mortality, and sub-lethal effects • Identify, quantify and evaluate the post-impact status and if applicable, recovery of key behaviour and breeding activities of shorebirds and seabirds (e.g. foraging and/or nesting activity and reproductive success) over time and with regard to control sites
Marine mega-fauna assessment • Pinnipeds • Cetaceans	**Pinnipeds** Identify and quantify the status and recovery of pinniped populations (Australian sea lion, *Neophoca cinerea*) related to a hydrocarbon spill and response activities. The objectives are to: • Identify mortality of pinnipeds, where possible, that is directly related to the hydrocarbon spill or indirectly associated to spill-related impacts (including boat strike and/or use of dispersants) • Assess the impact of the hydrocarbon spill on pinniped species populations as recorded for breeding colonies and haul-out sites of hydrocarbon exposure/contact • Evaluate the recovery of pinniped breeding colonies **Cetaceans** Identify and quantify the status and recovery of whale sharks, dugongs and cetaceans related to a hydrocarbon spill and response activities. The objectives are to: • Observe and quantify the presence of whale sharks, dugongs and cetaceans within the area that may be affected by hydrocarbons • Where possible, assess and quantify lethal impacts and/or sub-lethal impacts directly related to the hydrocarbon spill or other indirect impacts (including vessel strike and/or use of dispersants and impacts to important habitats) • If applicable, evaluate recovery of key biological activities of impacted species following impacts due to a hydrocarbon spill and undertaking response options.

Monitoring Plan	Aim/Objective
Benthic habitat assessment	To assess the impact (extent, severity, and persistence) and subsequent recovery of subtidal benthic habitats and associated biological communities in response to a hydrocarbon release and associated response activities. The specific objectives of this SMP are as follows: • Collect quantitative data to determine short-term and long-term (including direct and indirect) impacts of hydrocarbon (and implementation of response options) on benthic habitats and associated biological communities, post-spill and post-response recovery • Monitor the subsequent recovery of benthic habitats and associated biological communities from the impacts of the hydrocarbon release
Marine fish and elasmobranch assemblages assessment	To assess the impacts to and subsequent recovery of fish assemblages associated with specific benthic habitats (as identified in SMP: Benthic Habitat Assessment) in response to a hydrocarbon release and associated response activities. The specific objectives of this SMP are as follows: • Characterise the status of resident fish populations associated with habitats monitored in SMP: Benthic Habitat Assessment that are exposed/contacted by released hydrocarbons • Quantify any impacts to species (abundance, richness and density) and resident fish population structure (representative functional trophic groups) • Determine and monitor the impact of the released hydrocarbons and potential subsequent recovery to residual demersal fish populations
Fisheries impact assessment	To monitor potential contamination and tainting of important finfish and shellfish species from commercial, aquaculture and recreational fisheries to evaluate the likelihood that a hydrocarbon spill will have an impact on the fishing and/or aquaculture industry. The specific objectives of this SMP are as follows: • Assess any physiological impacts to important fish and shellfish species and if applicable, seafood quality and safety • Assess targeted fish and shellfish species for hydrocarbon contamination • Provide information that can be used to make inferences on the health of fisheries and the potential magnitude of impacts to fishing industries (commercial, aquaculture and recreational)
Heritage features assessment	To detect changes in the integrity of significant shipwrecks as a result of a hydrocarbon release and/or associated response activities.
Social impact assessment	To assess the extent, severity and likely persistence of impacts on cultural, commercial, recreational and/or industrial users from a hydrocarbon release and associated response activities. The specific objective of this SMP is as follows:

Monitoring Plan	Aim/Objective
	• Determine direct and indirect impacts of a hydrocarbon or chemical spill and associated response activities on cultural, commercial, recreational and/or industrial users and identify areas where monitoring may need to continue for an extended period of time following termination of the response.

11.1 Scientific Monitoring - environmental performance

Table 11-2 indicates the environmental performance standards and measurement criteria for the following Environmental Performance Outcome:

- Implement monitoring programs to assess and report on the impact, extent, severity, persistence and recovery of sensitive receptors contacted by a spill or affected by spill response.

Table 11-2: Environmental Performance – Scientific Monitoring

Performance Standard	Measurement Criteria
Response Preparedness	
Maintain contracts with third-party providers to provide access to suitably qualified and competent personnel and equipment to assist in the implementation of monitoring	Contract with third party service providers maintained through duration of Eureka 3D MSS
	Vessel contracts in place for the duration of Eureka 3D MSS
Response Implementation	
OMPs and SMPs will be activated in accordance with the initiation criteria provided in Table 9-1 and 9-2 of the Joint Industry OSM Framework (APPEA, 2021)	Incident Action Plan and Incident Log confirm OMPs and SMPs are activated in accordance with the initiation criteria provided in Table 9-1 and 9-2 of the Joint Industry OSM Framework (APPEA, 2021)
Initiation criteria of OMPs and SMPs will be reviewed during the preparation of the initial Incident Action Plan (IAPs) and subsequent IAPs; and if any criteria are met, relevant OMPs and SMPs will be activated	Incident Action Plan/s
Monitoring to be conducted in accordance with the Operational and Scientific Monitoring Bridging Implementation Plan (Appendix H)	Incident log and monitoring records
Implementation of operational and scientific monitoring will comply with the Minimum Standards listed in Appendix A of the Joint Industry OSM Framework (APPEA, 2021)	Incident log and monitoring records

Performance Standard	Measurement Criteria
Once post-spill SMP monitoring reports are drafted they will be peer reviewed by an expert panel	Monitoring records
OMPs and SMPs will be terminated in accordance with the termination criteria provided in Table 6-1 of the Joint Industry OSM Framework (APPEA, 2021)	Incident Action Plan and Incident Log confirm OMPs and SMPs are terminated in accordance with the termination criteria provided in Table 6-1 of the Joint Industry OSM Framework (APPEA, 2021)

12. Response Termination

Terminating the spill response may involve demobilising personnel and equipment from response locations, post-incident reporting, identifying improvement opportunities, reviewing and updating plans and restocking equipment supplies. Planning to demobilise should occur ahead of time, during the response, to facilitate rapid demobilisation of resources that are no longer needed, and which can significantly reduce response costs.

The decision to terminate individual response strategies will be made by the relevant Control Agency (Table 2-2), according to the termination criteria shown for each strategy (Sections 6 - 9).

Scientific monitoring may continue after response operations have ceased and may be used to inform remediation activities.

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Appendix A Roles and responsibilities of Titleholder personnel in State MEECC/ DOT IMT/ FOB

Table A1-1 outlines the key roles and responsibilities of titleholder personnel potentially required to be positioned in the State Maritime Environmental Emergency Coordination Centre (MEECC)/ DoT IMT/ FOB in the event of a Level 2/3 spill that impacts WA waters or land. It should be noted the requirements outlines in Table A1-1 are the initial requirements, and not the minimum or maximum requirements.

Table A1-1: Roles and Responsibilities of Titleholder Personnel Positioned in State Maritime Environmental Emergency Coordination Centre (MEECC)/ DOT IMT/ FOB

Key Roles	Responsibilities
Crisis Management Team Liaison Officer (DoT MEEC)	• Provide a direct liaison between the Crisis Management Team and the State MEECC. • Facilitate effective communications and coordination between the Crisis Management Team Leader and the State SMEEC. • Offer advice to SMEEC on matters pertaining to titleholder crisis management policies and procedures.
Deputy Incident Officer (DoT IMT)	• Provide a direct liaison between the titleholder IMT and the DoT IMT. • Facilitate effective communications and coordination between the titleholder Incident Controller and the DoT Incident Controller. • Offer advice to the DoT Incident Controller on matters pertaining to the titleholder incident response policies and procedures. • Offer advice to the Safety Coordinator on matters pertaining to titleholder safety policies and procedures, particularly as they relate to titleholder employees or contractors operating under the control of the DoT IMT.
Deputy Intelligence Officer (DoT IMT)	• As part of the Intelligence Team, assist the Intelligence Officer in the performance of their duties in relation to situation and awareness. • Facilitate the provision of relevant modelling and predications from the titleholder IMT. • Assist in the interpretation of modelling and predictions originating from the titleholder IMT. • Facilitate the provision of relevant situation and awareness information originating from the DoT IMT to the titleholder IMT. • Facilitate the provision of relevant mapping from the titleholder IMT. • Assist in the interpretation of mapping originating from the titleholder IMT. • Facilitate the provision of relevant mapping originating from the DoT IMT to the titleholder IMT.
Deputy Planning Officer (DoT IMT)	• As part of the Planning Team, assist the Planning Officer in the performance of their duties in relation to the interpretation of existing response plans and the development of incident action plans and related sub plans. • Facilitate the provision of relevant IAP and sub plans from the titleholder IMT. • Assist in the interpretation of the titleholder OPEP from titleholder. • Assist in the interpretation of the titleholder IAP and sub plans from the titleholder IMT. • Facilitate the provision of relevant IAP and sub plans originating from the DoT IMT to the titleholder IMT. • Assist in the interpretation of titleholder's existing resource plans. • Facilitate the provision of relevant components of the resource sub plan originating from the DoT IMT to the titleholder IMT. *Note: this individual must have intimate knowledge of the relevant titleholder OPEP and planning processes.*

Key Roles	Responsibilities
Environmental Support Officer (DoT IMT)	• As part of the Intelligence Team, assist the Environmental Coordinator in the performance of their duties in relation to the provision of environmental support into the planning process. • Assist in the interpretation of the titleholder OPEP and relevant TRP plans. • Facilitate in requesting, obtaining and interpreting environmental monitoring data originating from the titleholder IMT. • Facilitate the provision of relevant environmental information and advice originating from the DoT IMT to the titleholder IMT.
Deputy Public Information Officer (DoT IMT)	• As part of the Public Information Team, provide a direct liaison between the titleholder Media team and DoT IMT Media team. • Facilitate effective communications and coordination between titleholder and DoT media teams. • Assist in the release of joint media statements and conduct of joint media briefings. • Assist in the release of joint information and warnings through the DoT Information & Warnings team. • Offer advice to the DoT Media Coordinator on matters pertaining to titleholder media policies and procedures. • Facilitate effective communications and coordination between titleholder and DoT Community Liaison teams. • Assist in the conduct of joint community briefings and events. • Offer advice to the DoT Community Liaison Coordinator on matters pertaining to the titleholder community liaison policies and procedures. • Facilitate the effective transfer of relevant information obtained through the Contact Centre to the titleholder IMT.
Deputy Logistics Officer (DoT IMT)	• As part of the Logistics Team, assist the Logistics Officer in the performance of their duties in relation to the provision of supplies to sustain the response effort. • Facilitate the acquisition of appropriate supplies through titleholder's private contract arrangements. • Collects Request Forms from DoT to action via the titleholder IMT. *Note: this individual must have intimate knowledge of the relevant titleholder logistics processes and contracts.*
Deputy Operations Officer (DoT IMT)	• As part of the Operations Team, assist the Operations Officer in the performance of their duties in relation to the implementation and management of operational activities undertaken to resolve an incident. • Facilitate effective communications and coordination between the titleholder Operations Section and the DoT Operations Section. • Offer advice to the DoT Operations Officer on matters pertaining to titleholder incident response procedures and requirements. • Identify efficiencies and assist to resolve potential conflicts around resource allocation and simultaneous operations of titleholder and DoT response efforts.
Deputy Waste Management Coordinator (DoT IMT)	• As part of the Operations Team, assist the Waste Management Coordinator in the performance of their duties in relation to the provision of the management and disposal of waste collected in State waters. • Facilitate the disposal of waste through titleholder's existing private contract arrangements related to waste management and in line with legislative and regulatory requirements. • Collects Waste Collection Request Forms from DoT to action via the titleholder IMT.
Deputy Finance Officer (DoT IMT)	• As part of the Finance Team, assist the Finance Officer in the performance of their duties in relation to the setting up and payment of accounts for those services acquired through titleholder's private contract arrangements. • Facilitate the communication of financial monitoring information to the titleholder to allow them to track the overall cost of the response.

Key Roles	Responsibilities
	• Assist the Finance Officer in the tracking of financial commitments through the response, including the supply contracts commissioned directly by DoT and to be charged back to titleholder.
Deputy Division Commander (DoT FOB)	• As part of the Field Operations Team, assist the Division Commander in the performance of their duties in relation to the oversight and coordination of field operational activities undertaken in line with the IMT Operations Section's direction. • Provide a direct liaison between titleholder's Forward Operations Base/s (FOB/s) and the DoT FOB. • Facilitate effective communications and coordination between titleholder On-Scene Commander and the DoT Division Commander. • Offer advice to the DoT Division Commander on matters pertaining to titleholder incident response policies and procedures. • Assist the Safety Coordinator deployed in the FOB in the performance of their duties, particularly as they relate to titleholder employees or contractors. • Offer advice to the Safety Coordinator deployed in the FOB on matters pertaining to titleholder safety policies and procedures.

Appendix B Visual Surveillance Logs

Vessel visual observer log

Survey Details						
Date	Start time	End Time	Observers			
Incident			Area of Survey			
Vessel type	Call sign					
Weather Conditions						
Wind speed (knots)		Wind direction				
Cloud cover (%)		Visibility				
Time high water		Current direction				
Time low water		Current speed (nM)				
Slick Details						
Slick grid parameters by lat/long		Slick grid parameters (vessel speed)		Slick grid dimensions		
Length Axis	Width Axis	Length Axis		Width Axis	Length	nm
Start Latitude	Start Latitude	Time (seconds)		Time (seconds)	Width	nm
Start Longitude	Start Longitude				Length	nm
End Latitude	End Latitude	Vessel speed (knots)		Vessel speed (knots)	Width	nm
End Longitude	End Longitude				Grid area	km^2
Visual appearance slick						
Colours, emulsification etc.						
Any marine fauna or other activities observed						

Aerial surveillance observation log

Date	Incident	Aircraft type	Call sign	Start time	End time	Av altitude/ air speed
Wind speed (kts)	**Wind direction**	**Visibility (nm)**	**Cloud base (ft)**	**Sea state**	**Observer name/s**	**Spill source**
Survey start /end coordinates	**Survey start time**	**Survey end time**	**Time high tide**	**Time low tide**	**Current speed (nm)**	**Current direction**
Notes (e.g. remote sensing used, wildlife or sensitive receptors observed, any response activities observed):						

Slick details

Slick	Time local	Slick (centre or start)		Slick (end)		Slick Orient Degrees	Oil slick length			Oil slick width			Area km^2	Coverage %	Oiled area km^2
		LAT N/S	LONG E/W	LAT N/S	LONG E/W		SOG KT	Time seconds	Distance km	SOG KT	Time seconds	Distance km			
A															
B															
C															
D															
E															

Appendix C Shoreline Assessment Form

Department of **Transport**

When blank, this form is classed as **OFFICIAL**, when filled out, this form is classed as **OFFICIAL-SENSITIVE.**

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Shoreline descriptors:

Shoreline Type	Abbr.		Note
Cliff	Cl		Height and slope
Platform	Pl		Height relative to tide
Reef	Re		Reef is an intertidal platform
Beach	Be		
Dune	Du		
Flats	Fl		
Artificial	A		e.g. wharf, sea wall
Shoreline substrate	**Abbr.**	**Size**	**Note**
Bedrock or rock	R		
Boulder	B	Larger than head	
Cobble	C	Fist to head size	
Pebble	P	Pen diameter to fist size	
Gravel	G	2-4mm diameter	
Mud/silt/clay	M	Less than 0.6mm	Mix with water, if it goes cloudy = mud, if it sinks = sand
Earth	E		Usually cliffs only
Shellgrit	Sh		Usually with sand (i.e. Sh/S)
Coral	Co		Dead coral, i.e. coral rubble *(if corals are live, record as coral in both substrate type and biological character)*
Artificial	A		e.g. rip-rap

Note: S/B would indicate boulders and sand in equal amounts. S(B) would indicate sand was the dominant substrate.

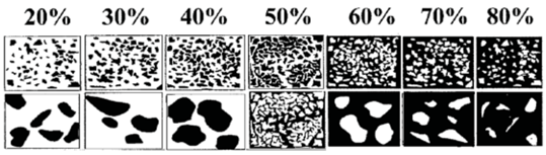
Biological character

This is flora and fauna living on the shoreline. Document this and indicate location on sketch map.

Oil description/character

- **Colour**
- **Viscosity: Solid** *(doesn't flow)*, **Viscous** *(flow slowly)*, **Fluid** *(flows easily)*
- **Stickiness: Very sticky** *(can't be wiped/washed off)*, **Sticky** *(partly removed by wiping/washing)*, **Non sticky** *(wipes of easily)*

Percentage oil cover

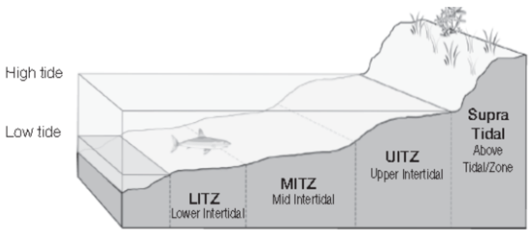


Oil thickness

Name	Abbr.	Thickness	Description
Pooled	Po	Can be measured in mm or cms	Pooled fresh or emulsified oil
Cover	Co	Over 1mm	Coverage of oil of measurable thickness but not pooled
Coat	Ct	Less than 1mm	This coach of oil that masks colour of substrate and can be scratched off with fingernail.
Stain	St	Less than 1mm	Very thin stain of oil which cannot be scratched off substrate with fingernail
Film or sheen	Fi or Shn	Extremely thin film or sheen	Substrate can usually be seen through oil. Can be described as brown, rainbow or silver.
Tar balls	Tb	Variety of sizes	Ball or clumps of weathered oil.

- To describe thickness of subsurface oil:
  - Depth = distance from substrate surface to top of buried layer
  - Thickness of lens = distance between top and bottom of buried layer

Shoreline tidal zones



Incident				**Ref No.**	
REPORTING DETAILS					
Assessment Team Leader		**Position/ Organisation**			
Team Members (name/org)					
Date Completed		**Time Completed**			
Reporting to		**Position/ Organisation**			
Date Received		**Time Received**			
LOCATION DETAILS					
Sector		**Segment**			
Name of Beach/Location		**Description (e.g. slope)**			
Topography/ Other Map		**Map Reference**			
Access Via	☐ Foot Only ☐ Road ☐ 4WD ☐ Boat ☐ Helicopter ☐ Gator/OUV				
Hazards					
TIMING					
First Assessment	☐ Yes ☐ No	**Last Assessment**	☐ Yes ☐ No		
Timing	☐ Pre Impact ☐ Post Impact Before Clean-Up ☐ Post Impact After Clean-Up				
Time Since	**Impact (days/hrs.):**	**Last Clean-up (days/hrs.):**			

ASSESSMENT

Parameter	LITZ	MITZ	UITZ	Supratidal
Shoreline Description				
Shoreline type				
Substrate type				
Length of shoreline				
Width of shoreline				
Biological character				
Oil Distribution and Character				
Oil band length				
Oil band width				
% cover in band				
Surface oil thickness				
Oil appearance/character				
Depth of buried oil (from surface)				
Description of buried oil				
Other				
Un oiled debris				
Oiled debris				

Sketch Map

Please include North point and scale

Notes

APPENDIX F: OPERATIONAL AND SCIENTIFIC MONITORING PLAN

Eureka 3D MSS: OSM Bridging Implementation Plan

Revision	Date	Reason for issue	Reviewers	Approvers
A	16/03/2023	Internal Review		
B	09/08/2023	Internal Review		
0	06/12/2023	Issued for Use	RPS	RPS

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Acronyms

Abbreviation/Acronym	Definition
AFMA	Australian Fisheries Management Authority
AIMS	Australian Institute of Marine Science
AIIMS	Australasian Integrated Incident Management System
ALA	Atlas of Living Australia
AMSA	Australian Maritime Safety Authority
AODN	Australian Ocean Data Network
APPEA	Australian Petroleum Production and Exploration Association
BTEXN	Benzene, toluene, ethylbenzene, xylene and naphthalene
BIA	Biologically Important Areas
CoC	Chain of Custody
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DBCA	Western Australian Department of Biodiversity Conservation and Attractions
DCCEEW	Department of Climate Change, Energy, the Environment and Water (Cwth)
DWER	Western Australian Department of Water and Environmental Regulation
DoT	Western Australian Department of Transport
DPIRD	Western Australian Department of Primary Industries and Resource Development
EMBA	Environment that may be Affected
EP	Environment Plan
EPBC Act	*Environment Protection and Biodiversity Protection Act 1999* (Cwth)
EUL	Environment Unit Lead
GIS	Geographic Information System
GPS	Global Positioning System
IAP	Incident Action Plan
ICS	Incident Command System
IMOS	Integrated Marine Observing System
IMSA	Index of Marine Surveys for Assessments
IMT	Incident Management Team
IMT Leader	Incident Management Team Leader. Equivalent to an Incident Controller or Incident Commander.
IPIECA	International Petroleum Industry Environmental Conservation Association
KEF	Key Ecological Feature
MMO	Marine Mammal Observer
MSS	Marine Seismic Survey
OMP	Operational Monitoring Plan
OPEP	Oil Pollution Emergency Plan
OPGGS (Env)	Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009
OSM	Operational and Scientific Monitoring

Abbreviation/Acronym	Definition
OSM-BIP	Operational and Scientific Monitoring – Bridging Implementation Plan
OSRA	Oil Spill Response Atlas
OSTM	Oil Spill Trajectory Modelling
PAH	Polycyclic Aromatic Hydrocarbons
PPE	Personal Protective Equipment
QA/QC	Quality Assurance and Quality Control
SIMA	Spill Impact Mitigation Assessment
SMP	Scientific Monitoring Plan
UWA	University of Western Australia
WAMSI	Western Australian Marine Science Institution

Part A – Preparedness

This Plan is presented in two parts. Part A outlines the relationship between the Pilot Energy's environmental management document framework and the Joint Industry Operational and Scientific Monitoring (OSM) Framework (APPEA, 2021). Part B provides operationally focussed guidance for Titleholder personnel and OSM Service Providers to coordinate the implementation of monitoring plans.

1. Introduction

Pilot Energy has elected to use the Joint Industry OSM Framework and supporting operational monitoring plans (OMPs) and scientific monitoring plans (SMPs) as the foundation of its operational and scientific monitoring approach. The Joint Industry OSM Framework is available on the APPEA Environment Publications Webpage. Use of the Joint Industry OSM Framework requires each Titleholder to develop a Bridging Implementation Plan (OSM-BIP) (this plan) that fully describes how the Framework interfaces with Titleholders own activities, spill risks and internal management systems.

Table 1-1 describes key documents that form Pilot Energy's environmental management document framework.

Activation of OSM should follow the process listed in Part B: Section 12 Activation Process.

Table 1-1: Key documents in Titleholder's environmental management framework

Document	Description
Eureka 3D Marine Seismic Survey (MSS) Environment Plan (EP)	The Eureka 3D MSS EP describes the activity and the location, the environment, the risks to the environment as a result of the activity and the associated management controls. Of particular relevance to this plan, it identifies sensitive receptors, potential impacts from hydrocarbon spills and the environment that may be affected (EMBA)
Eureka 3D MSS Oil Pollution Emergency Plan (OPEP) (Appendix E)	The OPEP outlines preparedness and response arrangements for the worst-case credible spill scenario that may occur as a result of the Eureka 3D marine seismic survey. It describes the relevant spill management arrangements for the various jurisdictions within the Environment that May be Affected, the process for selecting response strategies and the appropriateness of available response strategies for each scenario. The plan also provides response implementation guidance for each response strategy.
Emergency Response Procedure (PE-05-PRO-003)	Outlines the actions to be taken in the event of an emergency situation occurring at Pilot Energy's operations. This includes the arrangements for the planning, development and communication of emergency preparedness/ response procedures for the effective management of emergencies at Pilot projects.
Incident Management Procedure (PE-07-PRO-001)	Outlines the requirements for incident management at Pilot Energy including responsibilities, response procedures, reporting, incident classification, investigation, notifiable incidents and record management.
Emergency Management Contacts Directory (or similar)	Provide a summary of what is included in this document. **Worked example**: This document contains all relevant contact and communications information to enable effective communication amongst the response personnel and external stakeholders, including relevant OSM contacts. State frequency it is updated

Figure 1-1 illustrates how the OSM-BIP, OPEP and EP relate to each other during a spill response. Operational and scientific monitoring should commence when the initiation criteria outlined in Tables 5-1 and 6-1 of the Joint Industry OSM Framework are met.

Note: the monitor and evaluate strategy in the Eureka 3D MSS OPEP(Appendix E – Section 6) includes a wide range of tactics, including oil spill trajectory modelling that is often included in operational monitoring. Pilot Energy has retained spill modelling in the OPEP to ensure data inputs are managed by the Pilot Energy IMT and rapidly fed into the Common Operating Picture with other monitor and evaluate tactics during the initial stages of the spill.

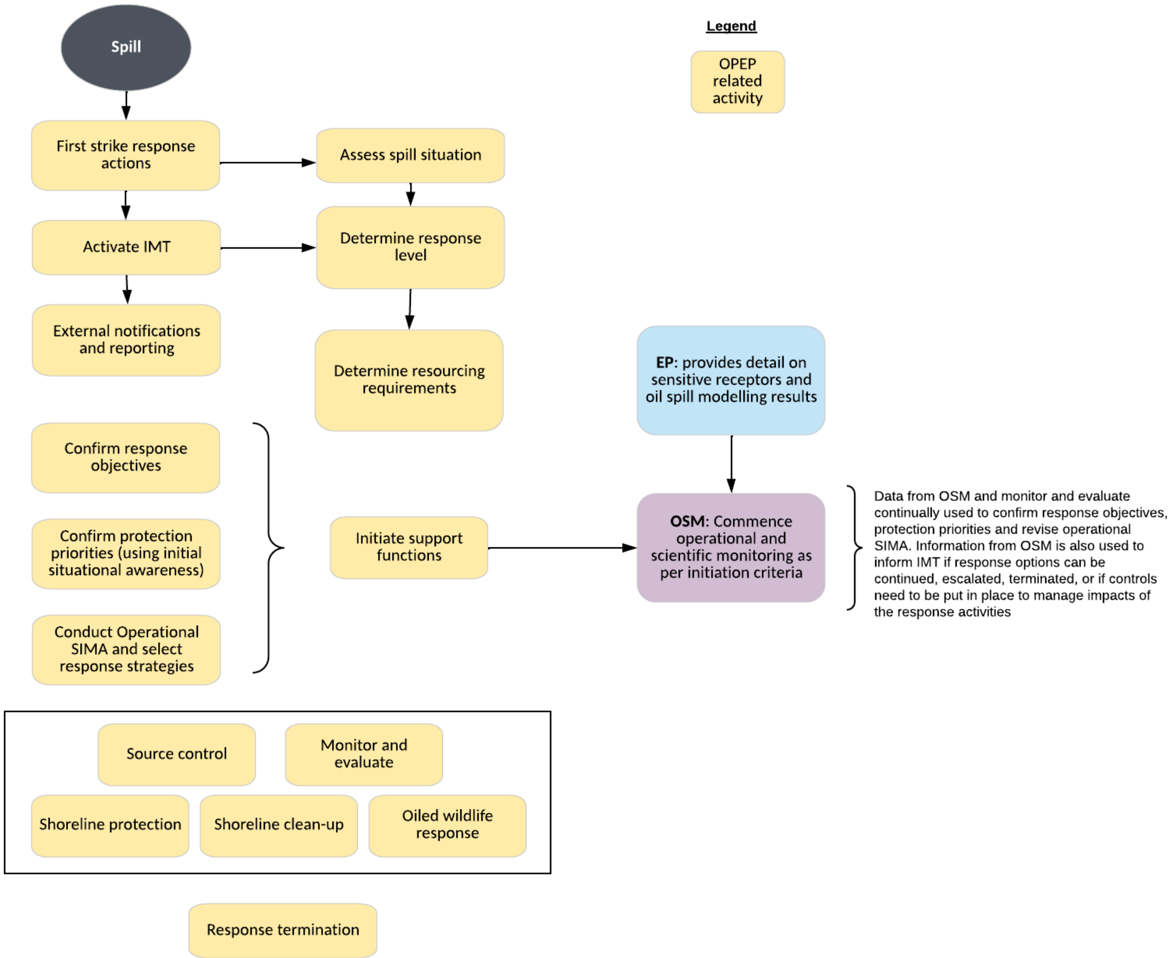

Figure 1-1: Relationship between the OSM-BIP, OPEP and EP during a Spill Response

2. EMBA and Monitoring Priorities

The EMBA is defined in the Eureka 3D MSS EP (Section 4) as the area potentially impacted by hydrocarbons from a spill event above impact concentration thresholds. The EMBA was determined using stochastic modelling results of oil spill trajectory modelling for a vessel spill in the south-east corner of the Operational Area (scenario 1) (RPS, 2023) from 100 simulations and applying the following thresholds:

- 1 g/m^2 floating oil thickness, which is considered to be below levels which would cause environmental harm and is more indicative of the areas perceived to be affected due to its visibility on the sea-surface
- 10 g/m^2 for accumulated (shoreline) oil, which represents the area visibly contacted by the spill
- 10 ppb for dissolved hydrocarbons corresponds generally with potential for exceedance of water quality triggers
- 10 ppb entrained hydrocarbons represents the low exposure zone and corresponds generally with potential for exceedance of water quality triggers.

Detailed information on the spill risks, modelling analysis of scenarios and response protection priorities is provided in the Eureka 3D MSS EP (Section 8.6) and Eureka 3D MSS OPEP (Appendix G – Section 3).

Monitoring priorities have been drawn from the stochastic modelling results (RPS, 2023). These priorities were identified through analysis of hydrocarbon spill modelling results against the location of key sensitive receptors with high conservation value; including habitat, species (e.g. State/Commonwealth protected areas, protected species), the sensitivity and/or recoverability of receptors to hydrocarbon impacts, and important socio-economic/heritage values. Monitoring priorities were identified as those sensitive receptors contacted by entrained hydrocarbons at the low threshold ($\leq$10 ppb) and floating hydrocarbons at the low threshold ($\leq$1 g/m^2) within 7 days at a probability > 5%, as listed in Table 2-2. Modelling did not predict any shoreline accumulation at the low threshold ($\leq$10 g/m^2) at greater than 5% probability and at less than 7 days for the worst-case scenario.

In addition to these locations, there are receptors that are transient (i.e. cetaceans, seabirds) and others that are broadscale, such as managed fisheries with large spatial extents, Key Ecological Features (KEFs) and Biologically Important Areas (BIAs). These receptors are described in detail in the Eureka 3D MSS EP (Section 4). Table 2-1 lists the KEFs within the EMBA and describes how they may be affected by the MGO spill.

The monitoring protection priority areas identified (Table 2-2) and KEFs potentially contacted are listed for planning purposes and are based on stochastic modelling data. Therefore, it is unlikely that all of these receptors would be contacted, or contacted within 7 days, during a spill event. During a spill event, Pilot Energy will work with its monitoring providers and key stakeholders in the initial stages of the spill regarding priority receptors and to assist in the finalisation of the monitoring design. This process is outlined in Section 13.

Table 2-1: Key Ecological Features in the EMBA

Key Ecological Feature	Impact Description
Ancient coastline at 90-120 m depth contour	Benthic biodiversity and productivity occur where the ancient coastline forms a prominent escarpment (Department of Sustainability, Environment, Water, Population and Communities [DSEWPC] , 2012). Benthic receptors associated with this KEF would be at a low risk of exposure to hydrocarbons from a surface spill due to the depth of water they occur.
Commonwealth marine environment surrounding the Houtman Abrolhos Island	The Houtman Abrolhos Islands and surrounding reefs support a unique mix of temperate and tropical species. The Houtman Abrolhos Islands are the largest seabird breeding station in the eastern Indian Ocean. They support more than one million pairs of breeding seabirds, .and include a range of benthic habitats and associated fisheries resources (DSEWPC, 2012).

Key Ecological Feature	Impact Description
	Coral and fish surrounding the Houtman Abrolhos islands may be at risk from entrained hydrocarbons. Birds may be at exposed directly and indirectly to entrained hydrocarbons during foraging activities.
Commonwealth marine environment within and adjacent to the west coast inshore lagoons	These lagoons are important for benthic productivity, including macroalgae and seagrass communities, and breeding and nursery aggregations for many temperate and tropical marine species. (McClatchie *et al.,* 2006) The lagoons are dominated by seagrass and epiphytic algae, which provide habitat and food for many marine species (directly and indirectly). Seagrass meadows occur in more sheltered areas and in the inter-reef lagoons along exposed sections of the coast while emergent reefs and small islands create a diverse topography. This mix of sheltered and exposed environments forms a complex mosaic of habitats. The lagoons are also important areas for the recruitment of commercially and recreationally important fishery species, including western rock lobster. Extensive schools of migratory fish visit the area annually, including herring, garfish, tailor and Australian salmon (McClatchie *et al*., 2006). Exposure to hydrocarbons can be toxic to seagrasses and macroalgae. Fishes are most vulnerable to hydrocarbons during their embryonic, larval and juvenile life stages.
Western demersal slope and associated fish communities	The western continental slope provides important habitat for demersal fish communities. The Demersal slope and associated fish communities of the Central Western Province are recognised as a KEF for their high levels of biodiversity and endemism. Given demersal fish species are found at depths below 400 m they are at low risk of exposure to hydrocarbons from a surface spill.
Western rock lobster	The Western rock lobster is defined as a KEF due to its presumed ecological role as an important part of the food web on the west coast continental shelf. Impacts from a hydrocarbon spill will vary depending on the level of exposure and duration of exposure, life stage, and location (shallow versus deep water habitats). Larval life stages are likely the most vulnerable to the effects of hydrocarbons.
Perth Canyon and adjacent shelf break, and other west coast canyons	The Perth Canyon is the largest known undersea canyon in Australian waters (DSEWPaC 2012a). Deep ocean currents rise to the surface, creating upwelling zones which support larger aggregations of small fish, crustaceans and molluscs, as well as varying epibiota. The west coast canyons are believed to be associated with small periodic upwellings that locally increase productivity and attract aggregations of marine life (DSEWPaC 2012a). The high productivity of biota feeding other marine life would be vulnerable to the effects of hydrocarbons and disruptions in the foodchain.

Table 2-2: Spill Modelling Results for MGO spill with a Probability of Contact >5% and <7 days (RPS, 2023)

Priority Monitoring Areas	Key Sensitivities (specific to location)	Key Sensitivities (throughout area)	Probability (%) of contact of ≥10 ppb entrained hydrocarbon	Min. arrival time ≥10 ppb entrained hydrocarbon (days)	Probability (%) of contact of ≥1 g/m^2 floating hydrocarbon	Min. arrival time ≥1 g/m^2 floating hydrocarbon (days)
Clio Bank (submerged) (situated in the Abrolhos special purpose zone)	-	• Extensive meadows of seagrass that grow in shallow lagoons which provide an important nursery habitat for juvenile fish and western rock lobster (CALM, 2000) • Abalone occur on intertidal reefs • Macroalgal communities • Humpback whale and bottlenose dolphins (*Tursiops truncatus*) regularly seen in the area (CALM, 2000) • White shark foraging • Inshore islands between Cliff Head and Grey are important breeding areas for seabirds (Dunlop and Wooller, 1990; CALM, 2004) • Seabird foraging • Sea lion foraging • Cultural heritage-mainland areas have been identified as a significant area for Noongar people	14	6.8	<1	NC
Geelvink Channel Shoals (submerged) (situated between the Houtman Abrolhos Islands and the mainland between Horrocks and Geraldton)	• Humpback whale migration • Seabird foraging • Shipping channel to and from Geraldton		41	5.2	<1	NC
Cliff Head – White Point	-		12	0.5	<1	NC
Illawong – Cliff Head and Beagle Islands Nature Reserve	• Australian sea lion breeding on East Beagle Island (CALM, 2004)		44 (Beagle Islands Nature Reserve: 20)	0.1 (Beagle Islands Nature Reserve: 0.5)	13 (Beagle Islands Nature Reserve:1)	0.1 (Beagle Islands Nature Reserve:0.9)
Leeman - Coolimba	-		21	1.0	1	1.3
Green Head - Leeman	• Australian sea lion breeding on North Fisherman Island (CALM 2000)		20	1.5	<1	NC

Priority Monitoring Areas	Key Sensitivities (specific to location)	Key Sensitivities (throughout area)	Probability (%) of contact of ≥10 ppb entrained hydrocarbon	Min. arrival time ≥10 ppb entrained hydrocarbon (days)	Probability (%) of contact of ≥1 g/m^2 floating hydrocarbon	Min. arrival time ≥1 g/m^2 floating hydrocarbon (days)
	• Boullanger Island dunnart is only found on Boullanger Island (CALM, 2004) • Dibblers are found on Boullanger and Whitlock islands (CALM, 2004)	– The coast area between Greenhead and Jurien has the largest number of midden deposits in the south-west of WA (CALM, 2004) – Coast dunes in the Jurien Bay region were used as burial sites (CALM, 2004) • Several shipwrecks have been recorded between Cliff Head and Grey (CALM, 2004)				
Jurien Bay Marine Park	-		20	1.5	<1	NC
Booker Valley – Island Point*	• Dibblers are found on Boullanger and Whitlock islands (CALM, 2004)		13	2.7	<1	NC
Thirsty Point – Booker Valley*	• Australian sea lion breeding on Buller Island (CALM, 2004)		12	4.0	<1	NC
Grey – Thirsty Point*	-		11	4.9	<1	NC
North Tail Reef* (submerged)	-		9	3.1	<1	NC
Sand Knoll Ledge* (submerged)	-		6	6.0	<1	NC
Direction Bank (submerged) (situated in the Jurien special purpose zone)	-		18	3.8	<1	NC

** Locations within Jurien Bay Marine Park*

3. Relevant Existing Baseline Information Sources

Pilot Energy has access to a number of different baseline data sources that are relevant to the high value receptors in the EMBA. These include:

3.1 Australian Ocean Data Network

The Australian Ocean Data Network (AODN) is the primary access point for search, discovery, access and download of data collected by the Australian marine community. Data is presented as a regional view of all the data available from the AODN. Primary datasets are contributed to by Commonwealth Government agencies, State Government agencies, Universities, the Integrated Marine Observing System (IMOS - an Australian Government Research Infrastructure project), and the Western Australian Marine Science Institution (WAMSI).

Access is via the following link https://portal.aodn.org.au/search

3.2 Western Australian Oil Spill Response Atlas

The Western Australian Oil Spill Response Atlas (OSRA) is a spatial database of environmental, logistical and oil spill response data. Using a geographical information system (GIS) platform, OSRA displays datasets collated from a range of custodians allowing decision makers to visualise environmental sensitivities and response considerations in a selected location. Oil spill trajectory modelling (OSTM) can be overlaid to assist in determining protection priorities, establishing suitable response strategies and identifying available resources for both contingency and incident planning. OSRA is managed by the Oil Spill Response Coordination unit within Department of Transport (DoT) Marine Safety and is part funded through the National Plan for Maritime Environmental Emergencies and the Australian Maritime Safety Authority (AMSA).

Access is via the following link https://www.transport.wa.gov.au/imarine/oil-spill-response-and-planning-tools.asp

3.3 The Atlas of Living Australia

The Atlas of Living Australia (ALA) is a collaborative, online, open resource that contains information on all the known species in Australia aggregated from a wide range of data providers. It provides a searchable database when considering species within the EMBA. The ALA receives support from the Australian Government through the National Collaborative Research Infrastructure Strategy and is hosted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

Access is via the following link https://www.ala.org.au/

3.4 Index of Marine Surveys for Assessment

The Index of Marine Surveys for Assessments (IMSA) is an online portal to information about marine-based environmental surveys in Western Australia. IMSA is a project of the WA Department of Water and Environmental Regulation (DWER) for the systematic capture and sharing of marine data created as part of an environmental impact assessment.

Access via the following link
https://biocollect.ala.org.au/imsa#max%3D20%26sort%3DdateCreatedSort

3.5 Other Sources

Reports and peer reviewed journal articles were also accessed via research and journal databases such as PubMed and Google Scholar.

Species recovery plans for various protected species and ecological communities can be found in using this link: http://www.environment.gov.au/cgi-bin/sprat/public/publicshowallrps.pl

The Marine Bioregional Plan for the South-west Marine Region (DSEWPC, 2012) describes the marine environment and conservation values (protected species, protected places and key ecological features) of the South-west Marine Region, and can be accessed using this link: https://www.dcceew.gov.au/environment/marine/marine-bioregional-plans/south-west

The South-west Marine Parks Network Management Plan (Director of National Parks, 2018) describes the marine environment and conservation values (protected species, protected places and key ecological features) of the Australian Marine Parks in the South-west Marine Region, including the Abrolhos Marine Park and the Jurien Marine Park.

In addition, some receptors within the Jurien Bay Marine Park (State waters) are included in ongoing monitoring as part of the Department of Biodiversity Conservation and Attractions (DBCA) Marine Monitoring Program.

4. Baseline Data Review

Pilot Energy has compiled a list of available baseline data relevant to the high value receptors in the EMBA (Baseline data sources) and reviewed this information to assess the spatial and temporal relevance of this data and comparison of methods and parameters to those outlined in the Joint Industry SMPs. This review focused on priority monitoring locations with a minimum hydrocarbon contact timeframe of less than 7 days for the worst-case spill (Section 2).

The criteria used during the baseline data review is outlined in Table 4-1.

Table 4-1: Assessment Criteria for Baseline Data Review

Year of most recent data capture	Duration of monitoring program	Frequency of data capture	Similarity of methods to Joint Industry SMP	Similarity of parameters to Joint Industry SMP
High = 2015–2020	High = > 4 years	High = 4+ sampling trips per year	High	High
Medium = 2010–2014	Medium = 2–4 years	Medium = 2–3 sampling trips per year	Medium	Medium
Low = <2010	Low = <2 years	Low = one-off sampling trip	Low	Low

This assessment was then used to determine if the available baseline data could be used to detect change in receptors at priority monitoring locations in the event of a significant impact. Table 4-2 compares priority monitoring locations and receptors, and provides guidance on where post-spill, pre-impact monitoring should be prioritised.

The different categories are listed in Table 4-2 include:

- Not applicable (N/A) – this receptor and relevant SMP is not applicable to the priority monitoring location (i.e. shoreline habitat not present at submerged shoals);
- Survey – current monitoring/knowledge is considered sufficient (i.e. could be used to detect level of change in the event of a significant impact) and is considered a lower priority for post-spill, pre-impact data collection; and
- Priority survey – current monitoring/knowledge is not in place, not suitable or not practicable; and post-spill pre-impact baseline data collection should be prioritised.

It is noted that it is difficult to obtain absolute statistical proof of oil spill impacts, due to the variability (spatially and temporally) of the natural environment, the lack of experimental control due to the nature of spills and because suitable baseline data may not be available (Kirby et al., 2018). Alternative approaches exist for detecting impacts where post-spill, pre-impact monitoring may not be feasible. These include impact versus control design approaches and/or a gradient approach. The

Joint Industry OSM Framework provides guidance and considerations for survey designs to enable the acquisition of sufficiently powerful data during SMP implementation.

Once SMP monitoring reports are drafted (post-spill) they should be peer reviewed by an expert panel (Refer to Section 10.10 of the Joint Industry OSM Framework).

Table 4-2: Recommended Priority Monitoring Locations versus SMPs

Location	SMP									
	Water quality impact assessment	**Sediment quality impact assessment**	**Intertidal and coastal habitat assessment**	**Seabirds and shorebirds**	**Marine mega-fauna assessment – Pinnipeds**	**Marine mega-fauna assessment – whale sharks, dugong and cetaceans**	**Benthic habitat assessment**	**Marine fish and elasmobranch assemblages assessment**	**Fisheries impact assessment**	**Heritage and social impact assessment**
Jurien Bay Marine Park*	Priority survey	Priority survey	Priority survey	Priority survey	Survey	Priority survey	Survey	Survey	Survey	Priority survey (Locations to be determined in consultation with key stakeholders)
Cliff Head – White Point	Priority survey	Priority survey	Priority survey	Priority survey	Survey	Priority survey	Priority survey	Priority survey	Survey	
Illawong – Cliff Head	Priority survey	Priority survey	Priority survey	Priority survey	Survey	Priority survey	Priority survey	Priority survey	Survey	
Leeman - Coolimba	Priority survey	Priority survey	Priority survey	Priority survey	Survey	Priority survey	Priority survey	Priority survey	Survey	
Green Head - Leeman	Priority survey	Priority survey	Priority survey	Priority survey	Survey	Priority survey	Priority survey	Priority survey	Survey	
Beagle Islands Nature Reserve	Priority survey	Priority survey	Priority survey	Priority survey	Survey	Priority survey	Priority survey	Priority survey	Survey	
Clio Bank (submerged)	Priority survey	Priority survey	N/A	Priority survey	Priority survey	Priority survey	Priority survey	Priority survey	Survey	
Direction Bank (submerged)	Priority survey	Priority survey	N/A	Priority survey	Survey	Priority survey	Priority survey	Priority survey	Survey	
Geelvink Channel Shoal (submerged)	Priority survey	Priority survey	N/A	Priority survey	Priority survey	Priority survey	Priority survey	Priority survey	Survey	

** Including Booker Valley – Island Point; Thirsty Point – Booker Valley; Grey -Thirsty Point; North Tail Reef; Sand Knoll Ledge*

5. OSM Organisational Structure

The IMT structure for Pilot Energy is based on the IPIECA Good Practice Guidelines – Incident Management System for the Oil and Gas Industry (IPIECA, 2014). This system aligns with the international Incident Command System (ICS) and the Australasian Integrated Incident Management System (AIIMS). The Incident Management Team (IMT) will be responsible for coordinating OSM activities, which will be led by the Planning Section within the IMT, with support from each Section, in particular the Operations Section.

The Pilot Energy IMT structure is shown in Figure 5-1.

Figure 5-2 illustrates the structure of the OSM Management Team during the response phase. The IMT Leader is ultimately accountable for managing the response operation, which includes this plan. Depending on the scale of the event, individual people may perform multiple roles; similarly, multiple people may share the same role.

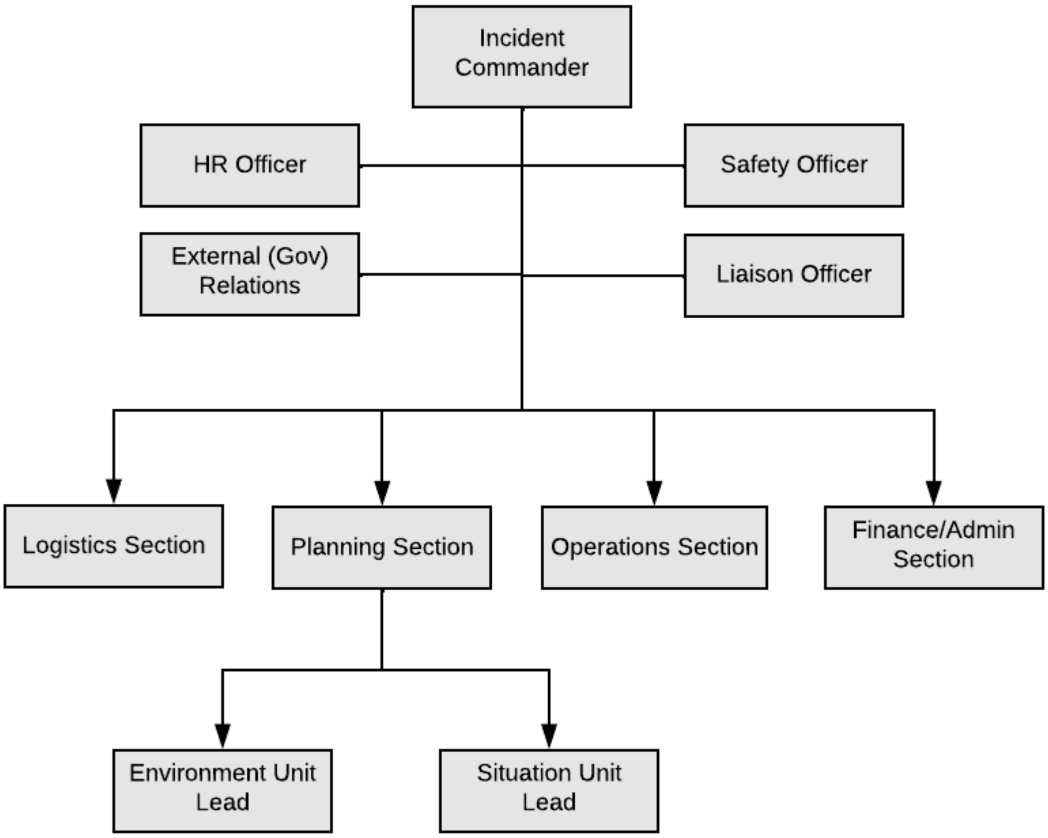

Figure 5-1: Pilot Energy IMT Structure

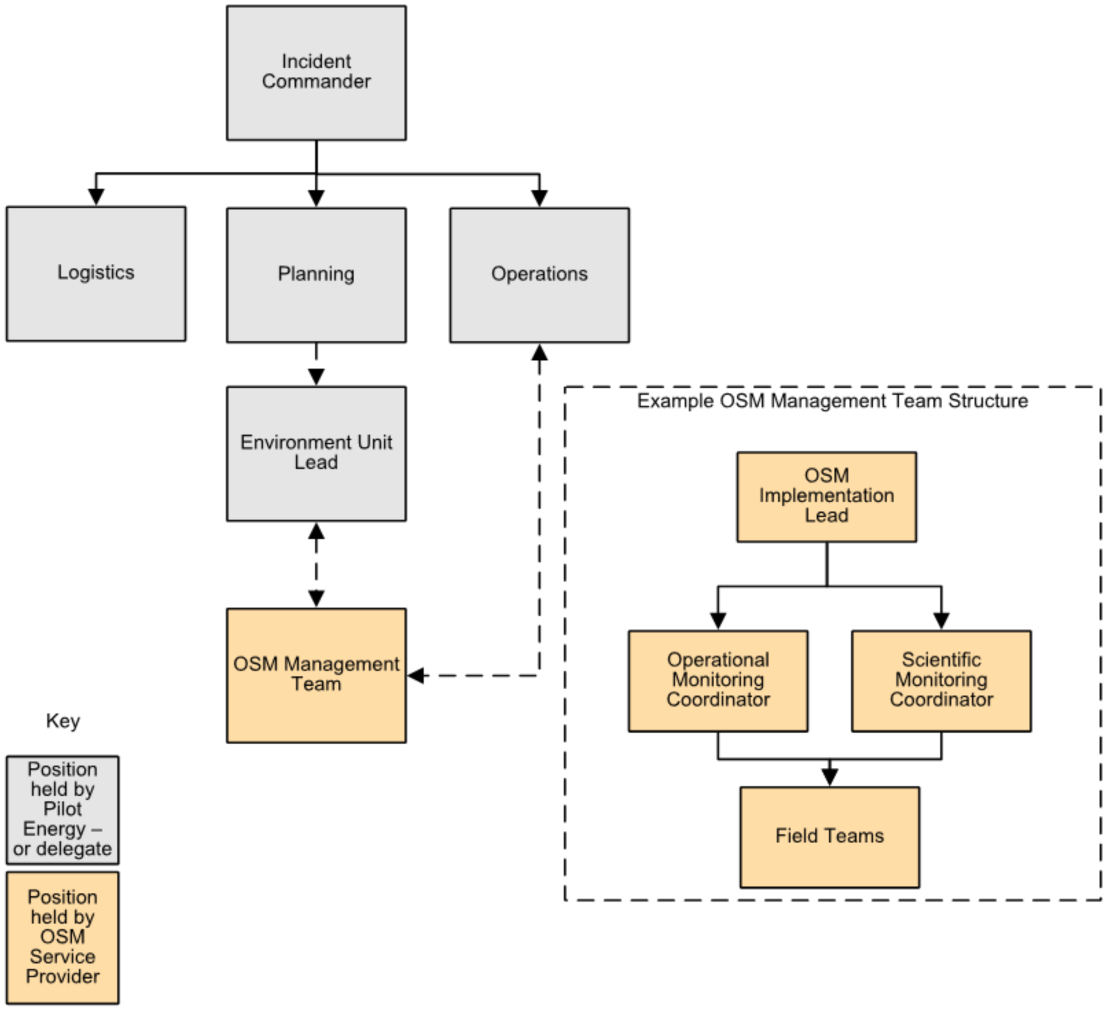

Figure 5-2: Pilot Energy IMT Structure with OSM Team

6. OSM Roles and Responsibilities

OSM roles and responsibilities are listed in Section 10.13.2 of the Joint Industry OSM Framework. Table 6-1 outlines the roles held by Pilot Energy and the OSM Services Provider.

During the post-response phase the Environment Unit Lead and the OSM Services Provider OSM Implementation Lead will continue to be responsible for the coordination and delivery of monitoring plans.

Table 6-1: Roles and Responsibilities for OSM

Role	Held by
Environment Unit Lead (EUL)	Environmental Consultants
Situation Unit Lead	Pilot Energy Planning Lead
OSM Implementation Lead	OSM Service Provider
Operational Monitoring Coordinator and Scientific Monitoring Coordinator	OSM Service Provider
OSM Field Operations Manager	OSM Service Provider
OSM Field Teams	OSM Service Provider

7. Mobilisation and Timing of OMP and SMP implementation

Table 7-1 provides an indicative implementation schedule for OMP and SMPs in the EMBA and adjacent waters. The locations listed are aligned to the initial monitoring priorities described in Section 2.

Table 7-1: Indicative OMP and SMP Implementation Schedule for OSM Activities if Initiation Criteria are Met

Proximity to spill source	Monitoring type	0–48 hours from OSM activation	Within 3-5 days of OSM activation	~5-7 days from OSM activation	>Two weeks from OSM activation
Spill site and surrounding waters	OM	• Activation of OMP Team Leads. • Finalise OMPs. • Commence activation and mobilisation of OM personnel.	• OMP: Hydrocarbon Properties And Weathering Behaviour, where resources are available (e.g. Supply Vessel with onboard sampling equipment). • OMP: Water Quality Assessment • OMP: Sediment Quality Assessment • OMP: Marine Fauna Assessment	-	As results from implemented OMPs are available, data are provided to relevant personnel in IMT (e.g. Planning) and used in the Incident Action Planning process for the next operational period. OMP is redesigned or reallocated according to the specifics of the actual spill.
	SM	• Commence activation and mobilisation process. • Activation of SMP Team Leads.	• Continue to activate and mobilise personnel. • Work on finalising SMPs.	• SMP: Water quality impact assessment • SMP: Sediment quality impact assessment • SMP: Marine fish and elasmobranch assemblages assessment • SMP: Marine mega-fauna assessment	Continue SMP monitoring until termination criteria are met
Sensitive receptors (including shorelines) where modelling shows contact within 72 hours (3 days) • Cliff Head – White Point (0.5 days)	OM	• Activation of OMP Team Leads. • Finalise OMPs. • Commence activation and mobilisation of OM personnel.	• OMP: Hydrocarbon properties and weathering behaviour at sea • OMP: Water quality assessment • OMP: Sediment quality assessment	-	As results from implemented OMPs are available, data are provided to relevant personnel in IMT (Situation Unit Lead) and used in the Incident Action Planning process for the next operational period. OMP is

Proximity to spill source	Monitoring type	0–48 hours from OSM activation	Within 3-5 days of OSM activation	~5-7 days from OSM activation	>Two weeks from OSM activation
• Illawong – Cliff Head (0.1 days) • Leeman – Coolimba (1.0 days) • Green Head – Leeman (1.5 days) • Beagle Islands Nature Reserve (0.5 days) • Booker Valley – Island Point (2.7 days)			• OMP: Shoreline clean-up assessment • OMP: Marine fauna assessment		redesigned or reallocated according to the specifics of the actual spill until termination criteria are met
	SM	• Activation of SMP Team Leads and finalisation of SMPs requiring reactive baseline monitoring data to be obtained pre-impact.	• Implementation of reactive baseline data monitoring (if applicable). • Finalisation of the remaining SMPs (where individual SMP initiation criteria are met).	• SMP: Water quality impact assessment • SMP: Sediment quality impact assessment • SMP: Intertidal and coastal habitat assessment • SMP: Seabirds and shorebirds • SMP: Marine mega-fauna assessment • SMP: Benthic habitat assessment • SMP: Marine fish and elasmobranch assemblages assessment • SMP: Commercial and recreational fisheries impact assessment • SMP: Heritage and social impact assessment	Continue SMP monitoring until termination criteria are met
Sensitive receptors (including shorelines) where modelling shows contact >3 days	OM	-	• Activation of OMP Team Leads. • Finalise OMPs.	• OMP: Hydrocarbon properties and weathering behaviour at sea	As results from implemented OMPs are available, data are provided to relevant personnel in IMT

Proximity to spill source	Monitoring type	0–48 hours from OSM activation	Within 3-5 days of OSM activation	~5-7 days from OSM activation	>Two weeks from OSM activation
• Thirsty Point – Booker Valley (4.0 days) • Grey – Thirsty Point (4.9 days) • Direction Bank (3.8 days) • North Tail Reef (3.1 days)			• Commence activation and mobilisation of OM personnel.	• OMP: Water quality assessment • OMP: Sediment quality assessment • OMP: Shoreline clean-up assessment • OMP: Marine fauna assessment	(Situation Unit Lead) and used in the Incident Action Planning process for the next operational period. OMP is redesigned or reallocated according to the specifics of the actual spill until termination criteria are met
	SM	-	• Commence activation and mobilisation process • Activation of SMP Team Leads and finalisation of SMPs	• SMP: Water quality impact assessment • SMP: Sediment quality impact assessment • SMP: Marine mega-fauna assessment - reptiles • SMP: Marine fish and elasmobranch assemblages assessment • SMP: Intertidal and coastal habitat assessment • SMP: Seabirds and shorebirds • SMP: Benthic habitat assessment • SMP: Commercial and recreational fisheries impact assessment	Continue SMP monitoring until termination criteria are met

Proximity to spill source	Monitoring type	0–48 hours from OSM activation	Within 3-5 days of OSM activation	~5-7 days from OSM activation	>Two weeks from OSM activation
				• SMP: Heritage and social impact assessment	
Sensitive receptors (including shorelines) where modelling shows contact >3 days • Geelvink Channel Shoals (5.2 days) • Sand Knoll Ledge (6.0 days) • Clio Bank (6.8 days)	OM	-	• Activation of OMP Team Leads. • Finalise OMPs. • Commence activation and mobilisation of OM personnel.	• OMP: Hydrocarbon properties and weathering behaviour at sea • OMP: Water quality assessment • OMP: Sediment quality assessment • OMP: Marine fauna assessment	As results from implemented OMPs are available, data are provided to relevant personnel in IMT (Situation Unit Lead) and used in the Incident Action Planning process for the next operational period. OMP is redesigned or reallocated according to the specifics of the actual spill until termination criteria are met
	SM	-	• Commence activation and mobilisation process • Activation of SMP Team Leads and finalisation of SMPs	• SMP: Water quality impact assessment • SMP: Sediment quality impact assessment • SMP: Marine mega-fauna assessment • SMP: Marine fish and elasmobranch assemblages assessment • SMP: Seabirds and shorebirds • SMP: Benthic habitat assessment • SMP: Commercial and recreational	Continue SMP monitoring until termination criteria are met

Proximity to spill source	Monitoring type	0–48 hours from OSM activation	Within 3-5 days of OSM activation	~5-7 days from OSM activation	>Two weeks from OSM activation
				fisheries impact assessment • SMP: Heritage and social impact assessment	

8. Resource Requirements

The resources required to assist the IMT in the coordination and management of OSM are outlined in Table 8-1. The resources required to implement operational and scientific monitoring components are presented in Table 8-1 and Table 8-2 respectively, which is based on the monitoring priorities in Section 2 and implementation schedule outlined in Table 7-1. This assessment is based on the vessel-based MGO spill (320 m^3) as listed in Table 3-1 of the Eureka 3D MSS OPEP (Appendix E). It should be noted that a single spill will not contact all locations and receptors listed in Table 7-1.

Table 8-1: Resources Required for Key OSM Coordination Roles

Role	Resources Required	Arrangement
OSM Implementation Lead (OSM Monitoring Provider/s)	1 x Principal Scientist	OSM contractor
Operational Monitoring Coordinator and Scientific Monitoring Coordinator (OSM Service Provider/s)		
OSM Field Operations Manager (OSM Service Provider/s)	1 x Senior Scientist	

Table 8-2: Resources Required for Implementing OMPs

OMP	Resources Required	Arrangement
Hydrocarbon properties and weathering behaviour at sea)*	1 team (spill site and surrounds) 1 team (Cliff Head, Illawong, Leeman, Green Head, Beagle Islands, Booker Valley) 1 team (Thirsty Point, Grey, Direction Bank, North Tail Reef, Sand Knoll)	OSM contractor Marine contractors Laboratory arrangement

OMP	Resources Required	Arrangement
	1 team (Clio Bank, Geelvink Channel Shoals) Total 4 team leaders and 8 team members (3 personnel per team)	
Shoreline clean-up assessment	1 team (Cliff Head, Illawong, Leeman, Green Head, Beagle Islands, Booker Valley) 1 team (Thirsty Point, Grey) Total 2 team leaders and 4 team members (3 per team)	OSM contractor Marine contractors
Water quality assessment*	Refer to OMP: Hydrocarbon properties and weathering behaviour at sea resourcing* (all sites)	OSM contractor Marine contractors
Sediment quality assessment*	Refer to OMP: Hydrocarbon properties and weathering behaviour at sea resourcing* (all sites)	OSM contractor Marine contractors
Marine fauna assessment	1 team to conduct initial aerial surveys for all sites (2 observers per aircraft) Note: these resources may not be required if relevant scientific monitoring components initiation criteria have been triggered.	OSM contractor Marine contractors Aviation contractors

** Initial co-mobilisation between OMP: Hydrocarbon properties and weathering behaviour at sea, OMP: Water quality assessment and OMP: Sediment quality assessment*

Table 8-3: Resources Required for Implementing SMPs

SMP	Resources Required	Arrangement
Water quality impact assessment	1 team (spill site and surrounds) 1 team (Cliff Head, Illawong, Leeman, Green Head, Beagle Islands, Booker Valley) 1 team (Thirsty Point, Grey, Direction Bank, North Tail Reef, Sand Knoll) 1 team (Clio Bank, Geelvink Channel Shoals) Total 4 team leaders and 8 team members (3 personnel per team) Note: can be performed by the same team as OMP: Water quality assessment. This SMP may replace OMP: Water quality assessment if the OMPs termination criteria are triggered	OSM contractor Marine contractors Laboratory arrangement
Sediment quality impact assessment	Refer to SMP: Water quality impact assessment* (all sites)	OSM contractor Marine contractors Laboratory arrangement

SMP	Resources Required	Arrangement
Intertidal and coastal habitat assessment	1 team (Cliff Head, Illawong, Leeman, Green Head, Beagle Islands, Booker Valley) 1 team (Thirsty Point, Grey) Total 2 team leaders and 2 team members (2 per team)	OSM contractor Marine contractors Laboratory arrangement
Seabirds and shorebirds	1 team (Cliff Head, Illawong, Leeman, Green Head, Beagle Islands, Booker Valley) 1 team (Thirsty Point, Grey, Direction Bank, North Tail Reef, Sand Knoll) 1 team (Clio Bank, Geelvink Channel Shoals) Total 3 team leaders and 3 team members (2 per team) Note: can initially be performed by the same team as OMP: Marine fauna assessment – seabirds and shorebirds. This SMP may replace OMP: Marine fauna assessment – seabirds and shorebirds if the OMPs termination criteria are triggered	OSM contractor Marine contractors Laboratory arrangement
Marine mega-fauna assessment • Pinnipeds • Reptiles • Cetaceans	1 team (spill site and surrounds) 1 team (Cliff Head, Illawong, Leeman, Green Head, Beagle Islands, Booker Valley) 1 team (Thirsty Point, Grey, Direction Bank, North Tail Reef, Sand Knoll) 1 team (Clio Bank, Geelvink Channel Shoals) Total 4 team leaders and 12 team members (4 per team) Note: Aerial surveillance aspects can initially be performed by the same team as the relevant OMP: Marine fauna assessment. This SMP may replace the relevant OMP: Marine fauna assessment if the OMPs termination criteria are triggered	OSM contractor Marine contractors Laboratory arrangement
Benthic habitat assessment	1 team (Cliff Head, Illawong, Leeman, Green Head, Beagle Islands, Booker Valley) 1 team (Thirsty Point, Grey, Direction Bank, North Tail Reef, Sand Knoll) 1 team (Clio Bank, Geelvink Channel Shoals) Total 3 team leaders and 6 team members (3 per team)	OSM contractor Marine contractors Laboratory arrangement
Marine fish and elasmobranch assemblages assessment	1 team (spill site and surrounds) 1 team (Cliff Head, Illawong, Leeman, Green Head, Beagle Islands, Booker Valley) 1 team (Thirsty Point, Grey, Direction Bank, North Tail Reef, Sand Knoll) 1 team (Clio Bank, Geelvink Channel Shoals) Total 4 team leaders and 8 team members (3 per team) Note: can initially be performed by the same team as OMP: Marine fauna assessment – fish. This SMP may replace OMP: Marine fauna assessment – fish if the OMPs termination criteria are triggered	OSM contractor Marine contractors Laboratory arrangement

SMP	Resources Required	Arrangement
Fisheries impact assessment	1 team (Commonwealth fisheries with the potential to be impacted/are being impacted (e.g. Western Deepwater Trawl Fishery) Total 1 team leaders and 2 team members (3 per team) Note: can initially be performed by the same team as OMP: Marine fauna assessment – fish. This SMP may replace OMP: Marine fauna assessment – fish if the OMPs termination criteria are triggered	OSM contractor Marine contractors Laboratory arrangement
Heritage features assessment	1 team Total 1 team leader and 2 team members (3 per team)	OSM contractor Marine contractors Laboratory arrangement
Social impact assessment	1 team Total 1 team leader and 2 team members (3 per team)	OSM contractor

9. Capability Arrangements

Pilot Energy will engage an OSM Services Provider, providing standby OSM response and implementation services, prior to pre-mobilisation of the activity. Details of OSM services are provided in Table 9-1.

The OSM Services Provider is contracted to provide Pilot Energy with a Standby Capability and Competency Report at the commencement of the MSS, which details personnel requirements for OMPs/SMPs, numbers of available personnel and competencies for service provider and sub-contracted personnel.

Personnel listed on the report will be contactable via mobile phone during this period and accessible to a nearby port (i.e. Port Denison-Dongara or Fremantle) within 48 hours of Pilot Energy's initial activation of OSM Services.

Table 9-1: Worked Example – OSM Services Provider Standby and Implementation Services

Standby	Implementation
24/7 monitoring support accessed through 24 hour call out number	Provision of an OSM Implementation Lead to the Pilot Energy IMT within 12 hours of notification
Provision of a suitably trained personnel, which includes support from the service provider and its sub-contractors and suppliers	Provision of a first-strike scientific team within 24 hours of notification, available in Perth and ready to deploy
Report on personnel and equipment availability, prior to the commencement of the MSS	Development of scientific response and sampling plans (based on modelled hydrocarbon spill scenario)
Access to service providers network of scientific and engineering consulting expertise	Provision of a second-strike scientific team within 72 hours of notification, ready to deploy
Access to service providers local network of terrestrial consultants, laboratories and field service providers	Priority access to service providers staff and equipment

9.1 Personnel Competencies

Pilot Energy's OSM Service Contract specifies the competency requirements for key OSM personnel.

In addition and where practicable, Pilot Energy will engage its consultants in the initial stages of the monitoring program to help activate and mobilise monitoring teams, and finalise monitoring designs.

9.2 Equipment

Equipment requirements are listed in the individual OMPs and SMPs. A generalised breakdown of equipment types and the source is listed in Table 9-2.

In accordance with the OSM services contract, the OSM Services Provider will provide all specialised field monitoring equipment to implement individual OMPs and SMPs. Pilot Energy will remain responsible for support and field logistics, including monitoring platforms (e.g. vessels, vehicles and aircraft), flights and accommodation for personnel and transportation/couriers for samples to be sent back to laboratories.

Availability of field equipment will be listed in the OSM Services Provider's Standby Capability and Competency Report.

Table 9-2: OSM equipment

Equipment type	Source
Desktop equipment (e.g. Oil Spill Response Atlas, GIS)	Coordinated through OSM Service Provider
In-field specialised monitoring equipment (e.g. fluorometers, sample bottles, ROVs)	Coordinated through the OSM Services Provider's standby OSM response and implementation services
Logistical equipment (e.g. in-field accommodation, vessels, aircraft)	Marine contracts, aviation contracts.

9.3 Exercises

Testing of key service provider arrangements would be done as a standalone desktop test prior to the mobilisation of the activity, and would assess the capability and availability of resources by the service provider against the performance requirements. More information of exercise and testing arrangements is provided in Section 10 of the Eureka 3D MSS EP.

10. Capability Assessment

Table 10-1 demonstrates Pilot Energy's capability to implement each OMP and SMP, including an assessment of each monitoring plan, identification of likely monitoring platforms, major supporting infrastructure (e.g. offshore accommodation), reactive baseline monitoring requirements (Section 4.0), initial survey arrangements (e.g. aerial followed up with ground reconnaissance) and ability to combine with other monitoring plans. The personnel outlined is only relevant if the spill hits all receptors identified in table 8.3 at a high volume and threshold. Given the size and type of spill it is improbable that all personnel identified would be required and therefore activated.

Note that OMP: Surface chemical dispersant effectiveness and fate assessment and OMP: Subsea dispersant injection monitoring are not included in Table 10-1 as they have not been selected as suitable response strategies in the OPEP (Appendix E – Section 3.4).

Table 10-1: OSM Capability

Component	Total Personnel Required (Weeks 1–2) [1]	Personnel available via OSM Service Provider Standby Contract	Total Personnel Available
OSM Personnel embedded in IMT	1 OSM Implementation Lead (given nature/scale this person can also fill the role of OM and SM Coordinator) 1 Field Operations Manager	1 OSM Implementation Lead/ OM Monitoring Coordinator / SM Coordinator 1 Field Operations Manager	1 OSM Implementation Lead/ OM Monitoring Coordinator / SM Coordinator 1 Field Operations Manager
OMPs			
Hydrocarbon properties and weathering behaviour at sea*	4 team leaders 8 team members	4 team leaders 8 team members	4 team leaders 8 team members
Shoreline clean-up assessment	2 team leaders 4 team members	2 team leaders 4 team members	2 team leaders 4 team members
Water quality assessment*	Refer to OMP: Hydrocarbon properties and weathering behaviour at sea		
Sediment quality assessment*	Refer to OMP: Hydrocarbon properties and weathering behaviour at sea		
Marine fauna assessment	1 aerial team (including 1 Marine Mammal Observer (MMO) and 1 Aerial survey observer)	1 aerial team (including 1 Marine Mammal Observer (MMO) and 1 Aerial survey observer)	1 aerial team (including 1 Marine Mammal Observer (MMO) and 1 Aerial survey observer)
SMPs			
Water quality impact assessment	Note: can initially be performed by the same team as OMP: Water quality assessment. This SMP may replace OMP: Water quality assessment if the OMPs termination criteria are triggered		
Sediment quality impact assessment	Refer to SMP: Water quality impact assessment* (all sites)		

[1] If additional resources are required for week 3 onwards then this will be identified early in the monitoring process and Pilot Energy will activate additional contracted resources through its OSM Services Provider to increase capacity

Component	Total Personnel Required (Weeks 1–2) [1]	Personnel available via OSM Service Provider Standby Contract	Total Personnel Available
Intertidal and coastal habitat assessment	2 team leaders 2 team members	2 team leaders 2 team members	2 team leaders 2 team members
Seabirds and shorebirds	Note: can initially be performed by the same team as OMP: Marine fauna assessment – seabirds and shorebirds. This SMP may replace OMP: Marine fauna assessment – seabirds and shorebirds if the OMPs termination criteria are triggered		
Marine mega-fauna assessment	4 team leaders 12 team members	4 team leaders 12 team members	4 team leaders 12 team members
Benthic habitat assessment	3 team leaders 6 team members	3 team leaders 6 team members	3 team leaders 6 team members
Marine fish and elasmobranch assemblages assessment	4 team leaders 8 team members	4 team leaders 8 team members	4 team leaders 8 team members
Fisheries impact assessment	1 team leader 2 team members	1 team leader 2 team members	1 team leader 2 team members
Heritage features assessment	1 team leader 2 team members (including either ROV operator or marine diver/s)	1 team leader 2 team members (including either ROV operator or marine diver/s)	1 team leaders 2 team members (including either ROV operator or marine diver/s)
Social impact assessment	1 team leader 2 team members	N/A	1 team leader 2 team members

** Initial co-mobilisation between OMP: Hydrocarbon properties and weathering behaviour at sea and OMP: Water quality assessment and OMP: Sediment quality assessment*

11. Review of Plan

This document will be reviewed in the pre-mobilisation preoaration for the 3D MSS. Should any major changes have occurred this document will be revised. This could include changes required in response to one or more of the following:

- When major changes have occurred which affect Operational and/or Scientific Monitoring coordination or capabilities (e.g. change of service provider/s);
- Changes to the activity that affect Operational and/or Scientific Monitoring coordination or capabilities (e.g. a significant increase in spill risk);
- Changes to legislative context related to Operational and/or Scientific Monitoring (e.g. EPBC Act protected maters requirements);

The extent of changes made to this OSM Bridging Implementation Plan and resultant requirements for regulatory resubmission will be informed by the relevant Commonwealth regulations, i.e. the OPGGS (Env) Regulations.

Part B – Implementation

12. Activation Process

Pilot Energy's IMT Environment Unit Leader is responsible for activating OSM components, subject to approval from the IMT Leader. Table 12-1 outlines Pilot Energy's OSM activation process.

Table 12-1: OSM Activation Process

Responsibility	Task	Timeframe	Complete
Environment Unit Leader (Pilot Energy/ Environmental Consultants)	Review initiation criteria of OMPs and SMPs during the preparation of the initial Incident Action Plan (IAPs) and subsequent IAPs; and if any criteria are met, activate relevant OMPs and SMPs	Within 4 hours of spill notification	❑
	Obtain approval from Incident Commander Leader to initiate OSM	Within 4 hours of spill notification	❑
	Contact OSM Services Provider and notify on-call officer of incident, requesting provision of OSM Implementation Lead to the IMT	Within 4 hours of spill notification	❑
	Provide monitor and evaluate data (e.g. aerial surveillance, fate and weathering modelling, tracking buoy data) to OSM Services Provider	Within 1 hour of data being received by IMT	❑
	Liaise directly with OSM Services Provider to confirm which OMPs and SMPs are to be fully activated	Within 3 hours of monitor and evaluate data being received from IMT	❑
	Provide purchase order to OSM Services Provider (cross reference OSM Standby Services Scope of Work)	Within 72 hours of initial notification to OSM Services Provider	❑
	Record tasks in Personal Log	At time of completion of task	❑
OSM Services Provider	On-call officer to notify Service Provider Manager of activation and contact OSM Implementation Lead and Scientific Logistics Coordinator	Within 8 hours of notification being made to OSM Services Provider	❑
	Send OSM Implementation Lead and Scientific Logistics Coordinator to IMT	Within 12 hours of notification being made to OSM Services Provider	❑
	Liaise directly with EUL to confirm which OMPs and SMPs are to be fully activated	Within 4 hours of monitor and evaluate data being received from IMT	❑
	Confirm availability of initial personnel and equipment resources	Within 5 hours of monitor and evaluate data being received from IMT	❑

13. Monitoring Priorities

As described in Section 2, the available spill trajectory modelling has been analysed to understand the likely initial monitoring priorities for its activities in the EMBA. In addition, Table 4-2 lists comparability of available baseline data for receptors, to assist in identifying where post-spill, pre-impact monitoring should be prioritised.

The monitoring priorities provided in Section 2 and Table 4-2 are to be used for guidance when confirming monitoring priorities in consultation with key stakeholders and monitoring service providers (including subject matter experts, where available) at the time of the spill. Table 13-1 provides a checklist to assist in the confirmation of monitoring priorities for individual spills.

Table 13-1: Checklist for Determining Monitoring Priorities

Responsibility	Task	Timeframe	Complete
OSM Services Provider with input from Environment Unit Leader (EUL)	Confirm monitoring locations for activated OMPs and SMPs based on: • Current monitor and evaluate data (i.e. situational awareness data, including predicted time to receptor impact, aerial/vessel surveillance observations, tracking buoy data, satellite data); • Nature of hydrocarbon spill (i.e. surface release, hydrocarbon characteristics, volume, expected duration of release); • Seasonality and presence of receptors impacted or at risk of being impacted; • Current information on transient and broadscale receptors (surface and subsea); • Current operational considerations (e.g. weather, logistics); • Monitoring priorities identified in Section 2; and • Existing literature, baseline data, and monitoring programs.	Within 12 hours of monitor and evaluate data being received from IMT	❑
	Evaluate monitoring priorities in consultation with key stakeholders, including the appointed State Environment and Science Coordinator	Within 12 hours of monitor and evaluate data being received from IMT	❑
	Using the results of the baseline data analysis in Table 4-2 and the information above, determine priority locations for post-spill, pre-impact monitoring	Within 12 hours of monitor and evaluate data being received from IMT	❑
	Confirm the need for any additional reactive baseline monitoring data for SMPs and determine suitable locations, noting that suitable control or reference sites may be outside of the EMBA	Within 12 hours of monitor and evaluate data being received from IMT	❑
	Continually re-evaluate monitoring priorities in consultation with EUL and relevant key stakeholders throughout spill response	Ongoing	❑

14. Protected Matters Requirements

Table 14-1 provides a checklist to ensure monitoring personnel consider EPBC Act Protected Matters (MNES) and other protected matters requirements in the finalisation of OMPs and SMPs.

Appendix B outlines the management plans, recovery plans and conservation advice statements relevant for the protected matters within the EMBA that are likely to be relevant to the final design of the OMPs and SMPs. Appendix B also includes relevant priority monitoring locations where these receptors are known to occur in order to expedite consideration of relevant information into finalised monitoring designs.

Table 14-1: Checklist for Inclusion of Protected Matters into Monitoring Designs

Responsibility	Task	Complete
OSM Services Provider with input from EUL	Review Monitoring, Evaluation and Surveillance data and available OMP data to determine likely presence and encounter of protected species in predicted trajectory of the spill	❑
	Review the relevant recovery plan/wildlife conservation plan/conservation advice/management plan in Appendix B and determine if there have been any updates to the relevant conservation threats/actions. Integrate relevant considerations into the final monitoring design for affected OMPs and SMPs	❑
	Review restrictions on marine mammal buffer distances in SMP: Marine mega-fauna and ensure this is included in all relevant response and monitoring IAPs (e.g. Shoreline Protection Plan, Shoreline Clean-up Plan, OSM Plan), so that response and monitoring field teams maintain required buffer distances from fauna during operations	❑

15. Finalising Monitoring Design

The methods presented in the Joint Industry OMPs and SMPs are designed to allow Monitoring Providers with the flexibility to modify the standard operating procedures, so that the latest research, technologies, equipment, sampling methods and variables may be used. Monitoring designs may also be varied in-situ, according to the factors presented in Section 10.6 of the Joint Industry OSM Framework.

Pilot Energy's checklist for finalising monitoring designs post-spill is provided in Table 15-1. The OSM Implementation Lead will be responsible for approving the finalised monitoring design used in the OMPs and SMPs.

Table 15-1: Checklist for Finalising Monitoring Design

Responsibility	Task	Timeframe	Complete
OSM Services Provider	Confirm survey objectives, sampling technique, for each initiated OMP and SMP	Within 48 hours of initial monitoring priorities being confirmed by IMT	❑
	Determine suitable sampling frequency	Within 48 hours of initial monitoring priorities being confirmed by IMT	❑
	Finalise standard operating procedures	Within 48 hours of initial monitoring priorities being confirmed by IMT	❑
	Scientific monitoring: • Establish benchmarks and guidelines to be used • Confirm indicator species	Within 96 hours of initial monitoring priorities being confirmed by IMT	❑

Responsibility	Task	Timeframe	Complete
	• Confirm parameters and metrics		

16. Mobilisation

When the monitoring design has been finalised for each OMP and SMP, the OSM Services Provider shall work in conjunction with Pilot Energy to develop and execute a monitoring mobilisation plan, which will be incorporated into the Incident Action Planning process.

The OSM Services Provider will be required to coordinate the availability of personnel and equipment for all monitoring programs. Pilot Energy is responsible for flights, accommodation and victualing for field personnel. Pilot Energy will also be required to procure all vessels, aerial platforms and vehicles for OMP and SMP implementation.

A checklist for mobilising monitoring teams is provided in Table 16-1.

Table 16-1: Checklist for Mobilisation of Monitoring Teams

Responsibility	Task	Complete
OSM Services Provider with input from Environment Unit Leader	Confirm availability of all monitoring personnel (noting required competencies in Section 11.3 of the Joint Industry OSM Framework and individual OMPs/SMPs)	❑
	Allocate number of teams, personnel, equipment and supporting resource requirements	❑
	Undertake HAZIDs as required and consolidate/review field documentation including safety plans, emergency response plans, and daily field reports	❑
	Develop site-specific health and safety plans which is compliant with health safety and environment systems (including call in timing and procedures)	❑
	Conduct pre-mobilisation meeting with monitoring team/s on survey objectives, logistics, safety issues, reporting requirements and data management collection requirements	❑
	Determine data management delivery needs of the IMT/EMT and process requirements, including data transfer approach and frequency/timing	❑
	Confirm data formats and metadata requirements with personnel receiving data	❑
	Logistics	
	Confirm flights, accommodation, and car hire arrangements are in place	❑
	Develop field survey schedules, detailing staff rotation	❑
	Equipment	
	Confirm survey platform (vessel, vehicle, aircraft) has been secured to survey or access survey sites and ensure it is equipped with appropriate fridge and freezer space for transportation of samples (and carcasses if collecting)	❑
	Ensure vessels have correct fit-out specifications (e.g. winches, GPS, satellite, hi-ab, sufficient deck space, water supplies (fresh and/or salt), accommodation)	❑
	Confirm consumables (including personal protective equipment) have been purchased and will be delivered to required location	❑

Responsibility	Task	Complete
	Liaise with NATA-accredited laboratories to confirm availability, limits of detection, sampling holding times, transportation, obtain sample analysis quotes and arrange provision of appropriate sample containers, Chain of Custody (CoC) forms and suitable storage options for all samples. Make arrangements for couriers (if necessary)	❑
	Confirm specialist equipment requirements and availability (including redundancy)	❑
	Check GPS units and digital cameras are working and that sufficient spare batteries and memory cards are available	❑
	Confirm sufficient equipment to allow integration of survey software and navigational systems (e.g. GPS, additional equipment and adaptors), and additional GPS units prepared	❑
	Confirm GPS survey positions (where available) have been QA/QC checked and pre-loaded into navigation software/positioning system	❑
	Check field laptops, ensuring they have batteries (including spares), power cable, and are functional	❑
	Check if a first aid kit or specialist Personal Protective Equipment (PPE) is required	❑
	Confirm arrangements for freight to mobilisation port is in place	❑

17. Permits and Access Requirements

Permit and access requirements apply to marine parks, marine and terrestrial reserves, restricted heritage areas, operational areas of industrial sites, defence locations, certain fauna and managed fisheries. Table 17-1 lists relevant protected areas within the EMBA and the jurisdictional authority to be contacted to obtain the necessary permit or access permission.

The OSM Services Provider is responsible for submitting access and permit applications to all relevant Jurisdictional Authorities to conduct monitoring for OMPs and SMPs.

Table 17-1: Permits Required in EMBA

Receptor	Location	Jurisdictional Authority	Relevant information on permits
Permits for monitoring fauna	N/A	DCCEEW State government department with jurisdiction for fauna	Any interactions involving nationally listed threatened fauna may require approval from DCCEEW (http://www.environment.gov.au/biodiversity/threatened/permits) WA- appropriate permits can be found at: https://www.dpaw.wa.gov.au/plants-and-animals/licences-and-authorities?showall=&start=4
State Marine Protected Areas; Fish Habitat Protection Areas	• Jurien Bay Marine Park • Essex Rocks Nature Reserve • Buller, Whittell and Green Islands Nature Reserve • Cervantes Islands Nature Reserve • Beagle Islands Nature Reserve • Marmion Marine Park • Lipfert, Milligan, Etc Islands Nature Reserve • Sandland Island Nature Reserve • Ronsard Rocks Nature Reserve • Outer Rocks Nature Reserve • Fisherman Islands Nature Reserve	State government department with jurisdiction for parks and wildlife (DBCA) State government department with jurisdiction for fisheries (DPIRD)	No specific permitting requirements exist for monitoring in WA marine protected areas, but OSM Service Providers should contact DBCA and DPIRD prior to finalising monitoring design in protected areas. DBCA has a Marine Science Program for WA's Marine Protected Areas to undertake marine reaserach and monitoring that should be taken into account. Additional information is available at: https://www.dpaw.wa.gov.au/management/marine , https://www.dpaw.wa.gov.au/management/marine/marine-parks-and-reserves and https://www.fish.wa.gov.au/Sustainability-and-Environment/Aquatic-Biodiversity/Marine-Protected-Areas/Pages/default.aspx

Receptor	Location	Jurisdictional Authority	Relevant information on permits
	• Lancelin Island Lagoon Fish Habitat Protection • Abrolhos Islands Fish Habitat Protection		
Australian (Commonwealth) Marine Parks	• Abrolhos • Perth Canyon • Two Ricks • Jurien • South-west Corner	Director of National Parks Parks Australia	Permit and licence application information for Marine Protected Areas (including monitoring) can be found at: https://onlineservices.environment.gov.au/parks/australian-marine-parks and https://onlineservices.environment.gov.au/parks/australian-marine-parks/permits Additional information on permitting requirements in Australian Marine Parks can be obtained through Parks Australia via email marineparks@environment.gov.au or phone 1800 069 352 Information on permits to access biological resources in Commonwealth areas can be found at: http://www.environment.gov.au/topics/science-and-research/australias-biological-resources/access-biological-resources-commonwealth
Commonwealth Managed Fisheries	• Western Deepwater Trawl Fishery	Australian Fishing Management Authority (AFMA)	Commonwealth Managed Fisheries (scientific permit for research/monitoring in an Australian Fishing Zone) https://www.afma.gov.au/fisheries-services/fishing-rights-permits
Indigenous Cultural Heritage	Sites are located throughout EMBA	State government department with jurisdiction for indigenous heritage	Entry access permits to Aboriginal Lands in WA: https://www.wa.gov.au/service/aboriginal-affairs/aboriginal-heritage-conservation/apply-permit-access-or-travel-through-aboriginal-land Aboriginal heritage sites in WA: https://www.wa.gov.au/service/aboriginal-affairs/aboriginal-cultural-heritage/search-aboriginal-sites-or-heritage-places
Lancelin Defence Training Area	Lancelin	Department of Defence	Unexploded Ordanances (mapping information): https://www.defence.gov.au/UXO/default.asp Maritime military firing practice and exercise areas: https://www.hydro.gov.au/factsheets/FS_Navigation-Firing_Practice_and_Exercise_Areas.pdf
Industry (e.g. operational zone of offshore oil or gas platform)	• Triangle Energy Pty Ltd WA-31-L (29° 27’ 00.4” S 114° 52’ 12.1” E)	Operating company	Petroleum safety zones (up to 500 m from outer edge of well or equipment) – https://www.nopsema.gov.au/safety/safety-zones/

Receptor	Location	Jurisdictional Authority	Relevant information on permits
Shipwrecks	• Batavia Shipwreck Site	State/ or Commonwealth government department with jurisdiction for maritime cultural heritage/ archaeology	Underwater heritage protected zones (Commonwealth): www.environment.gov.au/heritage/underwater-heritage/protected-zones

18. Use of Data in Response Decision-making

18.1 Operational Monitoring to Inform Response Activities

The OSM Services Provider is responsible for the collection of data by field teams, which shall be QA/QC checked by the Field Team Lead in accordance with the requirements listed in the finalised OMPs and SMPs (where applicable). The Team Lead will be responsible for communicating data back to the OSM Management Team (led by the OSM Services Provider) via field reporting forms, debriefs and reports. Laboratory analysis reports should also be directed to the OSM Management Team.

The OSM Management Team is responsible for the interpretation and analysis of data. OMP data should be analysed rapidly so that it may be used to inform response planning and decisions in the current and/or next operating period. SMP data is designed to be more scientifically robust and long-term in nature and is not relied upon by the IMT for decision-making. Therefore, SMP data will be analysed more thoroughly by the OSM Management Team.

Once data is analysed and checked by the Field Team Lead, it will be provided to the IMT Situation Unit Lead, who will then distribute the data from each monitoring component to the relevant IMT Unit and/or Section. Table 18-1 provides guidance on the type of data generated from each OMP, which IMT Section/Unit requires the data and how the data may be used during a response.

Analysed data will then be incorporated into the Common Operating Picture (managed by the Situation Unit Lead) and used by the Environment Unit Lead during development of the operational Spill Impact Mitigation Assessment (SIMA), which would be included in the IAP for the current or next operating period.

As ultimately responsible for the IAPs, the Planning Section Chief will be required to determine if the response options can be commenced, continued, escalated, terminated, or if controls need to be put in place to manage impacts of the response activities. These decisions will be communicated to the broader IMT during regular situation debriefs.

Table 18-1: Data Generated from Each OMP and How this May be used by IMT in Decision Making

Operational Monitoring Plan	Data generated[2]	IMT Section requiring data	How data may be used by IMT
Hydrocarbon properties and weathering behaviour at sea	Hydrocarbon physical characteristics (e.g. viscosity, asphaltene content, fingerprinting, weathering ratios of hydrocarbon chains)	Planning Section to aid in response option selection / modification	Changes to the hydrocarbon properties will affect the window of opportunity for particular responses and the associated logistical requirements of these responses, such as use of chemical dispersants, recovery and pumping equipment suitability, hydrocarbon storage and hydrocarbon disposal requirements
Shoreline clean-up assessment	Assessment of shoreline character; assessment of shoreline oiling; recommendations for response activities; post-treatment surveys	Planning Section to aid in IAP development and response option selection / modification	Confirmation of shoreline character, habitats and fauna present which may influence selection of response tactics (e.g. no mechanical recovery if seabirds are known to be nesting); Oil deposition and/or removal rate for a shoreline sector will help determine effectiveness of relevant tactics (e.g. shoreline protection and/or clean-up operations); Assessment teams provide ground truthing of sites that are not possible via satellite imagery, therefore the IMT can rely on the recommendations of Assessment Teams (e.g. flagging access issues, suitable tactics, likely resourcing needs)
Water quality assessment	Distribution of oil in water column and change in hydrocarbon concentrations (e.g. total recoverable hydrocarbons; benzene, toluene, ethylbenzene, xylene and naphthalene [BTEXN], Polycyclic Aromatic Hydrocarbons [PAH]), physio-chemical parameters and dispersant detection	Situation Unit Lead to validate surveillance and modelling data; Planning Section for use in IAP	Confirm spatial extent of spill within the water column and verify spill modelling and surveillance data; extent of spill can in turn influence location of other OMP and SMP monitoring components and sites. Data can also influence ongoing use of dispersant through ongoing operational SIMA.
Sediment quality assessment	Distribution of oil in sediment and change in hydrocarbon concentrations (e.g. Total recoverable hydrocarbons, BTEXN, PAH)	Situation Unit Lead to validate surveillance and modelling data; Planning Section for use in IAP	Confirm spatial extent of spill; extent of spill can in turn influence location of other OMP and SMP monitoring components and sites

[2] Summary only. For additional detail, please refer to individual OMPs. Also note data outputs will be reliant on finalised monitoring design.

Operational Monitoring Plan	Data generated[2]	IMT Section requiring data	How data may be used by IMT
Marine fauna assessment • Pinnipeds • Cetaceans (observational only) • Seabirds and shorebirds • Fish	Rapid assessment of presence and distribution of marine fauna; evaluate impact of spill and response activities on fauna	Planning Section for use in IAP; Oiled Wildlife Unit/Division to help in developing Wildlife Response Sub-plan	Understanding of species, populations and geographical locations at greatest risk from spill impacts. IMT can use this information to help qualify locations with highest level of protection priority (e.g. factoring in seasonality of receptors); understanding the impacts of spill response activities can help IMT to modify or terminate activities if they are assessed as creating more harm than the oil alone (e.g. large shoreline clean-up teams and staging areas may disturb shorebird nesting resulting in adults abandoning chicks)

18.2 Impacts from Response Activities

Table 10-4 of the Joint Industry OSM Framework outlines the potential impacts from response activities and the relevant OMP/SMP for monitoring impacts. For example, if shoreline clean-up was being considered as a response option, then possible impacts resulting from that activity could include physical presence, ground disturbance, water/sediment quality decline and lighting/noise impacts to fauna.

When finalising monitoring designs, the OSM Implementation Lead shall review Table 10-4 of the Joint Industry OSM Framework to ensure potential impacts from response activities are considered and incorporated into relevant OMP/SMP designs.

18.3 Operational Monitoring of Effectiveness of Control Measures and to Ensure EPS are Met

The EPS relevant to spill response and OSM are included in the Eureka 3D MSS OPEP (Appendix E). When finalising monitoring designs, the OSM Implementation Lead and Environment Unit Lead (or delegate) shall review the Environmental Performance Standards listed in the Eureka 3D MSS OPEP (Appendix E) and integrate checks into the monitoring design that will help determine if relevant Environmental Performance Standards are being met.

19. Data Management

Minimum standards for data management are provided in Section 10.11 of the Joint Industry OSM Framework and will be adopted by Pilot Energy and the OSM Service Provider.

20. Quality Assurance and Quality Control

Refer to Section 10.11 of the Joint Industry OSM Framework for QA/QC minimum standards, which will be adopted by Pilot Energy and the OSM Service Provider.

21. Communication Protocols

21.1 OSM Services Provider/s

Communication protocols between Pilot Energy and its OSM Services Provider with respect to delivery of the OMPs and SMPs (during both preparedness and implementation) are intentionally defined to ensure clear and consistent information is provided in both directions.

The following communication protocols must be observed:

- During the preparedness phase (pre-spill) and during activation (prior to deployment) will be between a Pilot Energy Representative (or delegate) and the OSM Services Provider Lead respectively.
- During implementation (post deployment), primary communication occurs via two pathways:
  - Pilot Energy Representative and the OSM Services Provider Lead for contractual, management, scientific and general direction matters; and
  - Pilot Energy’s IMT and the OSM Services Provider’s Field Operations Manager for on-site matters.
- All OSM operational decisions should be logged in an OSM decision log by key personnel, including but not limited to the OSM Services Provider Implementation Lead, OSM Field

Operations Manager, Operational Monitoring Coordinator, Scientific Monitoring Coordinator and Field Team Leads.

- All OSM tasks, actions and requirements should be documented in an IAP during the response phase of the spill.
- The IMT Incident Commander/IMT Leader will keep the IMT Section Chiefs briefed of the OSM status as required.
- All correspondence (copies of emails and records of phone calls) between Pilot Energy and the OSM Services Provider during a response should be recorded and kept on file.
- All communication received by OSM Services Provider not in line with these protocols should be reported to the nominated Pilot Energy Representative who will seek guidance on the accuracy of the information received.
- Unless related to safety (e.g. evacuation), any direction or instruction received by the OSM Services Provider outside of these protocols should be confirmed via the nominated Pilot Energy Representative prior to implementation.

During the post-response phase all communications shall be between a nominated Pilot Energy Representative and the OSM Services Provider OSM Implementation Lead.

21.2 External Stakeholders

Results of OMPs and SMPs will be discussed with relevant stakeholders. Information will be shared with regulatory agencies/authorities as required and inputs received from stakeholders will be evaluated and where practicable, will be used to refine the ongoing spill response and/or ongoing operational and/or scientific monitoring.

Pilot Energy IMT will be the focal point for external engagement during the response operation .A focal point for post response communications will be assigned.

22. Stand Down Process

Monitoring for each component will continue until termination criteria for individual components are reached. Typically, OMPs will terminate when agreement has been reached with the Jurisdictional Authority relevant to the spill to terminate the response or a relevant SMP has been activated. SMPs will continue after the spill response has been terminated and until such time as their termination criteria are also reached. A list of criteria is provided in the OSM Framework.

After OMPs are terminated, the OMP monitoring teams will be advised to stand down. Following this stage, the OSM Services Provider will run a lessons-learnt meeting between Pilot Energy, all monitoring providers and other relevant stakeholders. It is the responsibility of Pilot Energy to ensure that lessons learnt are communicated to the relevant stakeholder groups. The lessons discussed should include both positive actions to be reinforced and lessons for actions that could be improved in future standby or response campaigns.

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Appendix A Baseline data sources

Table A-1: Baseline Data Sources

Receptor	Existing baseline monitoring	Source / Data Custodian	Spatial extent
Water and sediment quality	McAlpine, K. W., Wenziker, K. J., Apte, S. C., Masini, R. J. (2005) Background concentrations of selected toxicants in the coastal waters of the Jurien Bay Marine Park. Department of Environment, Perth, WA, Technical Series 119.	DWER (Link to report)	Jurien Bay Marine Park
	Department of Environment and Conservation (2007) Background quality of the marine sediments off the Western Australian mid west coast. Department of Environment and Conservation. Marine Technical	DWER (Link to report)	Jurien Bay Marine Park, Cliff Head, Champion Bay, Horrocks, Geraldton
	Rule, M. J., Bancroft, K. P., Kendrick, A. J. (2012) Baseline and quality of the Jurien Bay Marine Park: a benchmark for warm temperate Western Australia Conservation Science Western Australia, 8 (2): 241-249	DBCA (Link to report)	Jurien Bay Marine Park (Fisherman Islands, Hill River, Nambung Bay)
	Giraldo-Ospina A, Kendrick GA, Hovey RK. (2020) Depth moderates loss of marine foundation species after an extreme marine heatwave: could deep temperate reefs act as a refuge? Proc. R. Soc. B287: 20200709.http://dx.doi.org/10.1098/rspb.2020.0709	UWA (Link to report)	Jurien Bay and other areas in WA

Receptor	Existing baseline monitoring	Source / Data Custodian	Spatial extent
Benthic communities and fish assemblages	Sanderson PG (2000) A comparison of reef-protected environments in Western Australia: The central west and Ningaloo coasts. Earth Surface Processes and Landforms 25, 397–419.	Sanderson PG, UWA	Jurien Bay and other areas in WA
	Davidson, J. A., Bancroft, K. P. (2000) Broadscale habitat map and biological data of the major benthic habitats between Cervantes and Wedge Island in the proposed Jurien Bay Marine Conservation Reserve. Data Report: MRI/MW/JB-40/2000. February 2000. Marine Conservation Branch, Department of Conservation and Land Management, Fremantle, Western Australia. (Unpublished report).	DBCA (Link to report)	Cervantes to Wedge Island
	Klonowski, W.M., Fearns, P., Lynch, M. J. (2007) Retrieving key benthic cover types and bathymetry from hyperspectral imagery, Journal of Applied Remote Sensing 1(1), 011505	Curtin University	Jurien Bay Marine Park
	AIMS (2016). WAMSI 1 - Node 4.2.2a - Establishment of indicators for ecosystem based fisheries management - Benthic assemblages. Unpublished report prepared for WAMSI.	AIMS (Link to metadata)	Jurien Bay and other areas in WA
	Fairclough, D. V., Potter, I. C., Lek, E., Bivoltsis, A. K., Babcock, R. C. (2011). The fish communities and main fish populations of the Jurien Bay Marine Park	Murdoch University (Link to report)	Jurien Bay Marine Park
	Bellchambers, L.M. and Pember, M. B. 2014. Assessing the ecological impact of the western rock lobster fishery in fished and unfished areas FRDC Project 2008/013. Fisheries Research Report No. 254. Department of Fisheries, Western Australia. 108pp.	Fisheries Research Division (Link to report)	Jurien and Leeman
	Stat, M., John, J., DiBattista, J.D., Newman, S.J., Bunce, M. and Harvey, E.S. (2019), Combined use of eDNA metabarcoding and video surveillance for the assessment of fish biodiversity. Conservation Biology, 33: 196-205. https://doi.org/10.1111/cobi.13183	Macquarie University (Link to report)	Jurien Bay Marine Park
	Giraldo-Ospina A, Kendrick GA, Hovey RK. 2020 Depth moderates loss of marine foundation species after an extreme marine heatwave: could deep temperate reefs act as a refuge? Proc. R. Soc. B287: 20200709.http://dx.doi.org/10.1098/rspb.2020.0709	UWA (Link to report)	Jurien Bay and other areas in WA
	Goldsworthy DS, Saunders BJ, Parker JRC, Harvey ES (2020) Spatial assemblage structure of shallow-water reef fish in Southwest Australia. Mar Ecol Prog Ser 649:125-140. https://doi.org/10.3354/meps13445	Curtin University	Jurien Bay and other areas in WA
	Mulders YR, Wernberg T (2020) Fifteen years in a global warming hotspot: changes in subtidal mobile invertebrate communities. Mar Ecol Prog Ser 656:227-238.	UWA (Link to report)	Jurien Bay and other areas in WA

Receptor	Existing baseline monitoring	Source / Data Custodian	Spatial extent
	Wernberg, T. (2021). Marine Heatwave Drives Collapse of Kelp Forests in Western Australia. In: Canadell, J.G., Jackson, R.B. (eds) Ecosystem Collapse and Climate Change. Ecological Studies, vol 241. Springer, Cham. https://doi.org/10.1007/978-3-030-71330-0_12	UWA	Jurien Bay and other areas in WA
	Ross, C.L.; French, B.;Lester, E.K.;Wilson, S.K.; Day, P.B.;Taylor, M.D.; Barrett, N. (2021). Coral Communities on Marginal High-Latitude Reefs in West Australian Marine Parks. Diversity, 13, 554. https://doi.org/ 10.3390/d13110554	DBCA (Link to reference)	Jurien Bay Marine Park and other areas in WA
Seabirds and shorebirds	Dunlop, J. N. & Wooller, R. D. (1990). The breeding seabirds of south-western Australia: trends in species, populations and colonies. Corella 14:107-112.	(Link to reference)	Inshore Islands from Dongara to Mandurah and other areas in WA
	Dunlop, JN. (2009) The population dynamics of tropical seabirds establishing frontier colonies on islands off south-western Australia. Marine Ornithology 37: 99-105.	(Link to reference)	North Fisherman Island, Green Islets and other areas in WA
	Harrison, S. A. (2006). The influence of seabird-derived nutrients on island ecosystems in the oligotrophic marine waters of south-western Australia. https://ro.ecu.edu.au/theses/68	Edith Cowan University (Link to reference)	Favourite Island, Boullanger Island, Whitlock Island, North and South Cervantes Island and other areas in WA
Marine mammals	Campbell, R. 2005. Historical distribution and abundance of the Australian sea lion (*Neophoca cinerea*) on the west coast of Western Australia, Fisheries Research Report No. 148, Department of Fisheries, Western Australia, 42 p	Department of Fisheries (Link to reference)	Jurien Bay (North Fisherman Island, Beagle Island, Buller Island) and other locations in WA
	Möller, L.M., Attard, C.R.M., Bilgmann, K. et al. (2020) Movements and behaviour of blue whales satellite tagged in an Australian upwelling system. Sci Rep 10, 21165. https://doi.org/10.1038/s41598-020-78143-2	Flinders University (Link to reference)	WA coastline
	Goldsworthy, S. D. , Shaughnessy, P. D., Mackay, A. I., Bailleul, F., Holman, D., Lowther, A. D., Page, B., Waples, K., Raudino, H., Bryars, S., Anderson, T. (2021). Assessment of the status and trends in abundance of a coastal pinniped, the Australian seal lion *Neophoca cinerea*. Endangered Species Research, 44: 421-437.	Goldsworth, S. D, University of Adelaide (Link to reference)	Jurien Bay (North Fisherman Island, Beagle Island, Buller Island) and other locations in WA and SA
Commercial fisheries	Caputi N, Kangas M, Chandrapavan A, Hart A, Feng M, Marin M and de Lestang S (2019) Factors Affecting the Recovery of Invertebrate Stocks From the 2011 Western Australian Extreme Marine Heatwave. Front. Mar. Sci. 6:484. doi: 10.3389/fmars.2019.00484	DPIRD (Link to reference)	Jurien region and others

Receptor	Existing baseline monitoring	Source / Data Custodian	Spatial extent
	Commercial Fisheries data collected by WA Department of Fisheries (WA DoF) and Australian Fishing Management Authority (AFMA)	WA Department of Fisheries / Australian Fishing Management Authority	Australia wide

Appendix B Protected Matters in the EMBA

Receptor	Recovery plan / wildlife conservation plan / conservation advice / management plan (date issued)	Relevant threats and conservation actions	Relevant OMPs and SMPs	Relevant priority monitoring locations (quickest modelled time to contact[3])
***Mammals* (refer to Section 4 of EP for additional description of key receptors)**				
Southern right whale	Draft National Recovery Plan for the Southern Right Whale (*Eubalaena australis*) (DCCEEW, 2022)	• Relevant threats: anthropogenic underwater noise, vessel collision • Relevant management actions: Minimise vessel strike and assess and address anthropogenic noise.	• OMP: Marine fauna assessment – Cetaceans • SMP: Marine mega-fauna assessment – Whale sharks, dugongs and cetaceans	• 0.04 days to migration BIA
Sei whale	Approved Conservation Advice *Balaenoptera borealis* (sei whale) (TSSC, 2015a)	• Relevant threats: pollution, vessel disturbance • Relevant management actions: report vessel strikes		-
Humpback whale	Approved Conservation Advice for *Megaptera novaeangliae* (humpback whale) (TSSC, 2015b)	• Relevant threats: habitat degradation, vessel disturbance or strike. • Relevant management actions: Minimise vessel collisions.		• 0.04 days to migration BIA
Blue whale	Conservation Management Plan for the Blue Whale 2015 to 2025 (DoE, 2015a)	• Relevant threats: habitat degradation, vessel disturbance or strike. • Relevant management actions: Minimise vessel collisions and report vessel strikes		• 5.2 days to foraging IA

[3] Unless otherwise noted, all results are entrained hydrocarbon timeframes to contact.

Receptor	Recovery plan / wildlife conservation plan / conservation advice / management plan (date issued)	Relevant threats and conservation actions	Relevant OMPs and SMPs	Relevant priority monitoring locations (quickest modelled time to contact[3])
Australian Sea Lion	Recovery Plan for the Australian Sea Lion (*Neophoca cinerea*) (DSEWPC, 2013a)	• Relevant threats: habitat degradation, boating activities and aircraft can cause disturbance, human presence at sensitive sites • Relevant management actions: mitigation to prevent undue disturbance	• OMP: marine fauna assessment - Pinnipeds	• Illawong – Cliff Head (Australian sea lion breeding on East Beagle Island): 0.1 days • Green Head – Leeman (Australian sea lion breeding on North Fisherman Island): 1.5 days • Thirsty Point – Booker Valley (Australian sea lion breeding on Buller Island) • 0.4 days to Foraging areas
Reptiles **(refer to Section 4 of EP for additional description of key receptors)**				
Loggerhead turtle, green turtle, leatherback turtle, hawksbill turtle, flatback turtle	Recovery Plan for Marine Turtles in Australia (DoEE, 2017)	• Relevant threats: chemical and terrestrial discharge, light pollution, vessel disturbance, habitat modification • Relevant management actions from recovery plan: **Chemical and terrestrial discharge**	• OMP: Marine fauna assessment – Reptiles • SMP: Marine mega-fauna assessment – Reptiles	N/A (presence associated with foraging [no breeding sites])

Receptor	Recovery plan / wildlife conservation plan / conservation advice / management plan (date issued)	Relevant threats and conservation actions	Relevant OMPs and SMPs	Relevant priority monitoring locations (quickest modelled time to contact[3])
		– 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. – Quantify the impacts of decreased water quality on stock viability. – Quantify the accumulation and effects of anthropogenic toxins in marine turtles, their foraging habitats and subsequent stock viability.		
Sharks and rays **(refer to Section 4 of EP for additional description of key receptors)**				
White shark	Recovery Plan for the White Shark (*Carcharodon carcharias*) (DSEWPC, 2013b)	• Relevant threats: habitat modification. • Relevant management objectives: Continue to identify and protect habitat critical to the survival of the white shark and minimise the impact of threatening processes within these areas	• OMP: Marine fauna assessment – Fish • SMP: Marine mega-fauna assessment – Marine fish and elasmobranch assemblages assessment	• 0.04 day to foraging BIA
Scalloped hammerhead	No recovery plan in place	-		-
Grey nurse shark	Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (DoE, 2014)	• Relevant threats: pollution		-

Receptor	Recovery plan / wildlife conservation plan / conservation advice / management plan (date issued)	Relevant threats and conservation actions	Relevant OMPs and SMPs	Relevant priority monitoring locations (quickest modelled time to contact[3])
***Seabirds and Migratory Shorebirds* (refer to Section 4 of EP for additional description of key receptors)**				
Marine and migratory seabirds	Wildlife Conservation Plan for Seabirds (DoE, 2020)	• Relevant threat/s: shipping, marine debris, light pollution	• OMP: Shoreline clean-up assessment • OMP: Marine fauna assessment – Seabirds and shorebirds • SMP: Seabirds and shorebirds	-
Red knot, knot	Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015b) Approved Conservation Advice for *Calidris canutus* (red knot) (TSSC, 2016)	• Relevant threat/s: damage to nesting habitat, pollution • Relevant management actions: manage disturbance at important sites which are subject to anthropogenic disturbance when red knot are present – e.g. discourage or prohibit vehicle access, implement temporary site closures	• OMP: Shoreline clean-up assessment • OMP: Marine fauna assessment – Seabirds and shorebirds • SMP: Seabirds and shorebirds	-
Great knot	Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015b)	• Relevant threats: habitat modification, acute pollution, anthropogenic disturbance • No relevant management actions identified		-
Northern Siberian bar-tailed godwit, Russkoye bar-tailed godwit	Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015b)	• Relevant threats: habitat modification, acute pollution, anthropogenic disturbance • No relevant management actions identified		-
Curlew Sandpiper	-	-		-

Receptor	Recovery plan / wildlife conservation plan / conservation advice / management plan (date issued)	Relevant threats and conservation actions	Relevant OMPs and SMPs	Relevant priority monitoring locations (quickest modelled time to contact[3])
Lesser sand plover	Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015b)	• Relevant threats: habitat modification, acute pollution, anthropogenic disturbance • No relevant management actions identified		-
Australian lesser noddy	-	-		• 7.3 days to foraging BIA
Great sand plover	Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015b)	• Relevant threats: habitat modification, acute pollution, anthropogenic disturbance • No relevant management actions identified		-
Australian fairy tern	National Recovery Plan for the Australian fairy tern (*Sternula nereis nereis*) (Commonwealth of Australia, 2020)	• Relevant threats: habitat degradation and loss of breeding habitat, disturbance • Relevant management actions: reduce, or eliminate threats at breeding, non-breeding and foraging sites		• 1.5 days Jurien Bay Marine Park (breeding known to occur) • 0.4 days to foraging BIA
Threatened Ecological Communities **(refer to Section 4 of EP for additional description of key receptors for each location)**				
Sedgelands in Holocene dune swales of the southern Swan Coastal Plain	Sedgelands in Holocene Dune Swales Recovery Plan, (DEC, 2011)	• Relevant threats : Clearing (shoreline clean-up and/or shoreline based monitoring activities) • Relevant management actions: Protect and conserve remaining areas of the ecological community	• OMP: Shoreline clean-up assessment • SMP: Intertidal and Coastal Habitat Assessment	-

Receptor	Recovery plan / wildlife conservation plan / conservation advice / management plan (date issued)	Relevant threats and conservation actions	Relevant OMPs and SMPs	Relevant priority monitoring locations (quickest modelled time to contact[3])
Australian Marine Parks **(refer to Section 4 of EP for additional description of key receptors for each location)**				
Abrolhos MP	South-west Marine Parks Network Management Plan 2018 (Director of National Parks, 2018)	• Relevant management actions: Park protection and management—timely and appropriate preventative and restorative actions to protect natural, cultural and heritage values from impacts	• OMP: Water quality assessment • OMP: Sediment quality assessment • OMP: Marine fauna assessment – Seabirds and shorebirds • Cetaceans • Pinnipeds • OMP: Marine fauna assessment - fish • SMP: Water quality impact assessment • SMP: Sediment quality impact assessment • SMP: Seabirds and shorebirds • SMP: Marine mega-fauna assessment – Whale sharks, cetaceans and dugongs Pinnipeds • SMP: Benthic habitat assessment • SMP: Marine fish and elasmobranch	• 3.8 days
Perth Canyon MP				• 12.0 days
Two Rocks MP				• 11.9 days
Jurien MP				• 1.8 days
South-west Corner MP				• 27.8 days

Receptor	Recovery plan / wildlife conservation plan / conservation advice / management plan (date issued)	Relevant threats and conservation actions	Relevant OMPs and SMPs	Relevant priority monitoring locations (quickest modelled time to contact[3])
			assemblages assessment • SMP: Commercial and recreational fisheries impact assessment • SMP: Heritage and social impact assessment	
Western Australian Marine Parks **(refer to Section 4 of EP for additional description of key receptors for each location)**				
Essex Rocks Nature Reserve[4]	Jurien Bay Marine Park Management Plan 2005-2015 No. 49 (CALM, 2005)	• Relevant management issues: oil spills, damage to seagrass habitats by indiscriminate mooring and anchoring • Relevant management actions: ensure the values of the park are fed into predictive models for oil spills, apply appropriate anchoring controls	• OMP: Water quality assessment • OMP: Sediment quality assessment • OMP: Shoreline clean-up assessment • OMP: Marine fauna assessment – Seabirds and shorebirds Cetaceans Pinnipeds • OMP: Marine fauna assessment - fish • SMP: Water quality impact assessment	-
Buller, Whittell and Green Islands Nature Reserve[5]	Jurien Bay Marine Park Management Plan 2005-2015 No. 49 (CALM, 2005)	• Relevant management issues: oil spills, damage to seagrass habitats by indiscriminate mooring and anchoring • Relevant management actions: ensure the values of the park are fed into predictive models for oil spills, apply appropriate anchoring controls		-

[4] Within Jurien Bay Marine Park
[5] Within Jurien Bay Marine Park

Receptor	Recovery plan / wildlife conservation plan / conservation advice / management plan (date issued)	Relevant threats and conservation actions	Relevant OMPs and SMPs	Relevant priority monitoring locations (quickest modelled time to contact[3])
Abrolhos Islands Fish Habitat Protection	N/A	-	• SMP: Sediment quality impact assessment • SMP: Intertidal and Coastal Habitat Assessment • SMP: Seabirds and shorebirds • SMP: Marine mega-fauna assessment – Whale sharks, cetaceans and dugongs Pinnipeds • SMP: Benthic habitat assessment • SMP: Marine fish and elasmobranch assemblages assessment • SMP: Commercial and recreational fisheries impact assessment • SMP: Heritage and social impact assessment	-
Cervantes Islands Nature Reserve[6]	Jurien Bay Marine Park Management Plan 2005-2015 No. 49 (CALM, 2005)	• Relevant management issues: oil spills, damage to seagrass habitats by indiscriminate mooring and anchoring • Relevant management actions: ensure the values of the park are fed into predictive models for oil spills, apply appropriate anchoring controls		-
Jurien Bay Marine Park	Jurien Bay Marine Park Management Plan 2005-2015 No. 49 (CALM, 2005)	• Relevant management issues: oil spills, damage to seagrass habitats by indiscriminate mooring and anchoring • Relevant management actions: ensure the values of the park are fed into predictive models for oil spills, apply appropriate anchoring controls		• 1.5 days
Beagle Islands Nature Reserve	N/A	-		• 0.5 days
Marmion Marine Park	Marmion Marine Park Management Plan 1992-2002 No. 23 (CALM, 1992)	• Relevant management issues: oil spills, damage to reef habitats by indiscriminate mooring and anchoring • Relevant management actions: ensure the values of the park are fed into predictive models		• 20.0 days

[6] Within Jurien Bay Marine Park

Receptor	Recovery plan / wildlife conservation plan / conservation advice / management plan (date issued)	Relevant threats and conservation actions	Relevant OMPs and SMPs	Relevant priority monitoring locations (quickest modelled time to contact[3])
		for oil spills, apply appropriate anchoring controls		
Lancelin Island Lagoon Fish Habitat Protection	N/A	-		-
Lipfert, Milligan, Etc Islands Nature Reserve[7]	Jurien Bay Marine Park Management Plan 2005-2015 No. 49 (CALM, 2005)	• Relevant management issues: oil spills, damage to seagrass habitats by indiscriminate mooring and anchoring • Relevant management actions: ensure the values of the park are fed into predictive models for oil spills, apply appropriate anchoring controls		-
Sandland Island Nature Reserve[8]	Jurien Bay Marine Park Management Plan 2005-2015 No. 49 (CALM, 2005)	• Relevant management issues: oil spills, damage to seagrass habitats by indiscriminate mooring and anchoring • Relevant management actions: ensure the values of the park are fed into predictive models for oil spills, apply appropriate anchoring controls		-
Ronsard Rocks Nature Reserve[9]	Jurien Bay Marine Park Management Plan 2005-2015 No. 49 (CALM, 2005)	• Relevant management issues: oil spills, damage to seagrass habitats by indiscriminate mooring and anchoring		-

[7] Within Jurien Bay Marine Park

[8] Within Jurien Bay Marine Park

[9] Within Jurien Bay Marine Park

Receptor	Recovery plan / wildlife conservation plan / conservation advice / management plan (date issued)	Relevant threats and conservation actions	Relevant OMPs and SMPs	Relevant priority monitoring locations (quickest modelled time to contact[3])
		• Relevant management actions: ensure the values of the park are fed into predictive models for oil spills, apply appropriate anchoring controls		
Outer Rocks Nature Reserve	N/A	-		-
Fisherman Islands Nature Reserve[10]	Jurien Bay Marine Park Management Plan 2005-2015 No. 49 (CALM, 2005)	• Relevant management issues: oil spills, damage to seagrass habitats by indiscriminate mooring and anchoring • Relevant management actions: ensure the values of the park are fed into predictive models for oil spills, apply appropriate anchoring controls		-
Commonwealth Heritage Places **(refer to Section XX of EP for additional description of key receptors for each location)**				
Lancelin Defence Training Area	N/A	-	• OMP: Water quality assessment • OMP: Sediment quality assessment • MP: Water quality impact assessment • SMP: Sediment quality impact assessment	-

[10] Within Jurien Bay Marine Park

Receptor	Recovery plan / wildlife conservation plan / conservation advice / management plan (date issued)	Relevant threats and conservation actions	Relevant OMPs and SMPs	Relevant priority monitoring locations (quickest modelled time to contact[3])
National Heritage Places **(refer to Section XX of EP for additional description of key receptors for each location)**				
Batavia Shipwreck Site	N/A	-	• OMP: Water quality assessment • OMP: Sediment quality assessment • SMP: Water quality impact assessment • SMP: Sediment quality impact assessment • SMP: Heritage and social impact assessment • SMP: Benthic habitat assessment	-

APPENDIX G: UNDERWATER SOUND MODELLING

Eureka 3D Marine Seismic Survey

Acoustic Modelling for Assessing Marine Fauna Sound Exposures

JASCO Applied Sciences (Australia) Pty Ltd

3 May 2023

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Authors:

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Contents

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Executive Summary

JASCO Applied Sciences (JASCO) performed numerical modelling to derive underwater sound levels for the proposed Eureka 3D Marine Seismic Survey (MSS) to predict the potential impacts on key regional receptors including marine mammals, fish, turtles, benthic invertebrates, sponges, coral, and plankton. JASCO's specialised Airgun Array Source Model (AASM) was used along with complementary underwater acoustic propagation models to estimate sound levels at six sites, to account for variable coastal features and water depth.

The modelling considered source directivity and range-dependent environmental properties likely to be encountered within the survey area. Estimated 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 or accumulated sound exposure levels (SEL, L_E) as appropriate for different noise effect criteria.

For the accumulated sound exposure scenarios, the SEL_{24h} is a cumulative metric that reflects the dosimetric effect of noise levels within 24 hours. It assumes a receiver (e.g., an animal) is consistently exposed to the noise at a fixed position. More realistically, marine animals would not stay in the same location for 24 hours. Therefore, a radius for the SEL_{24h} criteria does not mean that marine fauna within this radius will be impaired, but rather that the animal could be exposed to the sound level associated with impairment, either Permanent Threshold Shift (PTS) or Temporary Threshold Shift (TTS), if it remained at that location for 24 hours.

Marine mammals – Results

- Maximum distance for behavioural response based on NOAA (2019) criterion of 160 dB re 1 µPa (SPL) varied between 9.20 and 6.51 km depending on the site.
- The results for marine mammal injury considered the criteria from Southall et al. (2019). 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.

Table 1. Maximum horizontal distance (R_{max}) for behavioural response thresholds, permanent threshold shift (PTS) and temporary threshold shift (TTS) for marine mammals. Maximum extents are in the broadside direction.

Hearing group	Maximum modelled distance to effect threshold (R_{max})		
	Behavioural response[1]	Impairment (km): PTS[2]	Impairment (km): TTS[2]
LF cetaceans (Baleen whales)	9.20	3.08 (SEL_{24h})	43.0 (SEL_{24h})
HF cetaceans (Dolphins, plus toothed, beaked, and bottlenose whales)		–	–
VHF cetaceans (*Kogia*, cephalorhynchid, and *L. australis*)		0.41 (PK)	0.84 (PK)
Other Carnivores in Water (Australian sea lion, Australian fur seal)		–	0.06

Noise exposure criteria: [1] NOAA (2019) and [2] Southall et al. (2019).
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Sea turtles

- The PK sea turtle impairment criteria from Finneran et al. (2017) were not exceeded beyond the modelled resolution of 20 m.

- The maximum distance for PTS onset was 0.06 and 2.10 km for TTS onset for the seismic source (Finneran et al. 2017).
- Behavioural response of turtles are shown in Table 2, based on 166 dB re 1 µPa and 175 dB re 1 µPa (SPL) (McCauley et al. 2000).

Table 2. Maximum horizontal distance (in km) to turtle behavioural response criteria, temporary threshold shift (TTS), and permanent threshold shift (PTS).

Hearing group	Maximum modelled distance (in km) to effect threshold (R_{max})			
	Behavioural response[1]	Behavioural disturbance[1]	Impairment: TTS[2]	Impairment: PTS[2]
Sea turtles	4.90 (166 dB re 1 µPa - SPL)	1.58 (175 dB re 1 µPa - SPL)	2.10 (SEL_{24h})	0.06 (SEL_{24h})

Noise exposure criteria: [1] McCauley et al. (2000) and [2] 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 (water column) 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 nine different depths within the survey area. Assessment was based on Popper et al. (2014) and considered both PK (seafloor and water column) and SEL_{24h} metrics (water column) associated with mortality, potential mortal injury and impairment.

Table 3. Maximum onset distances for single impulse and 24 hour sound exposure level (SEL_{24h}) for fish, fish eggs, and larvae injury and temporary threshold shift (TTS).

Relevant hearing group	Effect criteria	Metric associated with longest distance to criteria	R_{max} (km)
Fish: No swim bladder	Recoverable injury	PK	0.15
	TTS	SEL_{24h}	4.06
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing	Recoverable injury	PK	0.27
	TTS	SEL_{24h}	4.06
Fish eggs, and larvae (relevant to plankton)	Injury	PK	0.27

Benthic invertebrates, Cephalopods, Sponges, and Coral

To assist with assessing the potential effects on these receptors, the following results were determined:

- Crustaceans (representative of southern rock lobsters and crabs): The distance to no effect was reached between 206 and 292 m, based on 202 dB re 1 µPa PK-PK level from Payne et al. (2008).

- Bivalves (representative of scallops and mussels): The distance to no effect was reached between 58 and 7 m, based on a particle acceleration limit of 37.57 ms^{-2} at the seafloor as presented in Day et al. (2016a).
- Squid: The distance to the per–pulse SEL (L_E) startle (inking) response level of 162 dB re 1 $\mu Pa^2 s$ for squid (Fewtrell and McCauley 2012) was reached between 2.90 and 2.03 km.
- Sponges and coral: The threshold was reached at a maximum of 15 m, based on the PK sound level criteria of 226 dB re 1 µPa PK for sponges and corals (Heyward et al. 2018).

Divers

An SPL human health assessment of 145 dB re 1 µPa (SPL; L_p) derived from Parvin (2005) was considered for people swimming and diving. The sound level was reached at ranges between 36.4 and 24.1 km depending on the modelled site. This is the maximum range over all modelled azimuths, and it is typically in orientated offshore. This maximum range should not be used as an offset distance to the coast and the sound field contour maps should be used to inform any such offset.

1. Introduction

JASCO Applied Sciences (JASCO) performed numerical modelling to calculate underwater sound levels for the proposed Eureka 3D Marine Seismic Survey (MSS) to predict the potential impacts on key regional receptors including marine mammals, fish, turtles, benthic invertebrates, sponges, coral, and plankton. In total, six sites were used for modelling across the proposed survey area to account for variable coastal features and for small changes in sound propagation that could occur in the shallow coastal waters.

JASCO's specialised Airgun Array Source Model (AASM) was used to predict acoustic signatures and spectra for the source. 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 selected array signature to estimate sound levels considering environmental effects. Single-impulse sound fields were predicted at each of the defined locations, and accumulated sound exposure fields were predicted for each scenario. A worst-case sound speed profile that would be most supportive of sound propagation conditions for the potential survey period was defined and applied throughout.

The modelling 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; $L_{pk\text{-}pk}$), peak acceleration magnitude, and either single-impulse (i.e., per-pulse) or accumulated sound exposure levels (SEL, L_E) as appropriate for different noise effect criteria.

1. Modelling Scenarios

Two nominal acquisition scenarios were considered using both acoustic propagation modelling, are presented in Table 4. Acoustic source and propagation modelling was conducted at six individual single-impulse sites. The single impulse sites and the accumulated SEL scenarios were determined based on proposed survey line plans with lines orientated either at 0/180°. The locations of the modelled sites are provided in Table 5 and presented in Figure 1 . This study considered a 2495 in^3 seismic source towed in a double array configuration at an assumed speed of ~4.5 knots with an impulse interval (inter-pulse interval) of 12.5 m and a crossline array separation of 50 m. The acoustic propagation modelling utilised an August sound speed profile as this month will likely result in favourable propagation conditions within potential acquisition time periods for the proposed survey.

The single impulse sites and accumulated SEL scenarios were chosen to be representative of the range of water depths and the potential sound propagation characteristics within the Active Source Area. Seafloor sound levels were assessed at eight different representative water depths within the Active Source Area (10,12.5,15, 20, 25, 30, 40, and 50 m).

Table 4. Parameters for modelled scenarios

Scenario	Source volume (in^3)	Tow depth (m)	Tow direction (°)	Source configuration	Impulse interval (m)	Discharged impulses
1	2495	6	0 & 180	Double	12.5	11351
2						8558

Table 5. Location details for the single impulse modelled sites.

Site	Latitude (°S)	Longitude (°E)	MGA[1] Zone 50		Water depth (m)
			X (m)	Y (m)	
1	29° 28' 49.64"	114° 51' 05.04"	291676	6736859	25.0
2	29° 31' 38.47"	114° 51' 01.47"	291676	6731659	33.0
3	29° 37' 54.69"	114° 50' 53.49"	291676	6720072	30.0
4	29° 23' 08.13"	114° 40' 10.60"	273835	6747035	45.0
5	29° 30' 13.53"	114° 40' 17.24"	274276	6733941	47.0
6	29° 22' 53.53"	114° 38' 08.87"	270544	6747419	48.0

[1] Map Grid of Australia (MGA)

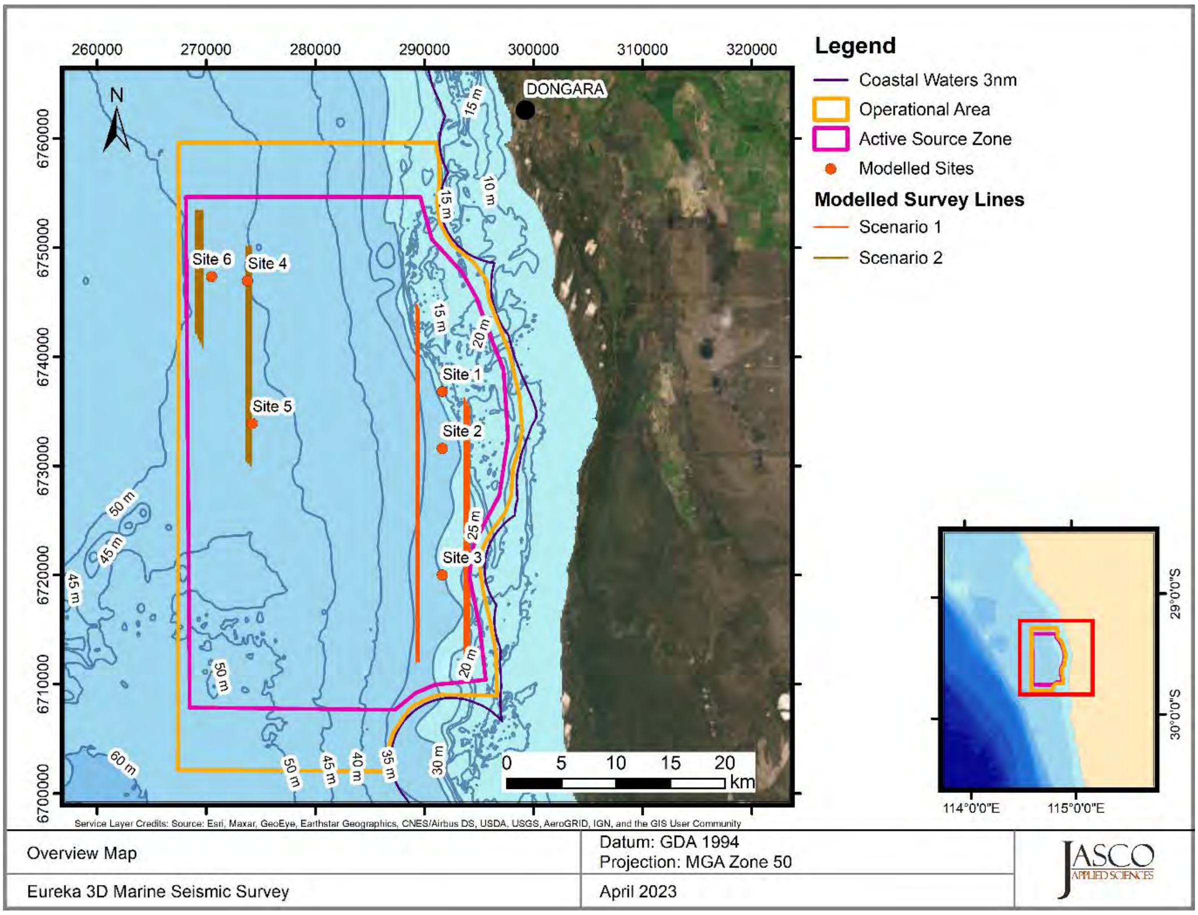


Figure 1. Overview of key survey features, modelled locations and the two survey scenarios.

2. Noise Effect Criteria

The perceived loudness of sound, especially impulsive noise such as that 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 hours. 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. (2019). 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 2.1–2.4 and Appendix A):

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 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) for impulsive noise, along with a sound level associated with behavioural disturbance 175 dB re 1 µPa (SPL; L_p) (McCauley et al. 2000).
6. Peak-peak pressure levels (PK-PK; $L_{pk\text{-}pk}$) and peak particle acceleration magnitude (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.
8. A startle (inking) response sound level of 162 dB re 1 µPa^{2}s per–pulse SEL (L_E) for squid from Fewtrell and McCauley (2012).
9. An SPL human health assessment threshold of 145 dB re 1 µPa (SPL; L_p) for sound exposure to people swimming and diving derived from Parvin (2005), and considering Ainslie (2008).

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.

2.1. 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 fatigue.

To help assess the potential for the possible injury and hearing sensitivity changes in marine mammals, this report applies the criteria recommended be Southall et al. (2019), considering both PTS and TTS. These criteria, along with the applied behavioural criteria (NOAA 2019), are summarised in Table 6, with descriptions included in Appendix A.4.1 (auditory impairment) and Appendix A.4.2 (behavioural response), with frequency weighting explained in Appendix A.5. Whilst the newly published Southall et al. (2021) includes 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 6. Unweighted sound pressure level (SPL), weighted 24-hour sound exposure level (SEL_{24h}), and peak pressure (PK) thresholds for acoustic effects on marine mammals.

Hearing group	NOAA (2019)	Southall et al. (2019)			
	Behaviour	PTS onset thresholds[1] (received level)		TTS onset thresholds[1] (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 (baleen whales)	160	183	219	168	213
High-frequency cetaceans (dolphins, plus toothed, beaked, and bottlenose whales)		185	230	170	224
Very-high-frequency cetaceans (*Kogia*, cephalorhynchid, and *L. australis*)		155	202	140	196
Pinnipeds[2] (Australian sea lion, Australian fur seal, New Zealand fur seal)		203	232	188	226

[1] Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS and TTS onset.
[2] Listed as pinnipeds but equivalent to other marine carnivores in water in the Southall et al. (2019) criteria.
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.

2.2. 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 7 for completeness only. Because the presence or absence of a swim bladder has a role in hearing, a 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 7 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.4.

Table 7. Criteria for seismic noise exposure for fish, adapted from Popper et al. (2014).

<table>
<tr><th rowspan="2">Type of animal</th><th rowspan="2">Mortality and Potential mortal injury</th><th colspan="3">Impairment</th><th rowspan="2">Behaviour</th></tr>
<tr><th>Recoverable injury</th><th>TTS</th><th>Masking</th></tr>
<tr><td>Fish:
No swim bladder (particle motion detection)</td><td>>219 dB SEL_{24h}
or
>213 dB PK</td><td>>216 dB SEL_{24h}
or
>213 dB PK</td><td>>>186 dB SEL_{24h}</td><td>(N) Low
(I) Low
(F) Low</td><td>(N) High
(I) Moderate
(F) Low</td></tr>
<tr><td>Fish:
Swim bladder not involved in hearing (particle motion detection)</td><td>210 dB SEL_{24h}
or
>207 dB PK</td><td>203 dB SEL_{24h}
or
>207 dB PK</td><td>>>186 dB SEL_{24h}</td><td>(N) Low
(I) Low
(F) Low</td><td>(N) High
(I) Moderate
(F) Low</td></tr>
<tr><td>Fish:
Swim bladder involved in hearing (primarily pressure detection)</td><td>207 dB SEL_{24h}
or
>207 dB PK</td><td>203 dB SEL_{24h}
or
>207 dB PK</td><td>186 dB SEL_{24h}</td><td>(N) Low
(I) Low
(F) Moderate</td><td>(N) High
(I) High
(F) Moderate</td></tr>
<tr><td>Fish eggs and fish larvae (relevant to plankton)</td><td>>210 dB SEL_{24h}
or
>207 dB PK</td><td>(N) Moderate
(I) Low
(F) Low</td><td>(N) Moderate
(I) Low
(F) Low</td><td>(N) Low
(I) Low
(F) Low</td><td>(N) Moderate
(I) Low
(F) Low</td></tr>
</table>

Peak sound level (PK) dB re 1 μPa; SEL_{24h} dB re 1μPa²·s. All criteria are presented as sound pressure, even for fish without swim bladders, since no data for particle motion exist. Relative risk (high, moderate, or low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

2.3. 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. (2000) 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 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 (McCauley et al. 2000) as the level that may result in a behavioural response to marine turtles. The 175 dB re 1 µPa level from (McCauley et al. 2000) is recommended as a criterion for behavioural disturbance. These are shown in Table 8.

Table 8. 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_{E24h}; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)
Behavioural response	McCauley et al. (2000)	166	NA	
Behavioural disturbance		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.

2.4. Invertebrates

2.4.1. Benthic Invertebrates (Crustaceans and Bivalves)

Research is ongoing into the relationship between sound and its effects on crustaceans (including southern rock lobsters and crabs), including the relevant metrics for 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 (including scallops, abalone, mussels, squid, and octopus).

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 in report) 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}.

2.4.2. 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 7), 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.

2.4.3. Squid

The responses of squid to airgun signals were investigated by Fewtrell and McCauley (2012). The authors conducted a number of experiments and examined the received per–pulse SEL for caged squid. They found that in one trial, where the received level of the first airgun impulse was 162 dB re 1 $\mu Pa^2 \cdot s$, the squid inked. This response was not observed again within this trial, however the authors stated that it was unknown if this was due to depleted ink reserves or habituation. In two other trials, the initial received levels were lower (132 and 146 dB re 1 $\mu Pa^2 \cdot s$ per–pulse SEL), and although the cumulative received levels did exceed 162 dB re 1 $\mu Pa^2 s$, no inking behaviour was observed. The authors hypothesised that the results also suggest that a gradual increase in received levels and prior exposure to air gun impulses decreases the severity of the alarm responses in this species. This aligns with findings of general habituation in response to predators in squid (Long et al. 1989). Recent work (Jones et al. 2020) supports these findings as well, indicating potential rapid, short–term habituation by squid to impulsive noise, however, similar response rates were seen 24 h later, which indicated that squid might re–sensitise to the noise.

The results presented in by Fewtrell and McCauley (2012) were stated by the authors to be preliminary, and while they stated that while it is possible that noise levels greater than 147 dB re 1 µPa²·s are required to induce avoidance behaviour, the level associated with inking, of 162 dB re 1 µPa²·s per–pulse SEL, has been considered as a startle response level for squid. In the absence of additional studies and thresholds this level may be considered for other cephalopods; however, it may be limited when applied to other species.

2.5. Human Health Assessment Threshold

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

The auditory threshold of hearing under water was lowest at 1 kHz (70 dB re 1 µPa SPL) and increased for lower and higher frequencies to around 120 dB re 1 µPa at 20 Hz and at 20 kHz (Parvin 1998). Fothergill et al. (2000) and Fothergill et al. (2001) conducted controlled acoustic exposure experiments on military divers under fully controlled conditions at a US Ocean Simulation Facility and an US Open water test facility; in all tests, the diver were covered with soft or hard shell dive suits and their position and distance relative to sound source, signal characteristics and received levels were controlled and documented (Pestorius et al. 2009). A total of 89 male Navy divers were exposed to pure tone signals and sweeps between 160–320 Hz at SPLs up to 160 dB re 1 µPa. The divers were exposed to these sounds over 100 seconds at depths from 10 to 40 metres. The divers rated the sounds on a severity scale. For frequencies between 100 and 500 Hz, at a received SPL of 130 dB re 1 µPa, divers and swimmers detected body vibration. None of the divers tested rated levels of 140 dB re 1 µPa as “very severe”; however, at 157 dB re 1 µPa, sound was rated as “very severe” 19 % of the time. No physiological damage was observed at the highest levels tested: 160 dB re 1 µPa (Fothergill et al. 2001). In a subsequent study, recreational divers were exposed to tonal signals or 30 Hz sweeps at frequencies between 100 and 500 Hz at received levels of 130–157 dB re 1 µPa (Pestorius et al. 2009). Each exposure lasted for 7 s. Nine female and 17 male scuba divers were tested, all wearing full body neoprene wetsuits. Diver aversion and perception of body vibration were used as test parameters. The results showed no sex–specific differences. The results differed as a function of frequency – while test results showed a strong overall variation between subjects, signals at 100 Hz elicited the strongest aversion in all tests and even at 148 dB a few diver ratings indicated extreme aversion. Due to this and the strong variation between test subjects, the following exposure limit for both military and recreational divers was suggested as a conservative measure: For frequencies between 100 and 500 Hz, the maximum SPL should be 145 dB re 1 µPa over a maximum continuous exposure of 100 seconds or with a maximum duty cycle of 20 % and a maximum daily cumulative total of 3 h. The trading relation between the maximum SPL and duration was 4 dB per doubling of duration (e.g., 141 dB SPL for a 200 second exposure) (Pestorius et al. 2009).

Considering only frequencies between 100 and 500 Hz, Parvin (2005) suggested 145 dB re 1 µPa as a safety criterion for recreational divers and swimmers. Seismic impulses are broadband sources, and therefore, to be precautionary, the 145 dB re 1 μPa SPL suggested by Fothergill et al. (2001) and Parvin (2005) has been applied in this study as a broadband SPL and as a human health assessment threshold for recreational divers and swimmers. This does not imply that this level is associated with the onset of injury.

3. Methods

3.1. Parameter Overview

The specifications of the seismic source and the environmental parameters used in the propagation models are described in detail in Appendix D. A single sound speed profile for August was considered in this modelling study; this was identified as the seasonal period that would provide the farthest propagation (Appendix D.3.2); as such it was selected to as part of a conservative approach to estimating distances to received sound level thresholds.

The propagation models used in this study consider a single geoacoustic profile. Several papers describe potential geoacoustic models estimated via acoustic inversion (Duncan et al. 2008, Fan et al. 2009). These models consist of a thin sand layer underlain by a semi-cemented limestone/calcarenite bottom. A nominal three layer representation of the seabed has been proposed based on this information; however, the studies all give slightly different geoacoustic values and layer thicknesses. The seabed model consists of sand/calcarenite/limestone basement where the geoacoustic parameters were averaged to obtain representative geoacoustic values.

3.2. 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 2495 in^3 seismic source was modelled with JASCO's Airgun Array Source Model (AASM). Although AASM accounts for notional pressure signatures of each seismic source with respect to the effects of surface-reflected signals on bubble oscillations and inter-bubble interactions, the surface-reflected signal (known as surface ghost) is not included in the far-field source signatures. The acoustic propagation models account for those surface reflections, which are a property of the propagating medium rather than the source.

AASM considers:

- Array layout.
- Volume, tow depth, and firing pressure of each airgun.
- Interactions between different airguns in the array.

All seismic sources considered were modelled over AASM's full frequency range, up to 25 kHz. Appendix B.1 details this model.

3.3. Sound Propagation Models

Three sound propagation models were used to predict the acoustic field around the seismic source:

- Combined range-dependent parabolic equation and Gaussian beam acoustic ray-trace model (MONM-BELLHOP, 10 Hz to 25 kHz).
- Full Waveform Range-dependent Acoustic Model (FWRAM, 10 to 1024 Hz).
- Wavenumber integration model (VSTACK, 10 to 1024 Hz).

The models were used in combination to characterise the acoustic fields at short and long ranges in terms of SEL, SPL, PK, and PK-PK. Appendix C details each model. MONM-BELLHOP was used to calculate SEL of a 360° area around each source location. FWRAM was used to model synthetic seismic pulses and to generate a generalised range-dependent SEL to SPL conversion function. 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 at 15, 20, 25, 30, 40, and 50 m water depths.

3.4. Geometry and Modelled Regions

To assess sound levels with MONM-BELLHOP, the sound field modelling calculated propagation losses up to distances of 80 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 80 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.

3.5. Accumulated SEL

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 (Section 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 impulses, it becomes computationally prohibitive to perform sound propagation modelling for every single event. The distance between the consecutive seismic impulses is small enough, such that the environmental parameters that influence sound propagation are virtually the same for many impulse points. The acoustic fields can, therefore, be modelled for a subset of seismic pulses and estimated at several adjacent ones. After sound fields from representative impulse locations are calculated, they are adjusted to account for the source position for nearby impulses.

Although estimating the cumulative sound field with the described approach is not as precise as modelling sound propagation at every impulse location, small-scale, site-specific sound propagation features tend to blur and become less relevant when sound fields from adjacent impulses are summed. Larger scale sound propagation features, primarily dependent on water depth, dominate the cumulative field. The accuracy of the present method acceptably reflects those large-scale features, thus providing a meaningful estimate of a wide area SEL field in a computationally feasible framework.

To produce the map of accumulated received sound level distributions and calculate distances to specified sound level thresholds, the maximum-over-depth were 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 (see 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. Results

4.1. Acoustic Source Levels and Directivity

AASM (Section 3.2) was used to predict the horizontal and vertical overpressure signatures and corresponding power spectrum levels for the 2495 in^3 source array (Table 9), with additional results provided in Appendix B.3 along with the horizontal directivity plots for this source.

Table 9. Far-field source levels for 2495 in^3 source at 2 m depth. Source levels are for a point-like acoustic source with equivalent far-field acoustic output in the specified direction. Sound level metrics are per-pulse and unweighted.

Direction	Peak source pressure level ($L_{S,pk}$; dB re 1 µPa m)	Per-pulse source SEL ($L_{S,E}$; dB 1 µPa^{2}m^{2}s)	
		10–2000 Hz	2000–25000 Hz
Broadside	249.2	224.5	184.0
Endfire	245.3	222.4	187.3
Vertical	255.2	228.0	194.6
Vertical (surface affected source level)	255.2	230.5	197.6

4.2. 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.
- 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).
- 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).
- Per-pulse SEL sound fields to determine the distances to the level associated with squid startle (inking) response (Fewtrell and McCauley 2012).
- 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)
- PK metrics at the seafloor are relevant to guidelines for fish, fish eggs and larvae 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.

The maximum and 95% distances to per-pulse SEL and SPL metrics are presented in Tables 10 and 18. The SPL sound fields, and distances to relevant isopleths can be visualised on the contour maps presented in Figures 2–7. The SPL sound fields are also presented as vertical slices for selected azimuths along the endfire and broadside directions out to 20 km, with the airgun array in the centre (Figures 8–11).

Maximum distances to maximum-over-depth water column PK thresholds were calculated for three modelled single impulse sites, Sites 1, 4, and 6, and presented in Table 12. Seafloor sound levels were assessed at eight different representative depths and Tables 13–14 present the PK and PK-PK results. At these eight depths particle motion was also calculated.

4.2.1. Tabulated Results

4.2.1.1. Entire Water Column

Table 10. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the seismic source to modelled maximum-over-depth (also maximised over tow modelled tow direction) 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 (25 m)		Site 2 (33 m)		Site 3 (30 m)		Site 4 (45 m)		Site 5 (47 m)		Site 6 (48 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	0.08	0.07	0.07	0.06	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06
180	0.30	0.26	0.30	0.26	0.30	0.26	0.28	0.22	0.30	0.23	0.26	0.23
170	1.10	0.87	1.20	0.95	1.22	1.00	1.14	0.91	1.06	0.92	1.12	0.92
162[1]	2.80	2.18	2.66	2.03	2.56	2.03	2.90	2.36	2.62	2.09	2.58	2.06
160[2]	3.38	2.70	3.24	2.44	3.20	2.38	3.38	2.80	3.22	2.54	3.20	2.52
150	7.70	6.21	8.12	6.72	8.31	6.74	9.52	7.44	8.08	6.28	8.21	6.27
140	19.2	14.9	17.8	14.6	19.1	15.7	22.9	17.7	23.8	19.0	23.2	18.7
130	54.4	48.4	49.6	40.9	51.2	43.2	48.0	36.8	46.9	40.7	49.7	41.5
120	73.1	61.0	98.6	62.4	75.8	61.6	82.4	65.8	99.2	72.9	99.4	69.7

[1] Startle response level for squid (Fewtrell and McCauley 2012).
[2] Low power zone assessment criteria DEWHA (2008).

Table 11. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the seismic source to modelled maximum-over-depth (also maximised over tow modelled tow direction) 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 (25 m)		Site 2 (33 m)		Site 3 (30 m)		Site 4 (45 m)		Site 5 (47 m)		Site 6 (48 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.06	0.06	0.06	0.06
190	0.28	0.23	0.26	0.22	0.26	0.22	0.22	0.20	0.24	0.20	0.24	0.20
180	0.90	0.76	0.90	0.76	0.94	0.78	0.86	0.68	0.80	0.70	0.82	0.68
175[1]	1.52	1.19	1.56	1.24	1.58	1.25	1.28	1.03	1.26	1.06	1.28	1.01
170	2.86	2.30	2.72	2.17	2.74	2.16	2.18	1.70	2.02	1.64	2.00	1.59
166[2]	4.90	4.02	4.26	3.22	4.14	3.14	3.78	3.07	3.50	2.71	3.34	2.63
160[3]	9.20	7.68	7.64	6.32	7.65	6.32	8.04	6.54	6.51	5.10	6.58	5.05
150	19.9	16.6	16.7	13.6	17.7	14.6	20.7	16.2	20.7	16.0	20.5	16.4
145[4]	30.0	25.0	24.1	19.2	27.9	22.1	29.8	23.8	36.4	31.2	35.4	29.7
140	53.6	45.1	41.1	33.1	48.3	39.9	46.5	33.3	44.8	40.1	47.9	40.8
130	98.4	65.2	70.8	60.0	70.6	58.2	72.9	58.5	98.7	61.7	99.0	62.1

[1] Threshold for turtle behavioural disturbance from impulsive noise.
[2] Threshold for turtle behavioural response to impulsive noise (NSF 2011).
[3] Marine mammal behavioural threshold for impulsive sound sources (NOAA 2019).
[4] Human health assessment threshold derived from (Parvin 2005).

Table 12. Maximum (R_{max}) horizontal distances (in km) from the seismic source to modelled maximum-over-depth (also maximised over tow modelled tow direction) peak pressure level (PK) thresholds based on Southall et al. (2019) for marine mammals, and Popper et al. (2014) for fish and Finneran et al. (2017) for sea turtles, Sites 3 and 5), with water depth indicated.

Hearing group	PK threshold (L_{pk}; dB re 1 µPa)	Distance R_{max} (km)	
		Site 4 (30 m)	Site 6 (47 m)
Low-frequency cetaceans (PTS)	219	0.06	0.04
Low-frequency cetaceans (TTS)	213	0.15	0.11
High-frequency cetaceans (PTS)	230	–	–
High-frequency cetaceans (TTS)	224	–	–
Very-high-frequency cetaceans (PTS)	202	0.41	0.39
Very-high-frequency cetaceans (TTS)	196	0.84	0.76
Other Carnivores in Water (PTS)	232	–	–
Other Carnivores in Water (TTS)	226	–	–
Sea Turtles (PTS)	232	–	–
Sea Turtles (TTS)	226	–	–
Fish: No swim bladder (also applied to sharks)	213	0.15	0.11
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae	207	0.27	0.24

A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).

4.2.1.2. Seafloor

Ranges presented at the seafloor (50 and 5 cm above the interface) provided in Tables 13 and 14 are different to those for the maximum-over-depth modelling results presented in Table 12. 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 13. 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 three water depths within the Operational Area.

Hearing group/animal type	PK threshold (L_{pk}; dB re 1 µPa)	Water Depth							
		10 m	12.5 m	15 m	20 m	25 m	30 m	40 m	50 m
		Distance R_{max} (m)							
Sound levels for sponges and corals[1]	226	6	7	9	15	13	13	*	*
Fish: No swim bladder (also applied to sharks)	213	50	48	59	66	70	57	65	71
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae	207	98	126	93	104	113	105	117	120

[1] Heyward et al. (2018)
An asterisk indicates that the sound level was not reached.

Table 14. Maximum (R_{max}) horizontal distances (in m) from the seismic source to modelled seafloor (receiver located 5 cm above seafloor) peak-peak pressure levels (PK-PK) at three water depths within the Active Source Area. Results included in relation to benthic invertebrates.

PK-PK ($L_{pk\text{-}pk}$; dB re 1 µPa)	Water Depth							
	10 m	12.5 m	15 m	20 m	25 m	30 m	40 m	50 m
	Distance R_{max} (m)							
213[1,2,3]	83	73	85	90	92	94	103	86
212[2,3]	86	88	89	103	100	100	111	121
210[1,2]	101	130	123	110	122	136	120	133
209[1,2]	112	132	150	124	126	141	167	145
202[4]	206	251	292	228	247	254	276	228

[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

4.2.1.2.1. Particle Motion Metrics

Table 15. Maximum (R_{max}) horizontal distances (in m) from the 2495 in^3 to particle motion threshold: Peak acceleration magnitude level (m/s^2) threshold for benthic invertebrates 5 cm above the seafloor, with water depth indicated. Results included in relation to benthic invertebrates (Section 2.4.1).

Hearing group/animal type	Peak Acceleration Magnitude (m/s^2)	Water Depth							
		10 m	12.5 m	15 m	20 m	25 m	30 m	40 m	50 m
		Distance R_{max} (m)							
Benthic invertebrates	37.57	58	48	44	40	43	47	54	7

4.2.2. Sound Field Maps and Graphs

4.2.2.1. Sound Level Contour Maps

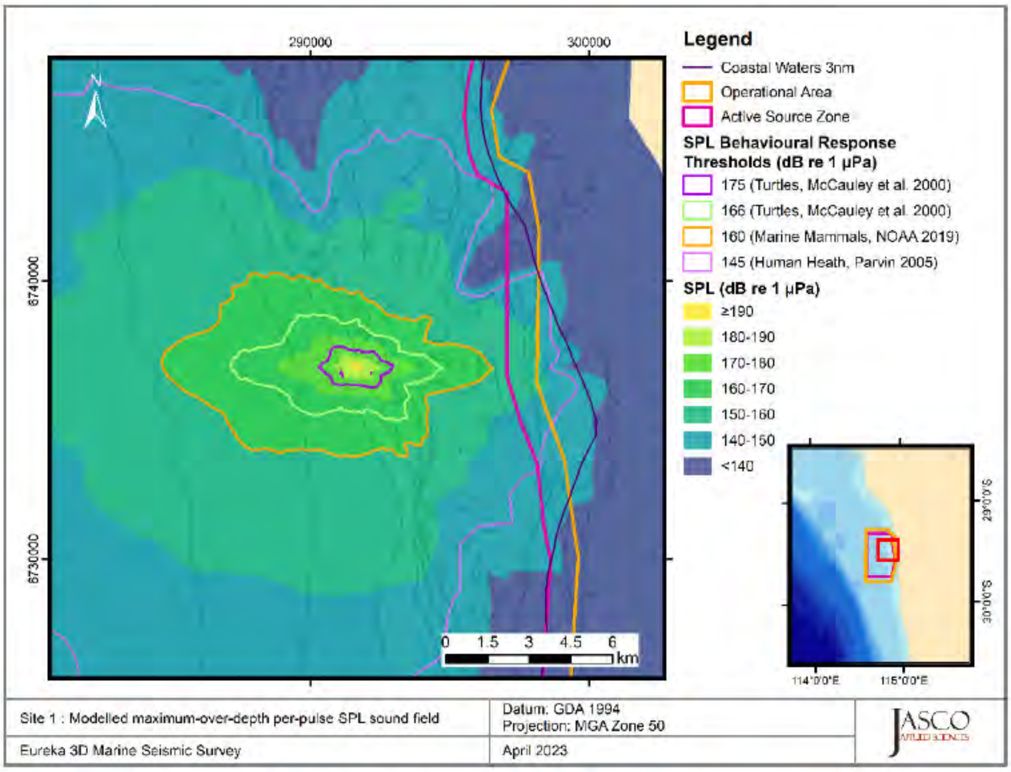


Figure 2. *Site 1, SPL, 2495 in^3 source, tow azimuth 0°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

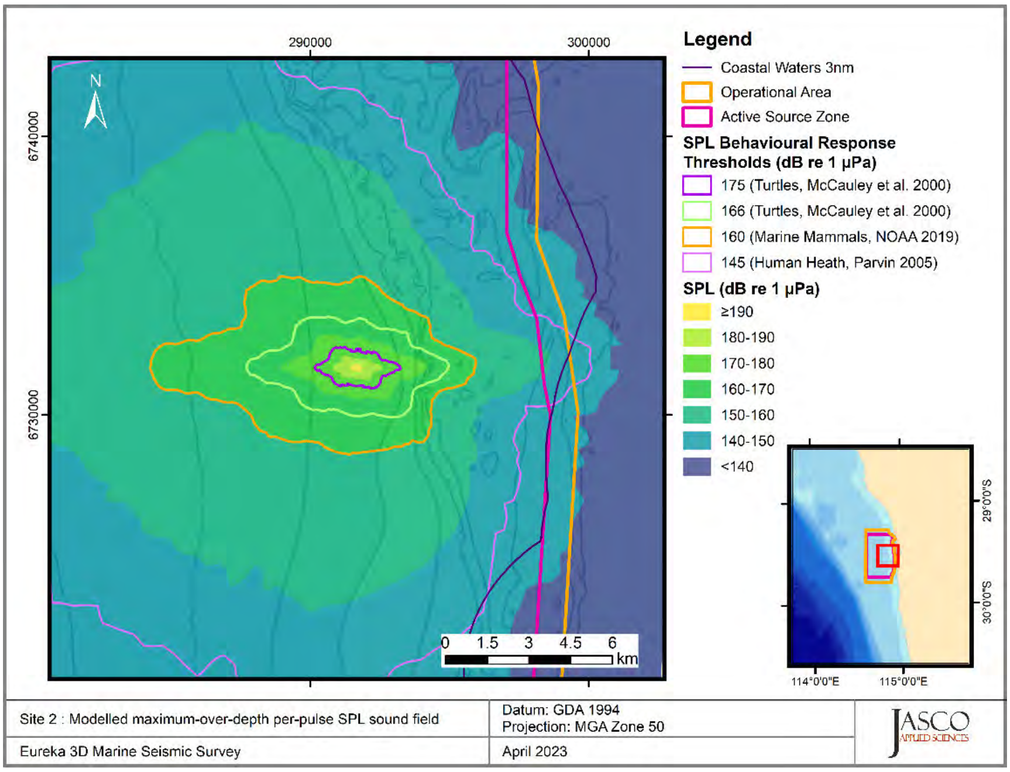


Figure 3. *Site 2, SPL, 2495 in³ source, tow azimuth 0°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

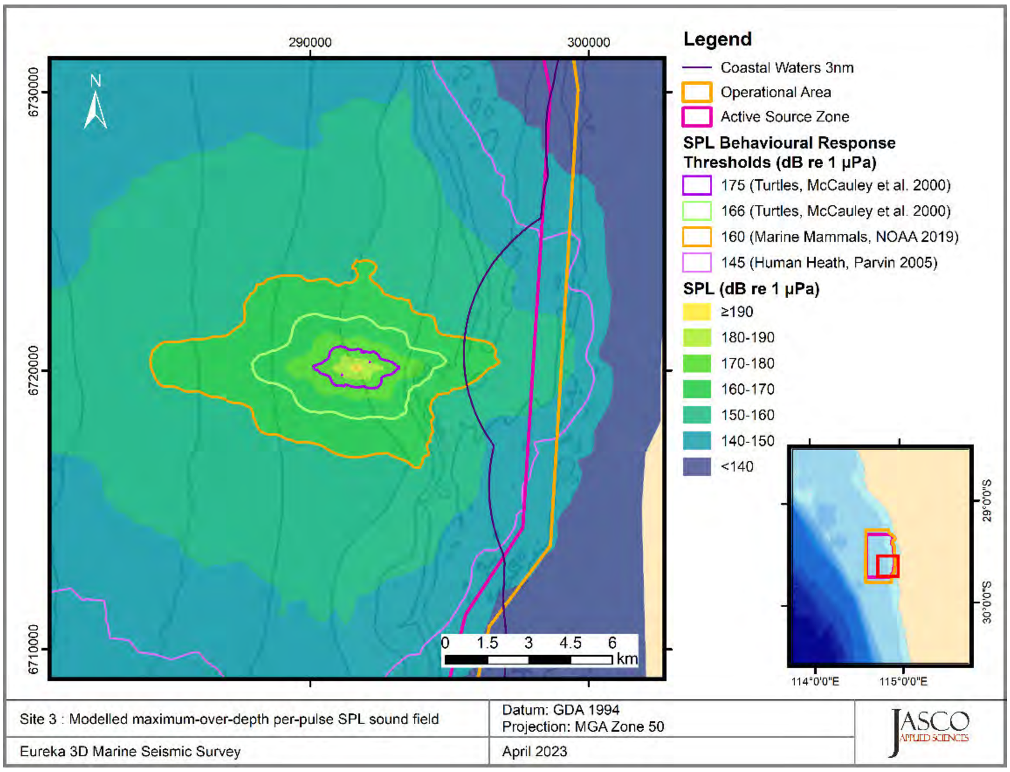


Figure 4. *Site 3, SPL, 2495 in³ source, tow azimuth 0°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

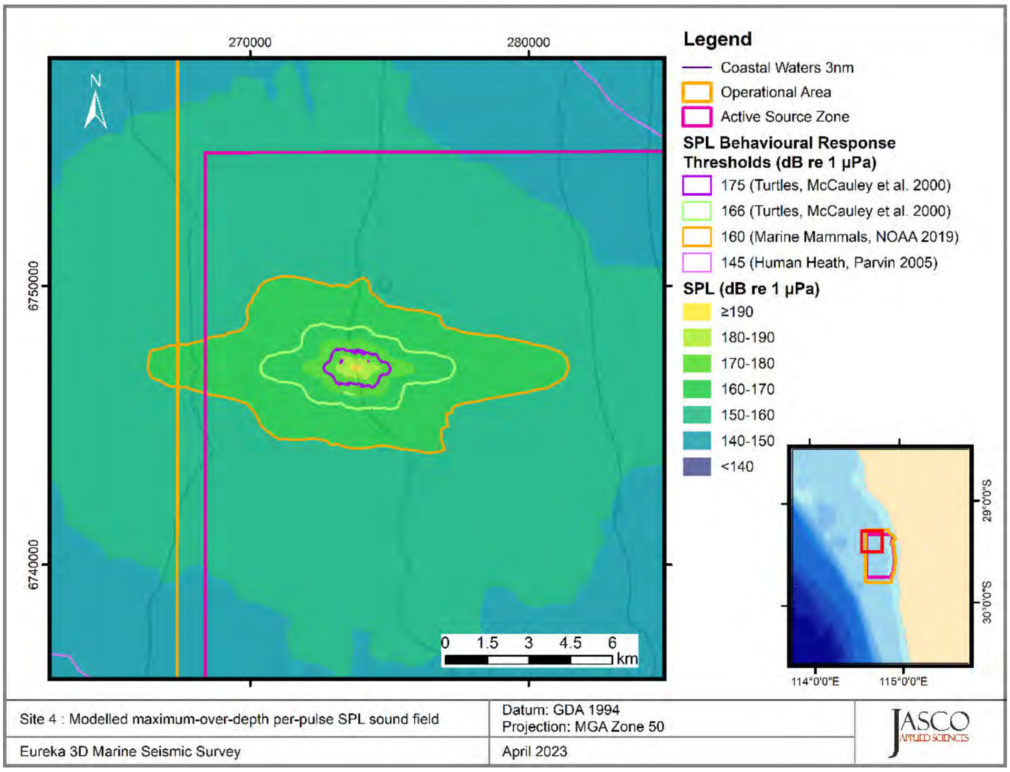


Figure 5. *Site 4, SPL, 2495 in³ source, tow azimuth 0°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

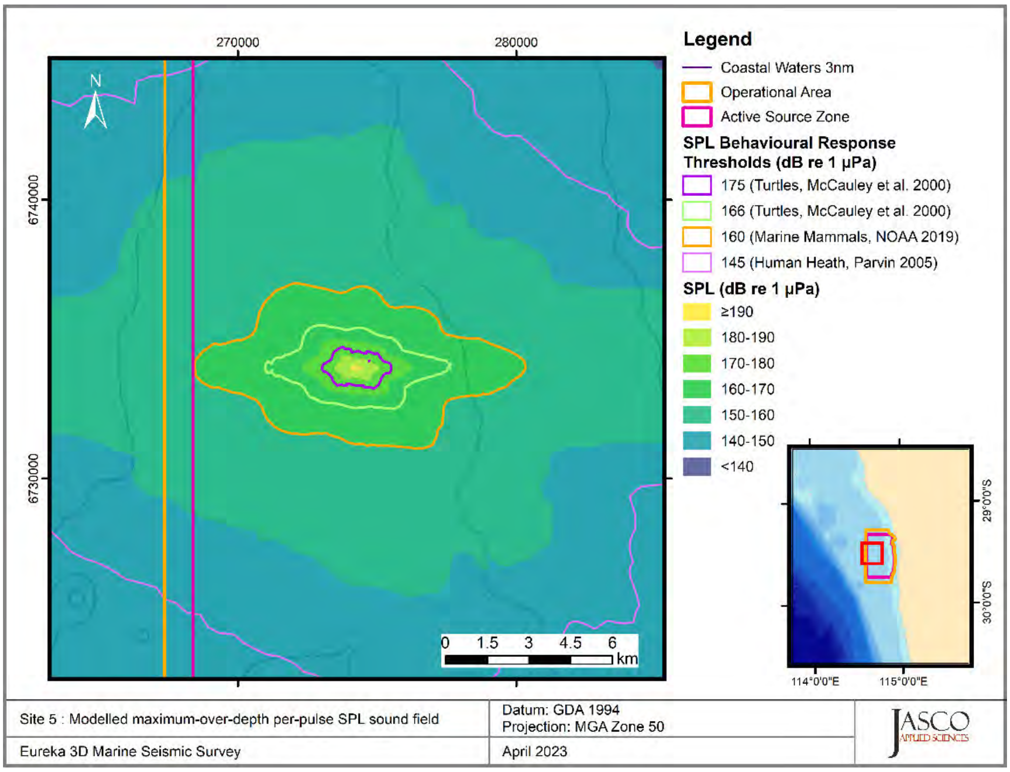


Figure 6. *Site 5, SPL, 2495 in³ source, tow azimuth 0°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

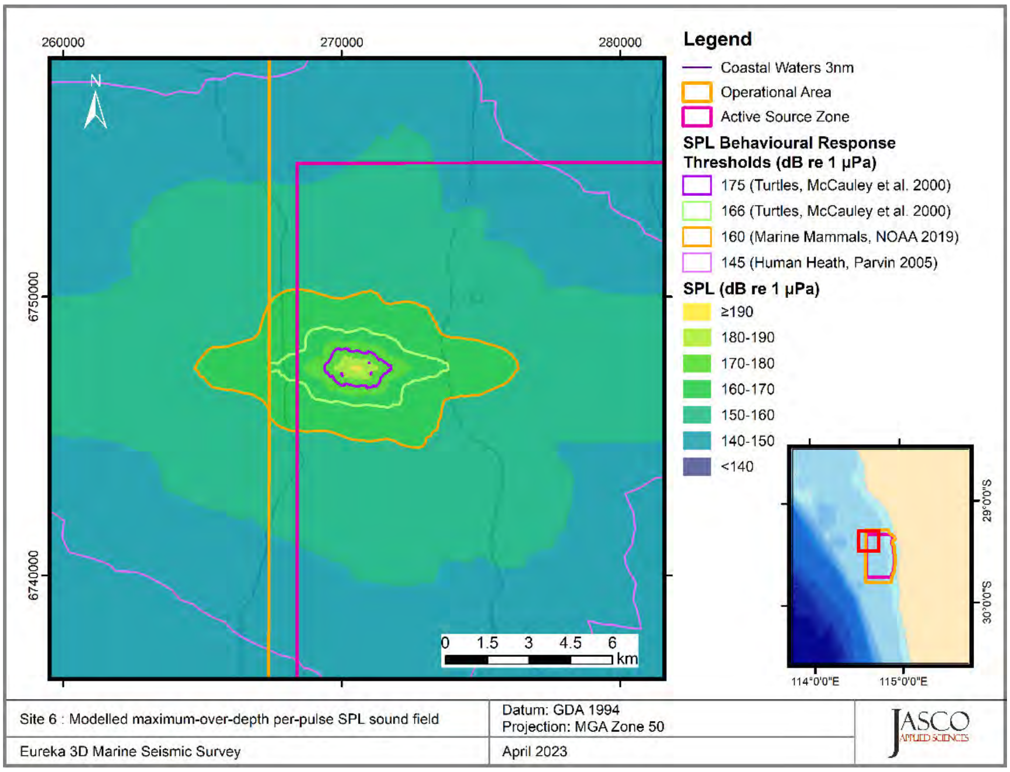


Figure 7. *Site 6, SPL, 2495 in³ source, tow azimuth 0°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

4.2.2.2. Sound Level Vertical Slices

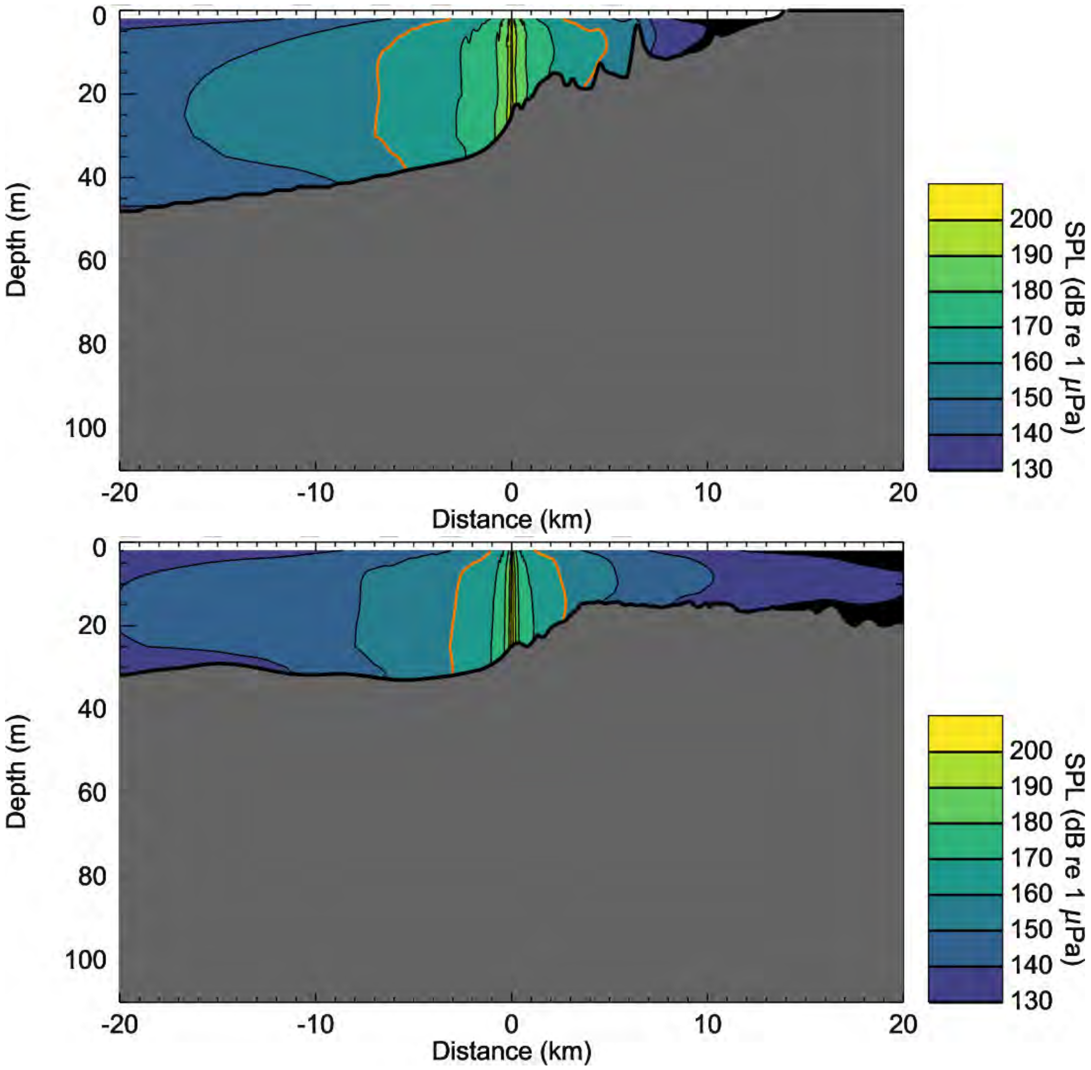


Figure 8. *Site 1, Scenario 1, tow azimuth 0°, SPL*: Sound level contours (vertical slice), perpendicular to (broadside, top) and along the tow direction (endfire, bottom). For context the behavioural response threshold for marine mammals is highlighted in orange. The positive distance direction in each slice is 90° clockwise from the tow azimuth for broadside, and the tow azimuth for the endfire slice.

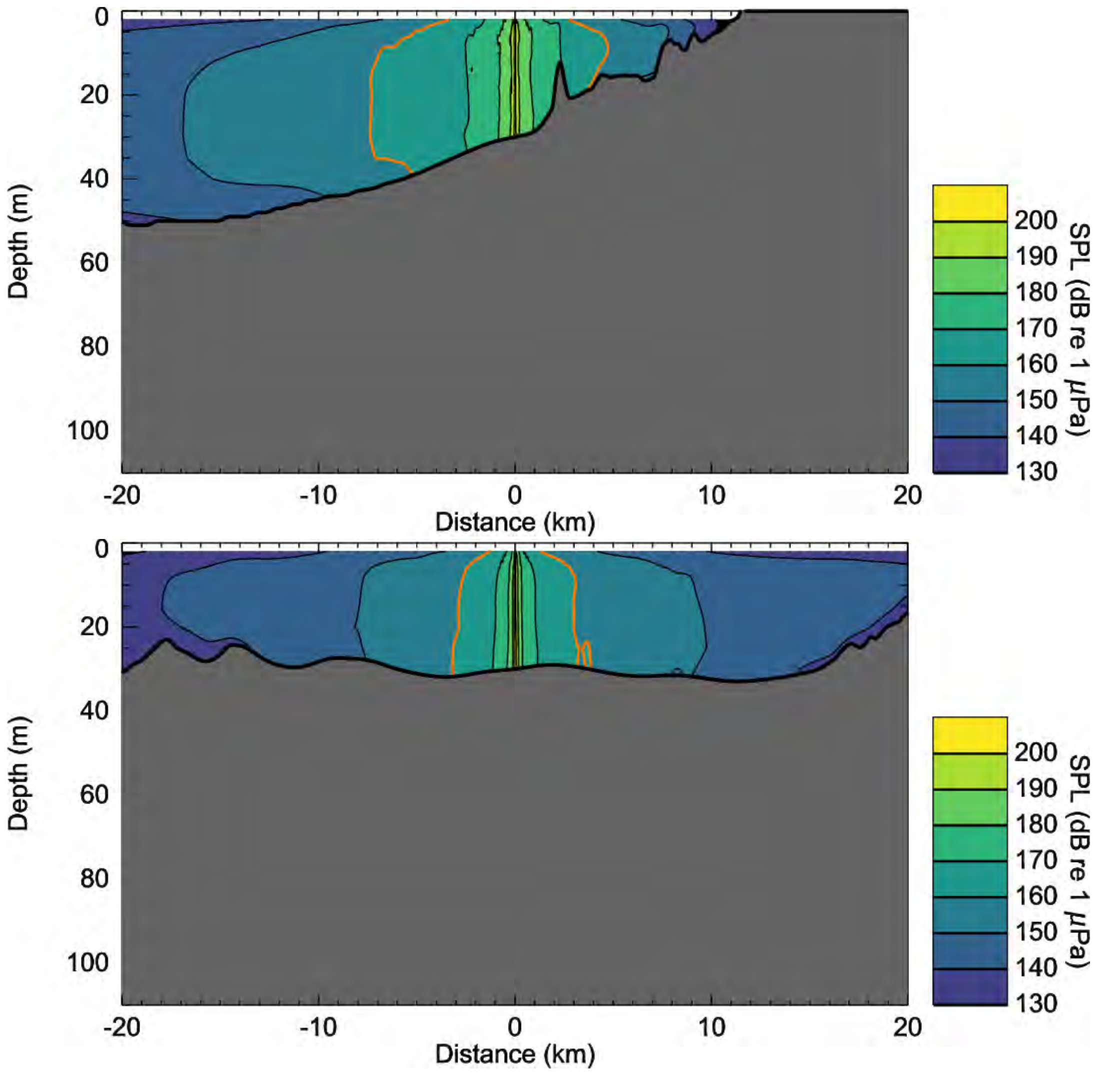


Figure 9. *Site 3, Scenario 1,tow azimuth 0°, SPL*: Sound level contours (vertical slice), perpendicular to (broadside, top) and along the tow direction (endfire, bottom). For context the behavioural response threshold for marine mammals is highlighted in orange. The positive distance direction in each slice is 90° clockwise from the tow azimuth for broadside, and the tow azimuth for the endfire slice.

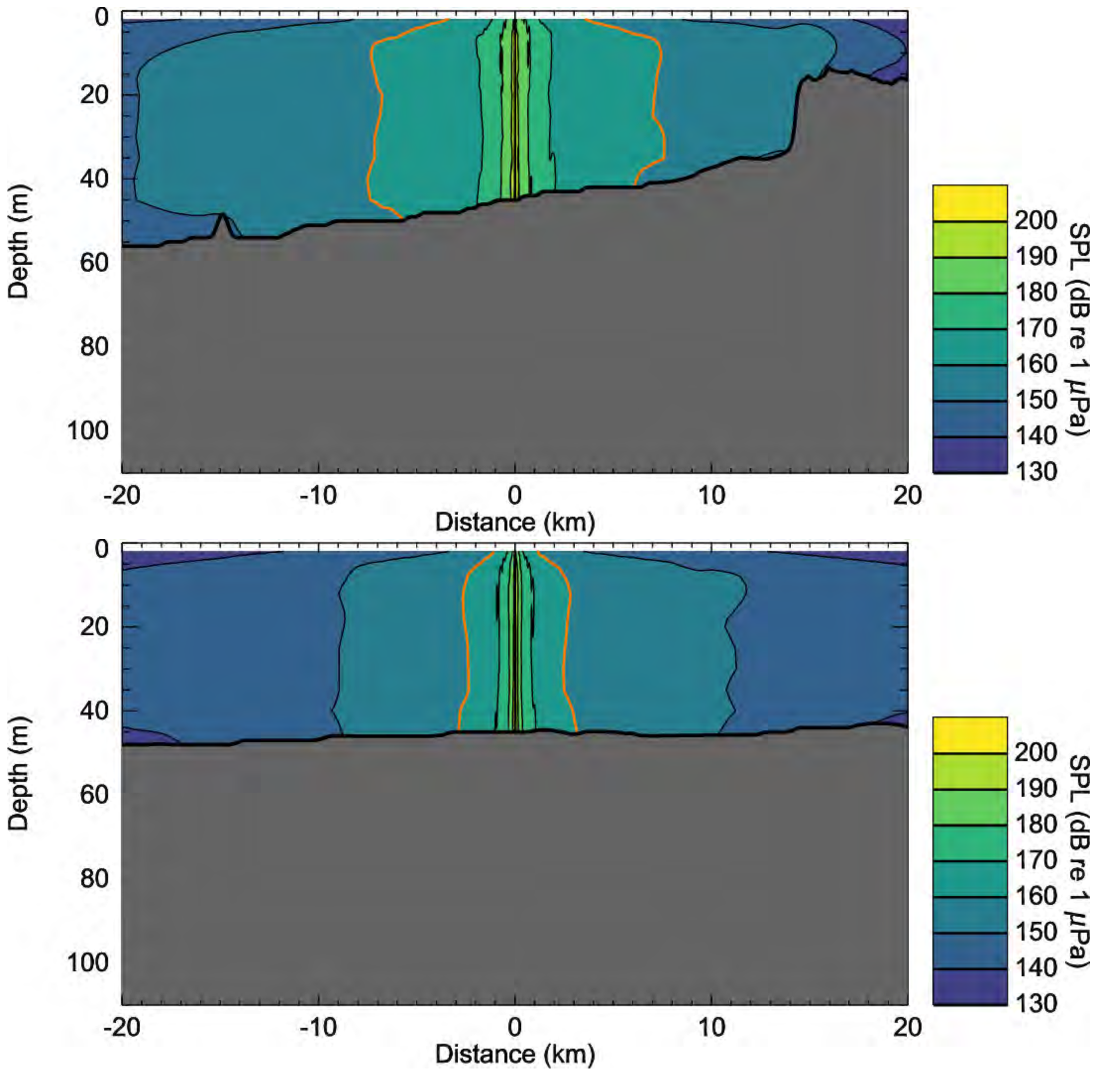
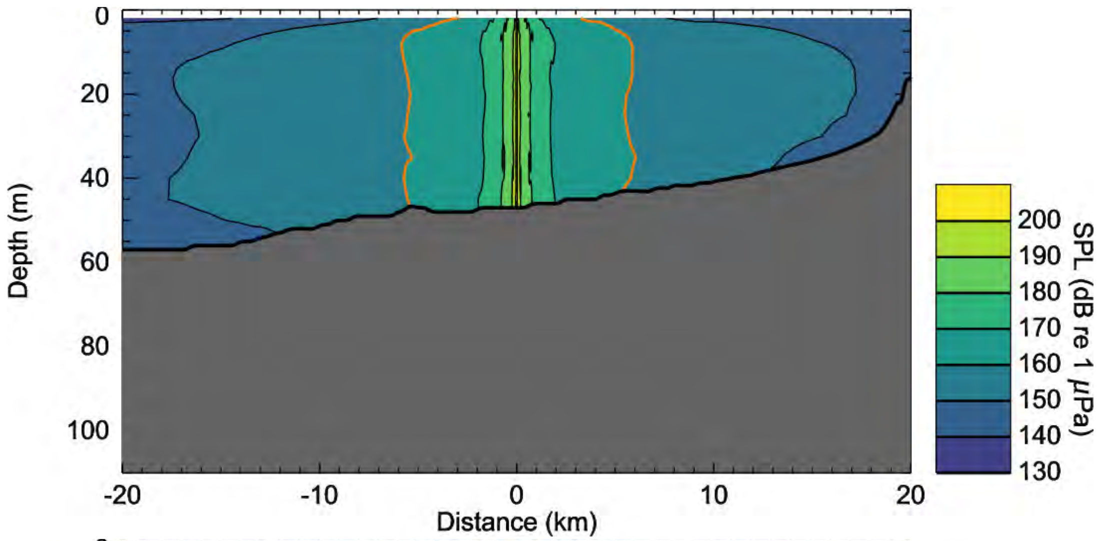


Figure 10. *Site 4, Scenario 2,tow azimuth 0°, SPL*: Sound level contours (vertical slice), perpendicular to (broadside, top) and along the tow direction (endfire, bottom). For context the behavioural response threshold for marine mammals is highlighted in orange. The positive distance direction in each slice is 90° clockwise from the tow azimuth for broadside, and the tow azimuth for the endfire slice.



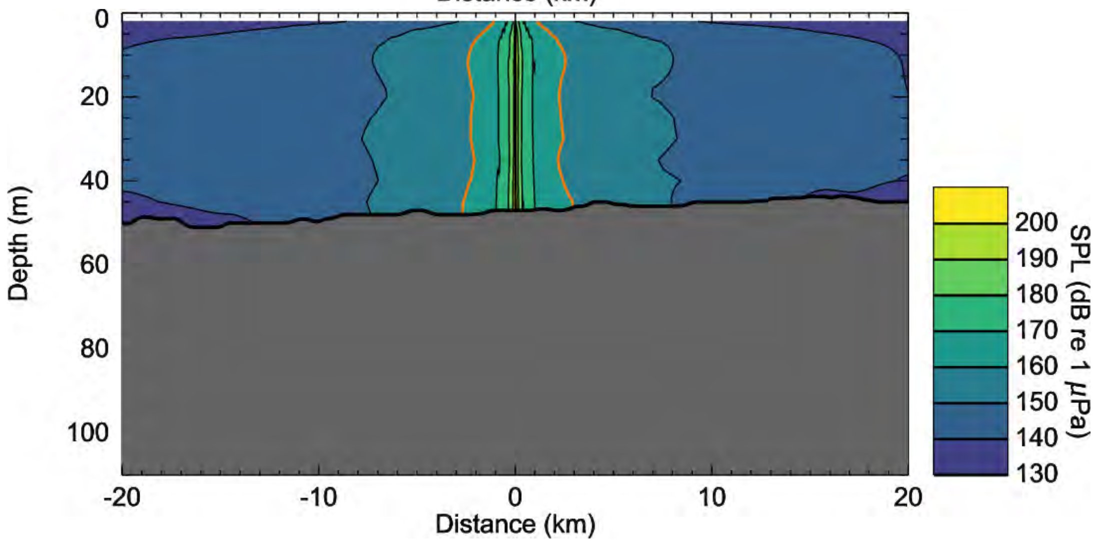


Figure 11. *Site 5, Scenario 2,tow azimuth 0°, SPL*: Sound level contours (vertical slice), perpendicular to (broadside, top) and along the tow direction (endfire, bottom). For context the behavioural response threshold for marine mammals is highlighted in orange. The positive distance direction in each slice is 90° clockwise from the tow azimuth for broadside, and the tow azimuth for the endfire slice.

4.3. Multiple Source Fields

This section presents the sound fields in terms of SEL accumulated over 24 hours of survey, for the two modelled scenarios (Section 1). 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 6), and to estimate maximum distance and the area for injury and TTS guidelines for fish (Tables 16–17).

The SEL_{24h} sound fields are presented as contour maps in Figures 12 and 13. 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.

4.3.1. Tabulated Results

Table 16. Marine mammal and sea turtle criteria: Maximum (R_{max}) horizontal distances (in km) and ensonified area (km^2) from the survey lines to permanent threshold shift (PTS) and temporary threshold shift (TTS) thresholds considering 24 hours of survey activity (maximum-over-depth).

Hearing group	Weighted SEL thresholds (L_{E24h}; dB re 1 µPa²·s)	Scenario 1		Scenario 2	
		R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)
PTS					
Low-frequency cetaceans	183	2.72	272	3.08	167
High-frequency cetaceans	185	-	-	–	–
Very-high-frequency cetaceans	155	0.06	5.68	0.06	6.19
Pinnipeds	203	-	-	–	–
Sea Turtles	204	0.06	5.68	0.06	6.19
TTS					
Low-frequency cetaceans	168	34.8	1884	43.0	2220
High-frequency cetaceans	170	0.06	3.91	0.06	5.56
Very-high-frequency cetaceans	140	0.44	58.7	0.42	37.2
Pinnipeds	188	0.06	4.71	0.06	5.56
Sea turtles	189	2.10	204	2.00	119.8

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 17. *Fish criteria*: Maximum horizontal distances (R_{max}, in km) from the survey lines and area (km^2) to injury and temporary threshold shift (TTS) thresholds considering 24 h of survey activity.

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)	Scenario 1		Scenario 2	
		R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)
Mortality and potential mortal injury					
I	219	0.06	4.71	0.06	4.75
II, fish eggs and larvae	210	0.06	5.68	0.06	6.19
III	207	0.06	5.68	0.06	6.19
Fish recoverable injury					
I	216	0.06	5.31	0.06	5.8
II, III	203	0.10	25.8	0.10	19.3
Fish TTS					
I, II, III	186	4.06	339	4.66	256

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 sound level was not reached.

4.3.2. Sound Level Contour Maps

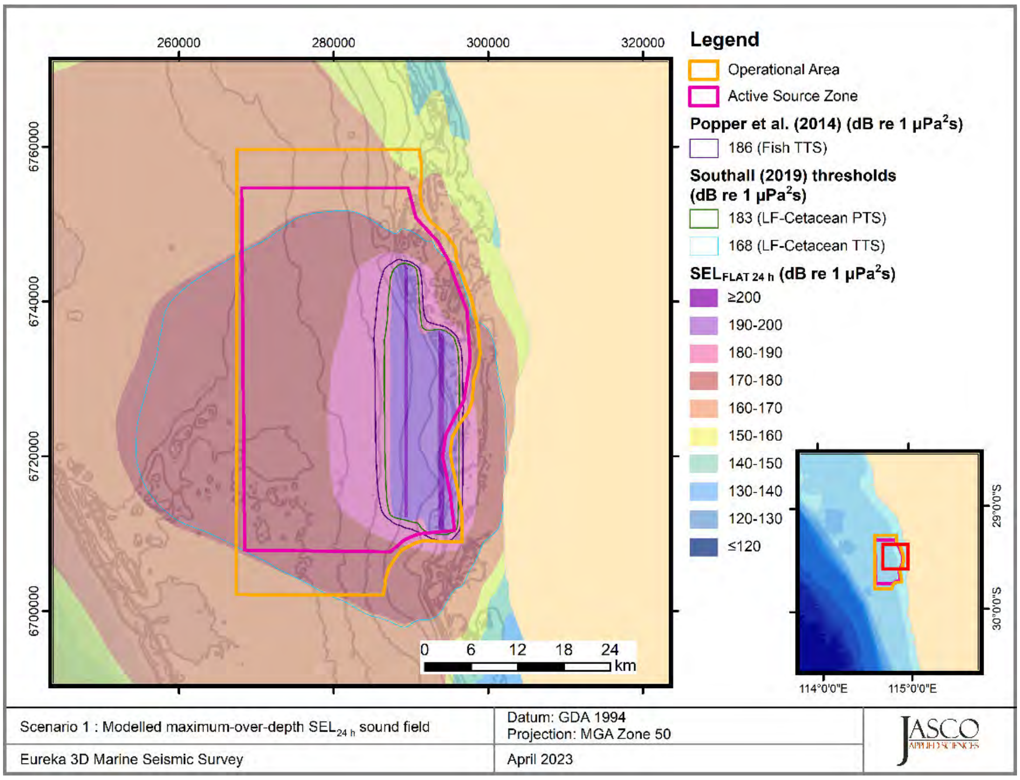


Figure 12. *Scenario 1*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h}, along with thresholds for LF-cetaceans and fish. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Tables 16 and 17 for tabulated radii.

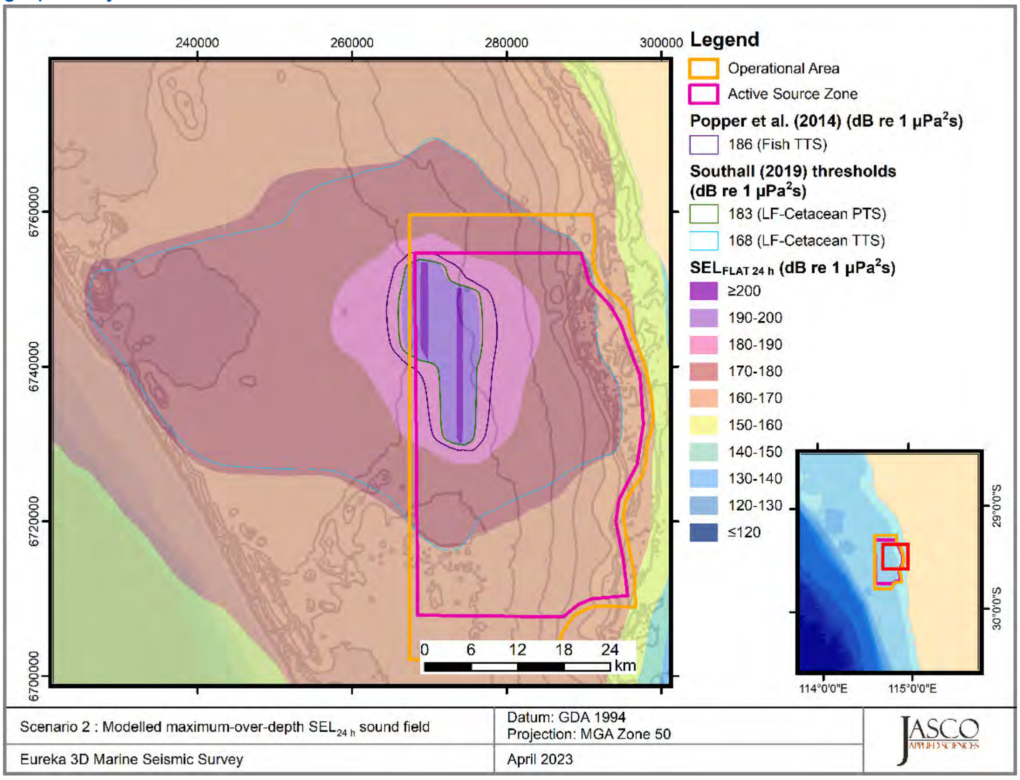


Figure 13. Scenario 2: Sound level contour map showing unweighted maximum-over-depth SEL_{24h}, along with thresholds for LF-cetaceans and fish. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Tables 16 and 17 for tabulated radii.

5. Discussion and Summary

The modelling study predicted underwater sound levels associated with the planned Eureka 3D MSS. The underwater sound field was modelled for a 2495 in^3 seismic source within the active source area.

Most acoustic energy from a seismic source is output at lower frequencies, in the tens to hundreds of hertz. 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.

5.1. Per-Pulse Sound Fields

The Eureka 3D MSS covers an area that is close to the Western Australia coastline; this required specifically selected sites to capture the propagation effects associated with shallow water depths and bathymetric features. The per-pulse modelled sites span water depths from about 25 to 48 m across an assumed single geological region. Seafloor sound levels were assessed at eight different representative water depths. The bathymetry within vicinity of the active source area varied approximately between 10–60 m; however, along a westward transect the environment generally transitions from coastal shallow waters to relatively deeper waters of the continental shelf and then the continental slope. The frequency content of the seismic source coupled with the bathymetry had a considerable effect on propagation at longer distances, with larger lobes of sound energy extending into the deeper waters. The maximum-over-depth sound footprint maps and vertical slice plots (Sections 4.2.2.1 and 4.2.2.2) assist in demonstrating the influence of the bathymetry and seabed interactions on the sound field.

Furthermore, sites located in deeper water have a lower “cut-off frequency (f_c)” than sites in shallower coast water. The cut-off frequency is a single number that describes how much acoustic energy can propagate with minimal loss between the 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 sources in waters greater than 30 m deep (i.e. sites associated with Scenario 2) the cut off frequency was less than 20 Hz. For these sites a comparatively larger amount of low-frequency energy can propagate in the water column compared to sources in shallow water below 30 m (i.e. sites associated with Scenario 1).

Based on available literature of the area, the seabed was modelled as a sand layer underlain by semi-cemented limestone/calcarenite. Acoustic propagation over calcarenite seabeds generally displayed higher rates of loss at distance away from the source as compared to seabeds that contain thick packages of unconsolidated sediments (Duncan et al. 2009). Literature suggests that the thickness of this layer is variable and could be on the order of several metres thick or in some locations non-existent(Duncan et al. 2008, Duncan et al. 2009, Fan et al. 2009). The distribution of sand layer is not well known and if the thickness of the sand layer is not as uniform as modelled then this variability could potentially lead to smaller radii if thinner or larger radii if thicker.

5.2. Multiple Pulse Sound Fields

The accumulated SEL over 24 hours of seismic source operation was modelled considering representative scenarios with a realistic acquisition pattern for the marine portion of the Eureka 3D MSS. The model methodology 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 and marine mammal criteria. The results were presented as maps of the accumulated exposure levels and tabulated values of ranges to threshold levels and exposure areas for the given effects criteria (Section 2).

The footprints and range maxima for all SEL_{24h} criteria are substantially influenced by the location of single impulse modelled sites. As discussed above, the footprints and range maxima for all accumulated SEL thresholds within the survey area are primarily influenced by the high levels in the offshore direction due to deepening waters. This results in generally different isopleth and threshold distances for Scenarios 1 and 2.

5.3. Summary

A summary of predicted distances to criteria from acoustic modelling are presented below.

Marine mammals

The maximum distance for behavioural response based on NOAA (2019) criterion of 160 dB re 1 µPa (SPL) varied between 9.20 and 6.51 km depending on the site. All results can be found in Section 4.2.1.1. The results for marine mammal injury considered the criteria from Southall et al. (2019). 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 18 summarises the maximum distances, along with the relevant metric. Results for PK thresholds can be found in Section 4.2.1.1 and SEL_{24h} can be found in Section 4.3.1.

Table 18. Summary of maximum horizontal distance (R_{max}) for behavioural response thresholds, permanent threshold shift (PTS) and temporary threshold shift (TTS) for marine mammals. Maximum extents are in the broadside direction.

Hearing group	Maximum modelled distance to effect threshold (R_{max})		
	Behavioural response[1]	Impairment (km): PTS[2]	Impairment (km): TTS[2]
LF cetaceans (Baleen whales)	9.20	3.08 (SEL_{24h})	43.0 (SEL_{24h})
HF cetaceans (Dolphins, plus toothed, beaked, and bottlenose whales)		–	–
VHF cetaceans (*Kogia*, cephalorhynchid, and *L. australis*)		0.41 (PK)	0.84 (PK)
Pinnipeds (Australian sea lion, Australian fur seal, New Zealand fur seal)		–	0.06

Noise exposure criteria: [1] NOAA (2019) and [2] Southall et al. (2019).
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Sea turtles

The PK sea turtle impairment criteria from Finneran et al. (2017) were not exceeded beyond the modelled resolution of 20 m. The maximum distance for PTS and TTS onset associated with the SEL_{24h} (Finneran et al. 2017) were respectively 0.06 and 2.10 km, and the behavioural response of turtles (McCauley et al. 2000) are summarised in Table 19. Results for PK and behavioural response thresholds can be found in Section 4.2.1.1 and SEL_{24h} can be found in Section 4.3.1.

Table 19. Summary of maximum horizontal distance (in km) to turtle behavioural response criteria, temporary threshold shift (TTS), and permanent threshold shift (PTS).

Hearing group	Maximum modelled distance (in km) to effect threshold (R_{max})			
	Behavioural response[1]	Behavioural disturbance[1]	Impairment: TTS[2]	Impairment: PTS[2]
Sea turtles	4.90 (166 dB re 1 µPa - SPL)	1.58 (175 dB re 1 µPa - SPL)	2.10 (SEL_{24h})	0.06 (SEL_{24h})

Noise exposure criteria: [1] McCauley et al. (2000) and [2] 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 (water column) 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 20 summarises distances to effect criteria for fish, fish eggs, and fish larvae along with the relevant metric. Seafloor sound levels were assessed at nine different depths within the survey area. Assessment was based on Popper et al. (2014) and considered both PK (seafloor and water column, Sections 4.2.1.1 and 4.2.1.2) and SEL_{24h} metrics (water column, Section 4.3.1) associated with mortality, potential mortal injury and impairment.

Table 20. Summary of maximum onset distances for single impulse and 24 hour sound exposure level (SEL_{24h}) for fish, fish eggs, and larvae injury and temporary threshold shift (TTS).

Relevant hearing group	Effect criteria	Metric associated with longest distance to criteria	R_{max} (km)
Fish: No swim bladder	Recoverable injury	PK	0.15
	TTS	SEL_{24h}	4.06
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing	Recoverable injury	PK	0.27
	TTS	SEL_{24h}	4.06
Fish eggs, and larvae (relevant to plankton)	Injury	PK	0.27

Benthic invertebrates, Cephalopods, Sponges, and Coral

A full set of tabulated results can be found in Section 4.2.1.2; however, to summarise the potential effects on these receptors, the following results are provided:

- Crustaceans (representative of southern rock lobsters and crabs): The distance to no effect was reached between 206 and 292 m, based on 202 dB re 1 µPa PK-PK level from Payne et al. (2008).
- Bivalves (representative of scallops and mussels): The distance to no effect was reached between 54 and 7 m, based on a particle acceleration limit of 37.57 ms^{-2} at the seafloor as presented in Day et al. (2016a).
- Squid: The distance to the per–pulse SEL (L_E) startle (inking) response level of 162 dB re 1 µPa^{2}s for squid (Fewtrell and McCauley 2012) was reached between 2.90 and 2.03 km.
- Sponges and coral: The threshold was reached at a maximum of 15 m, based on the PK sound level criteria of 226 dB re 1 µPa PK for sponges and corals (Heyward et al. 2018).

Divers

An SPL human health assessment of 145 dB re 1 μPa (SPL; L_p) derived from Parvin (2005) was considered for people swimming and diving. The sound level was reached at ranges between 36.4 and 24.1 km depending on the modelled site. This is the maximum range over all modelled azimuths, and it is typically in orientated offshore. This maximum range should not be used as an offset distance to the coast and the sound field contour maps should be used to inform any such offset.

Glossary

1/3-octave

One third of an octave. *Note*: A one-third octave is approximately equal to one decidecade (1/3 oct ≈ 1.003 ddec).

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.

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.

audiogram

A graph or table of hearing threshold as a function of frequency that describes the hearing sensitivity of an animal over its hearing range.

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.

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.

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

Ratio of energy (time-integrated square of a specified field variable) to bandwidth in a specified frequency band f_1 to f_2. In equation form, the energy spectral density E_f is given by:

$$E_f = \frac{2\int_{f_1}^{f_2} |X(f)|^2 \, \mathrm{d}f}{f_2 - f_1},$$

where $X(f)$ is the Fourier transform of the field variable $x(t)$

$$X(f) = \int_{-\infty}^{+\infty} x(t) \exp(-2\pi \mathrm{i} f t) \, \mathrm{d}t \, .$$

The field variable $x(t)$ is a scalar quantity, such as sound pressure. It can also be the magnitude or a specified component of a vector quantity such as sound particle displacement, sound particle velocity, or sound particle acceleration. The unit of energy spectral density depends on the nature of x, as follows:

- If x = sound pressure: Pa^2 s/Hz
- If x = sound particle displacement: m^2 s/Hz
- If x = sound particle velocity: $(m/s)^2$ s/Hz
- If x = sound particle acceleration: $(m/s^2)^2$ s/Hz

The factor of two on the right-hand side of the equation for E_f is needed to express a spectrum that is symmetric about $f = 0$, in terms of positive frequencies only. See entry 3.1.3.9 of ISO 18405 (2017).

energy spectral density level

The level ($L_{E,f}$) of the **energy spectral density** (E_f). Unit: decibel (dB).

$$L_{E,f} := 10 \log_{10}\left(E_f / E_{f,0}\right) \mathrm{dB}\,.$$

The frequency band and integration time should be specified.

As with **energy spectral density**, energy spectral density level can be expressed in terms of various field variables (e.g., sound pressure, sound particle displacement). The reference value ($E_{f,0}$) for energy spectral density level depends on the nature of field variable.

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.

functional hearing group

Category of animal species when classified according to their hearing sensitivity, hearing anatomy, and susceptibility to sound. For marine mammals, initial groupings were proposed by Southall et al. (2007), and revised groupings are developed as new research/data becomes available. Revised groupings proposed by Southall et al. (2019) include low-frequency cetaceans, high-frequency cetaceans, very high-frequency cetaceans, phocid carnivores in water, other carnivores in water, and sirenians. See auditory frequency weighting functions, which are often applied to these groups. Example hearing groups 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).

geoacoustic

Relating to the acoustic properties of the seabed.

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 **functional hearing** group.

impulsive sound

Qualitative term meaning sounds that are typically transient, brief (less than 1 s), 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 **functional hearing** group.

Monte Carlo simulation

The method of investigating the distribution of a non-linear multi-variate function by random sampling of all of its input variable distributions.

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*).

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.

odontocete

The presence of teeth, rather than baleen, characterizes these whales. Members of the Odontoceti are a suborder of cetaceans, a group comprised of whales, dolphins, and porpoises. The skulls of toothed whales are mostly asymmetric, an adaptation for their echolocation. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.

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 **functional hearing** group.

other marine carnivores in air (OCA)

See **functional hearing** group.

other marine carnivores in water (OCW)

See **functional 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.

particle acceleration

See **sound particle acceleration**.

particle displacement

See **sound particle displacement**.

particle motion

See **sound particle motion**.

particle velocity

See **sound particle velocity**.

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.

$$L_{p,\text{pk}} := 10\log_{10}\left(p_{\text{pk}}^2/p_0^2\right)\text{dB} \ = 20\log_{10}\left(p_{\text{pk}}/p_0\right)\text{dB}$$

The frequency band and time window should be specified. Abbreviation: PK or Lpk.

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 **functional 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.

power spectral density

Generic term, formally defined as power in a unit frequency band. Unit: watt per hertz (W/Hz). The term is sometimes loosely used to refer to the spectral density of other parameters such as squared sound pressure. ratio of **energy spectral density**, E_f, to time duration, Δt, in a specified temporal observation window. In equation form, the power spectral density P_f is given by:

$$P_f = \frac{E_f}{\Delta t}.$$

Power spectral density can be expressed in terms of various field variables (e.g., sound pressure, sound particle displacement).

power spectral density level

The level ($L_{P,f}$) of the **power spectral density** (P_f). Unit: decibel (dB).

$$L_{P,f} := 10 \log_{10}(P_f / P_{f,0})\ \mathrm{dB}\,.$$

The frequency band and integration time should be specified.

As with **power spectral density**, power spectral density level can be expressed in terms of various field variables (e.g., sound pressure, sound particle displacement). The reference value ($P_{f,0}$) for power spectral density level depends on the nature of field variable.

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).

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 µm/s^2

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 h) 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 µPa² s.

$$L_E := 10\log_{10}(E/E_0)\,\mathrm{dB} \;= 20\log_{10}\left(E^{1/2}/E_0^{1/2}\right)\,\mathrm{dB}$$

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: Pa² 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/s²). 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 µPa².

$$L_{p,\mathrm{rms}} := 10\log_{10}(p^2_{\mathrm{rms}}/p_0^2)\,\mathrm{dB} \;= 20\log_{10}(p_{\mathrm{rms}}/p_0)\,\mathrm{dB}$$

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.

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 $\mu Pa^2 m^2$.

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.

unweighted

Term indicating that no frequency weighting function is applied. Synonymous with flat weighting.

very high-frequency (VHF) cetacean

See **functional hearing** group.

wavelength

Distance over which a wave completes one cycle of oscillation. Unit: metre (m). Symbol: λ.

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Appendix A. Acoustic Metrics

A.1. Pressure Related Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 μPa. Because the perceived loudness of sound, especially pulsed sound such as from seismic airguns, pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate sound and its effects on marine life. Here we provide specific definitions of relevant metrics used in the accompanying report. Where possible, we follow the American National Standard Institute and International Organization for Standardization definitions and symbols for sound metrics (e.g., ISO 2017, ANSI R2013), but these standards are not always consistent.

The zero-to-peak sound pressure, or peak sound pressure (PK or $L_{p,pk}$; 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, $\mathrm{p(t)}$:

$$L_{p,\mathrm{pk}} = 10\log_{10}\frac{\max|p^2(t)|}{p_0^2} = 20\log_{10}\frac{\max|p(t)|}{p_0} \tag{A-1}$$

PK is often included as a criterion for assessing whether a sound is potentially injurious; however, because it does not account for the duration of an acoustic event, it is generally a poor indicator of perceived loudness.

The peak-to-peak sound pressure (PK-PK or $L_{p,pk\text{-}pk}$; 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, $\mathrm{p(t)}$:

$$L_{p,\mathrm{pk\text{-}pk}} = 10\log_{10}\frac{[\max(p(t)) - \min(p(t))]^2}{p_0^2} \tag{A-2}$$

The sound pressure level (SPL or L_p; dB re 1 μPa) is the root-mean-square (rms) pressure level in a stated frequency band over a specified time window (T; s). It is important to note that SPL always refers to an rms pressure level and therefore not instantaneous pressure:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T g(t)\,p^2(t)\,dt\Big/p_0^2\right) \tag{A-3}$$

where $\mathrm{g(t)}$ 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 $\mathrm{g(t)}$ 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 $\mathrm{g(t)}$ 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 $\mathrm{g(t)}$ 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):

$$L_E = 10\log_{10}\left(\int_T p^2(t)\,dt \Big/ T_0 p_0^2\right) \tag{A-4}$$

where T_0 is a reference time interval of 1 s. SEL continues to increase with time when non-zero pressure signals are present. It is a dose-type measurement, so the integration time applied must be carefully considered for its relevance to impact to the exposed recipients.

SEL can be calculated over a fixed duration, such as the time of a single event or a period with multiple acoustic events. When applied to pulsed sounds, SEL can be calculated by summing the SEL of the N individual pulses. For a fixed duration, the square pressure is integrated over the duration of interest. For multiple events, the SEL can be computed by summing (in linear units) the SEL of the N individual events:

$$L_{E,N} = 10\log_{10}\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}} \tag{A-5}$$

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.5) 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.2. Particle Acceleration and Velocity Metrics

Since sound is a mechanical wave, it can also be measured in terms of the vibratory motion of fluid particles. Particle motion can be measured in terms of three different (but related) quantities: displacement, velocity, or acceleration. Acoustic particle velocity is the time derivative of particle displacement, and likewise acceleration is the time derivative of velocity. For the present study, acoustic particle motion has been reported in terms of acceleration and velocity.

The particle velocity (v) is the physical speed of a particle in a material moving back and forth in the direction of the pressure wave. It can be derived from the pressure gradient and Euler's linearised momentum equation where ρ_0 is the density of the medium:

$$v = -\int \nabla p(t)dt/\rho_0 \tag{A-6}$$

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:

$$a = \frac{dv}{dt} = -\frac{\nabla p(t)}{\rho_0} \tag{A-7}$$

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:

$$|v| = \sqrt{v_x + v_y + v_z} \tag{A-8}$$

The magnitude of particle acceleration is calculated similarly from the particle acceleration in the x, y, and z directions.

A.3. 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, $f_{\mathrm{c}}(i)$, is defined as:

$$f_{\mathrm{c}}(i) = 10^{\frac{i}{10}}\,\mathrm{kHz} \tag{A-9}$$

and the low (f_{lo}) and high (f_{hi}) frequency limits of the ith decade band are defined as:

$$f_{\mathrm{lo},i} = 10^{\frac{-1}{20}} f_{\mathrm{c}}(i) \quad \text{and} \quad f_{\mathrm{hi},i} = 10^{\frac{1}{20}} f_{\mathrm{c}}(i) \tag{A-10}$$

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 ($f_{\mathrm{c}}(44)$ = 25 kHz).

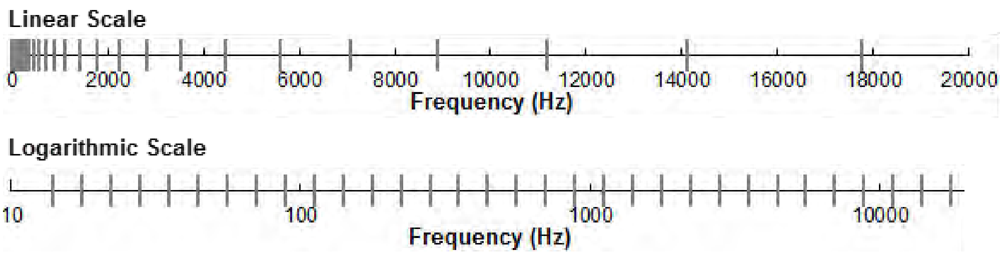

Figure A-1. Decidecade frequency bands (vertical lines) shown on a linear frequency scale and a logarithmic scale.

The sound pressure level in the ith band ($L_{p,i}$) is computed from the spectrum $S(f)$ between $f_{\mathrm{lo},i}$ and $f_{\mathrm{hi},i}$:

$$L_{p,i} = 10\log_{10} \int_{f_{\mathrm{lo},i}}^{f_{\mathrm{hi},i}} S(f)\,df \tag{A-11}$$

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.

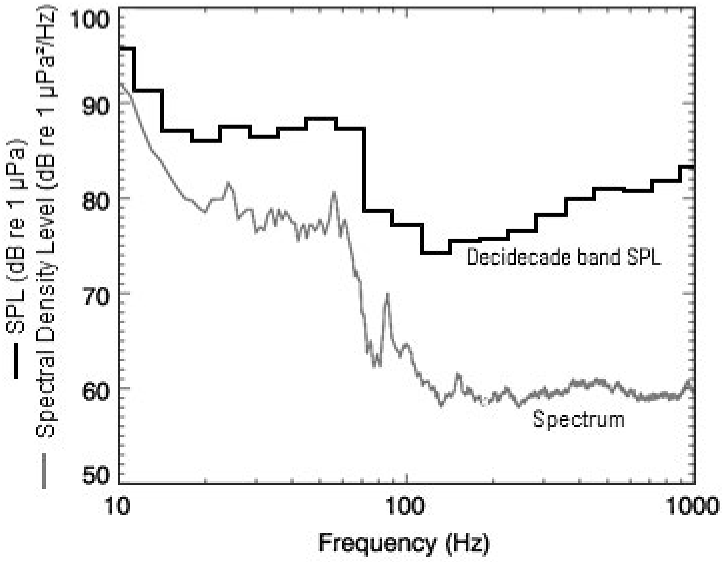

Figure A-2. Sound pressure spectral density levels and the corresponding decidecade band sound pressure levels of example ambient noise shown on a logarithmic frequency scale.

A.4. 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.4.1. 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. (2019) which is applied in this report.

A.4.2. Behavioural Response

Numerous studies on marine mammal behavioural responses to sound exposure have not resulted in consensus in the scientific community regarding the appropriate metric for assessing behavioural reactions. However, it is recognised that the context in which the sound is received affects the nature and extent of responses to a stimulus (Southall et al. 2007, Ellison and Frankel 2012, Southall et al. 2016).

For impulsive noise, NMFS currently uses step function thresholds of 160 dB re 1 µPa SPL (unweighted) to assess and regulate noise-induced behavioural impacts for marine mammals (NOAA 2018, NOAA 2019). The threshold for impulsive sound is derived from the High-Energy Seismic Survey (HESS) panel (HESS 1999) report that, in turn, is based on the responses of migrating mysticete whales to airgun sounds (Malme et al. 1984). The HESS team recognised that behavioural responses to sound may occur at lower levels, but significant responses were only likely to occur above a SPL of 140 dB re 1 µPa. Southall et al. (2007) found varying responses for most marine mammals between a SPL of 140 and 180 dB re 1 µPa, consistent with the HESS (1999) report, but lack of convergence in the data prevented them from suggesting explicit step functions.

A.5. 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.5.1. 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:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^2\right]^a\left[1+(f/f_{hi})^2\right]^b}\right)\right] \tag{A-13}$$

Finneran (2015)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 (2019). 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. (2019).

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 (*Kogia*, cephalorhynchid, and *L. australis*)	1.8	2	12,000	140,000	1.36
Other marine carnivores in water (Australian sea lion, Australian fur seal, New Zealand fur seal)	2.0	2	940	25,000	0.64

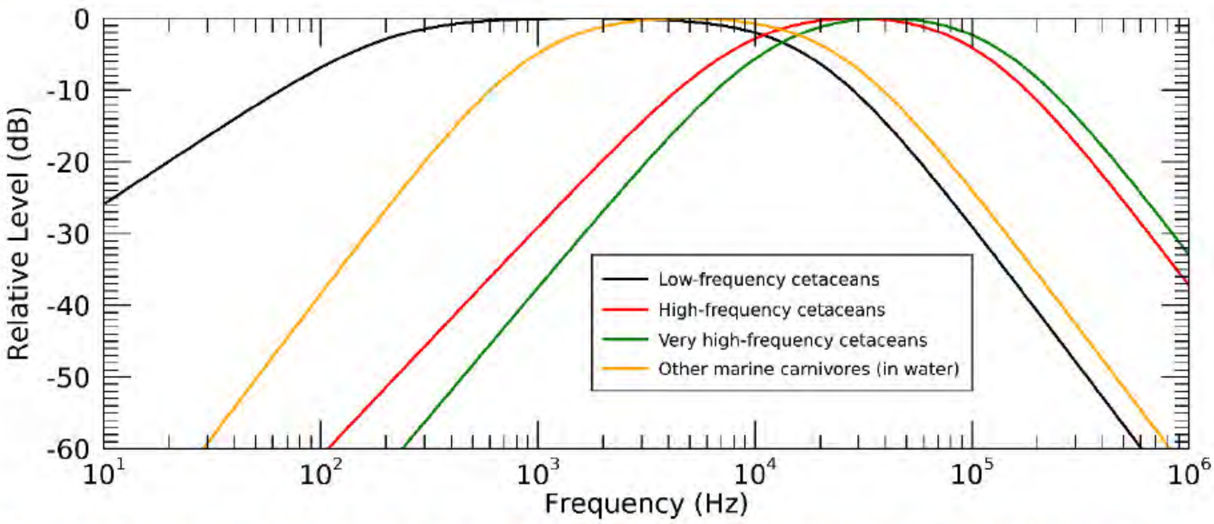

Figure A-3. Auditory weighting functions for functional marine mammal hearing groups used in this project as recommended by Southall et al. (2019).

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 Dragoset (1984), Laws et al. (1990), and Landro (1992). A global optimisation algorithm tunes free parameters in the model to a large library of airgun source signatures.

While airgun signatures are highly repeatable at the low frequencies, which are used for seismic imaging, their sound emissions have a large random component at higher frequencies that cannot be predicted using a deterministic model. Therefore, AASM uses a stochastic simulation to predict the high-frequency (800−25,000 Hz) sound emissions of individual airguns, using a data-driven multiple-regression model. The multiple-regression model is based on a statistical analysis of a large collection of high quality seismic source signature data recently obtained from the Joint Industry Program (JIP) on Sound and Marine Life (Mattsson and Jenkerson 2008). The stochastic model uses a Monte-Carlo simulation to simulate the random component of the high-frequency spectrum of each airgun in an array. The mean high-frequency spectra from the stochastic model augment the low-frequency signatures from the physical model, allowing AASM to predict airgun source levels at frequencies up to 25,000 Hz.

AASM produces a set of "notional" signatures for each array element based on:

- Array layout
- Volume, tow depth, and firing pressure of each airgun
- Interactions between different airguns in the array

These notional signatures are the pressure waveforms of the individual airguns at a standard reference distance of 1 m; they account for the interactions with the other airguns in the array. The signatures are summed with the appropriate phase delays to obtain the far-field source signature of the entire array in all directions. This far-field array signature is filtered into 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 seismic source used for modelling in this study is provided in Figure B-1 and details of the airgun parameters are provided in Table 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.

Table B-1. Layout of the modelled 2495 in^3 array. Tow depth is 6 m. Firing pressure for all guns is 2000 psi. Also see Figure B-1.

Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)	Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)
1	7.5	-4.4	6.0	90	13	7.5	3.6	6.0	60
2	7.5	-3.6	6.0	90	14	7.5	4.4	6.0	60
3	4.5	-4.5	6.0	250	15	4.5	3.5	6.0	250
4	4.5	-3.5	6.0	250	17	1.5	3.5	6.0	250
6	1.5	-3.5	6.0	250	18	1.5	4.5	6.0	250
8	-1.5	-3.6	6.0	100	19	-1.5	3.6	6.0	120
9	-4.5	-4.4	6.0	70	20	-1.5	4.4	6.0	120
10	-4.5	-3.6	6.0	70	21	-4.5	3.6	6.0	100
11	-7.5	-4.4	6.0	150	23	-7.5	3.6	6.0	70
12	-7.5	-3.6	6.0	150	24	-7.5	4.4	6.0	70

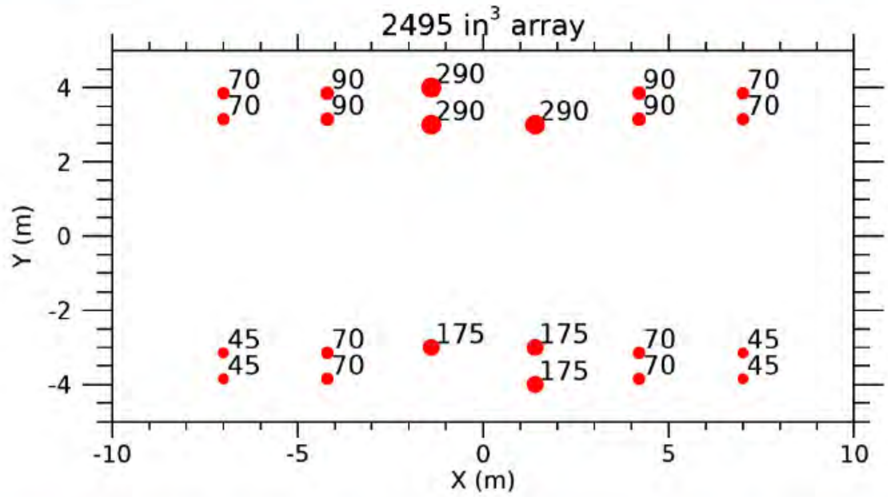

Figure B-1. Layout of the modelled 2495 in^3 array. Tow depth is 6 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table B-1.

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 seismic source (Appendix B.2). Horizontal decidecade-band source levels are shown as a function of band centre frequency and azimuth in Figure B-3.

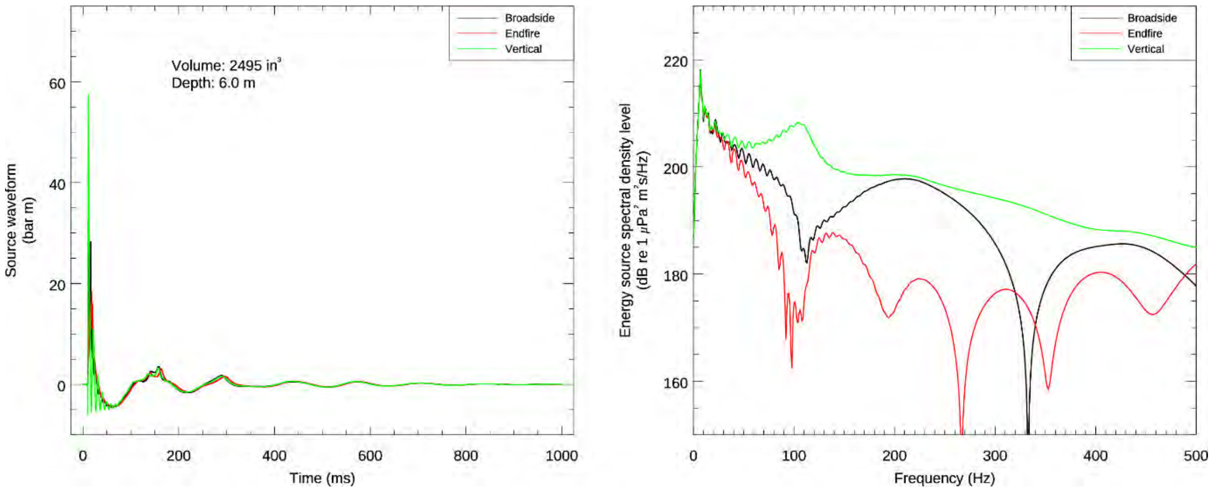

Figure B-2. Predicted source level details for the 2495 in^3 seismic source with a 6 m towed depth. (Left) the overpressure signature and (right) the power spectrum for in-plane horizontal (broadside), perpendicular (endfire), and vertical directions (no surface ghost).

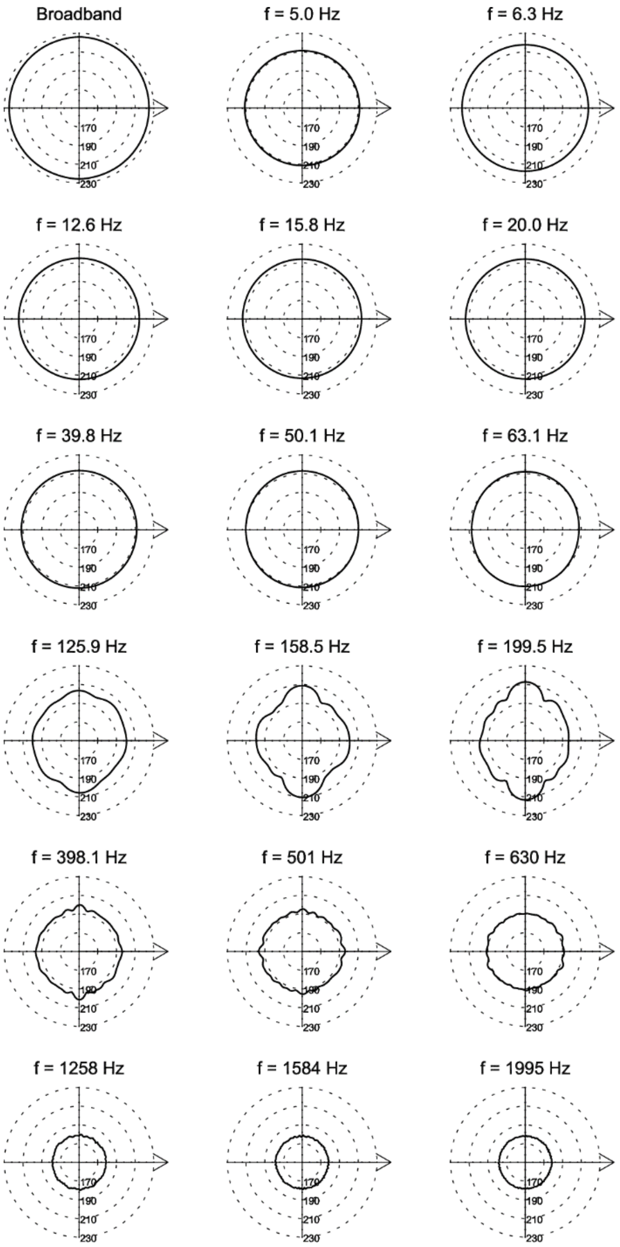

Figure B-3. Directionality of the predicted horizontal source levels for the 2495 in^3 seismic source, 5 Hz to 2 kHz. Source levels (in dB re 1 µPa^2·s m^2) are shown as a function of azimuth for the centre frequencies of the decidecade bands modelled; frequencies are shown above the plots. The perpendicular direction to the frame is to the right. Tow depth is 6 m.

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).

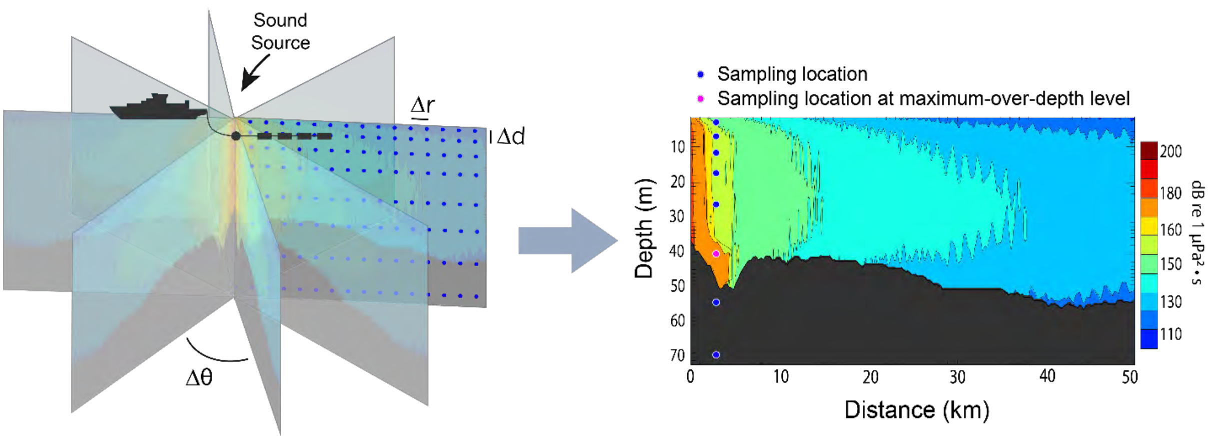

Figure C-1. The N×2-D and maximum-over-depth modelling approach used by MONM.

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 for two sites (100 and 200 m water depth) for both airgun arrays. 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 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.2, 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.

C.3.2. Limestone Seabed Propagation Loss

For all modelled sites, an additional broadband correction was applied to the propagation loss results from MONM to better account for the additional propagation loss associated with a calcarenite/limestone seabed. The differences between the broadband per-pulse SEL from MONM and VSTACK were extracted at the same modelled ranges and depths for corresponded range independent environments. The 90th percentile of the resultant dB differences in range bins were selected to generate a correction function for representative sites to be modelled. The conversion functions were applied after to the summed decidecade band levels from MONM, but before gridding, and radii calculations for each modelled site in each modelled scenario considered.

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.

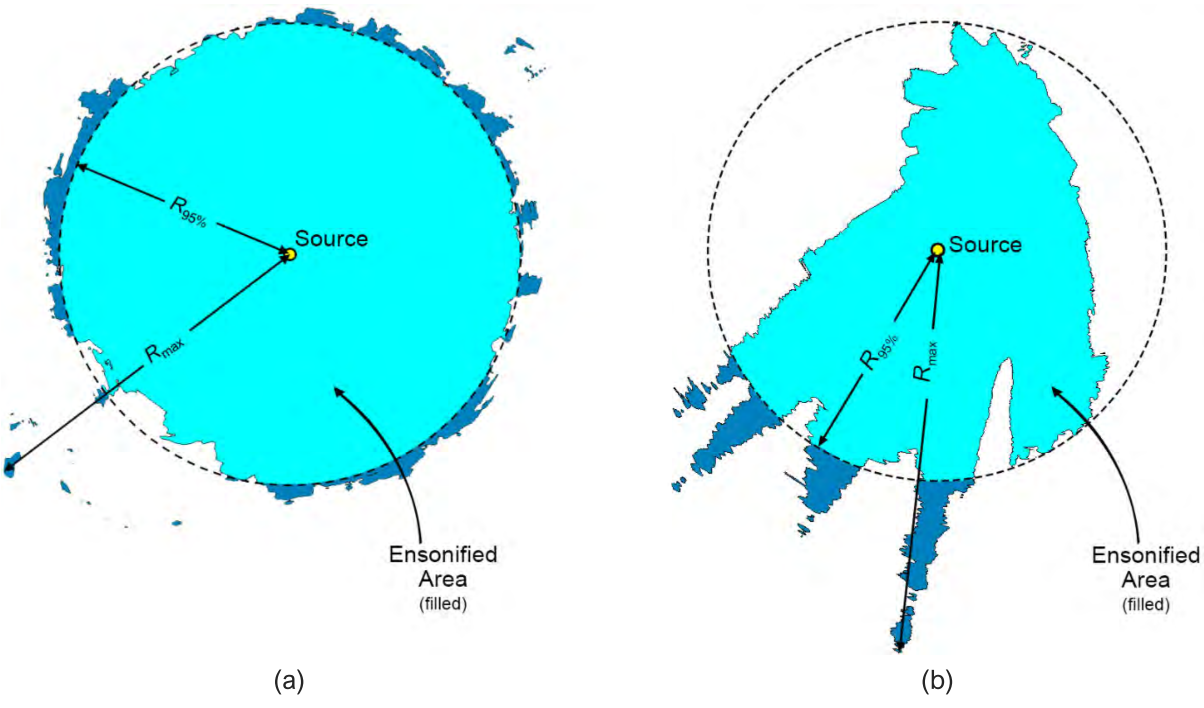

Figure D-1. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified areas bounded 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 10–1024 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 and D-3 show the conversion offsets for Sites 3 and 5 for the 2495 in^3 array; the spatial variation is caused by changes in the received airgun pulse as it propagates from the source.

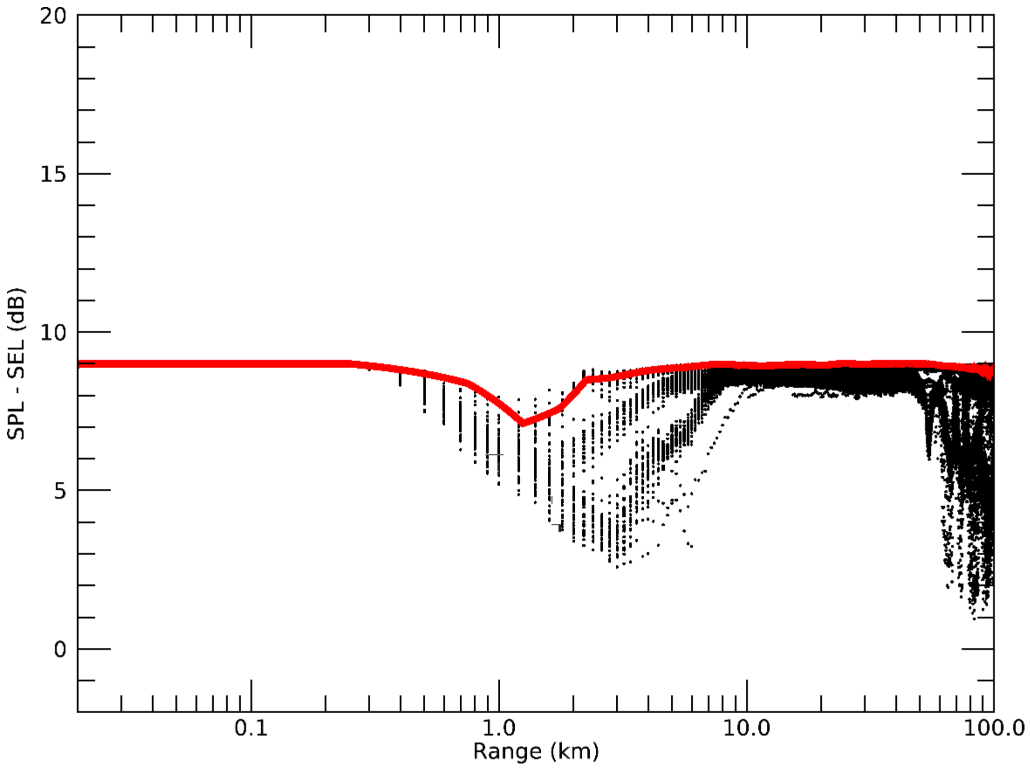

Figure D-2. *Site 3*: Range-and-depth-dependent conversion offsets for converting sound exposure level (SEL) to sound pressure level (SPL) for seismic pulses. Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

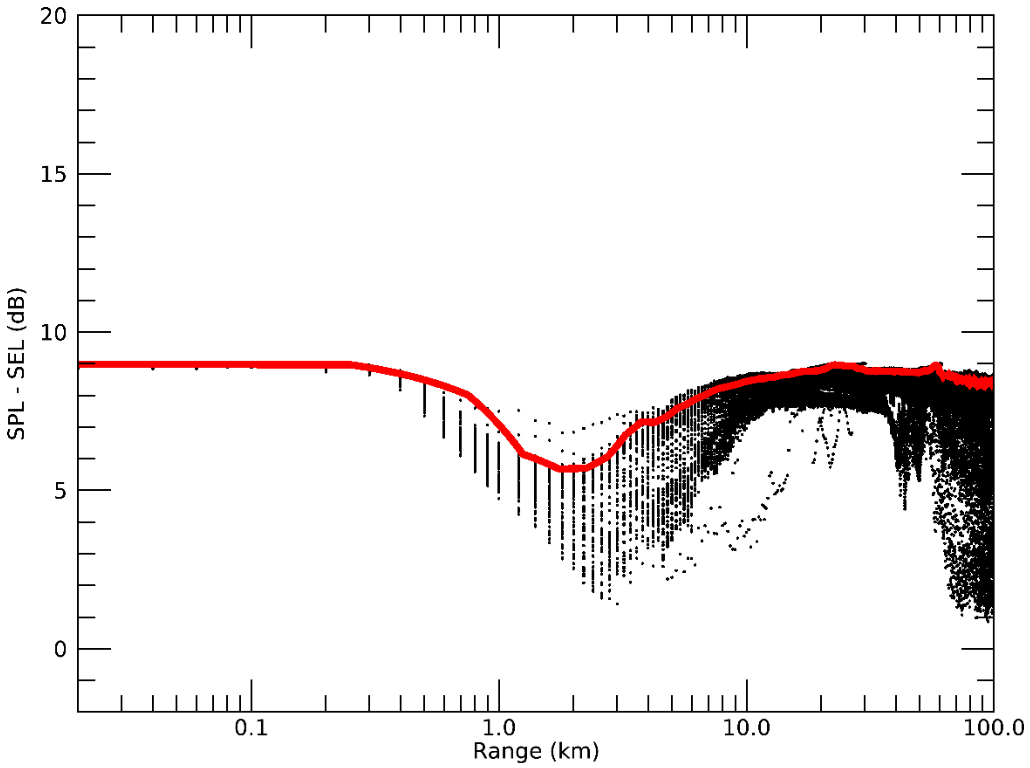

Figure D-3. *Site 5*: Range-and-depth-dependent conversion offsets for converting sound exposure level (SEL) to sound pressure level (SPL) for seismic pulses. Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

D.3. Environmental Parameters

D.3.1. Bathymetry

Water depths throughout the modelled area were extracted from high resolution bathymetry data supplied by the client and. The Australian Bathymetry and Topography Grid is a 9 arc-second grid rendered for Australian waters (Whiteway 2009). Re-rendering and merging of these two data sets was conducted by re-gridding and averaging the fine resolution bathymetry with the larger scale Australian Bathymetry and Topography Grid. The final dataset was grid onto a Map Grid of Australia (MGA) coordinate projection (Zone 50) with a regular grid spacing of 200 × 200 m to generate the bathymetry in Figure D-4. This process may result in some water depth mismatch between higher resolution data and the Australian Bathymetry and Topography Grid; however, care was taken to reduce the potential for edge artefacts in merged data corrupting numerical predictions.

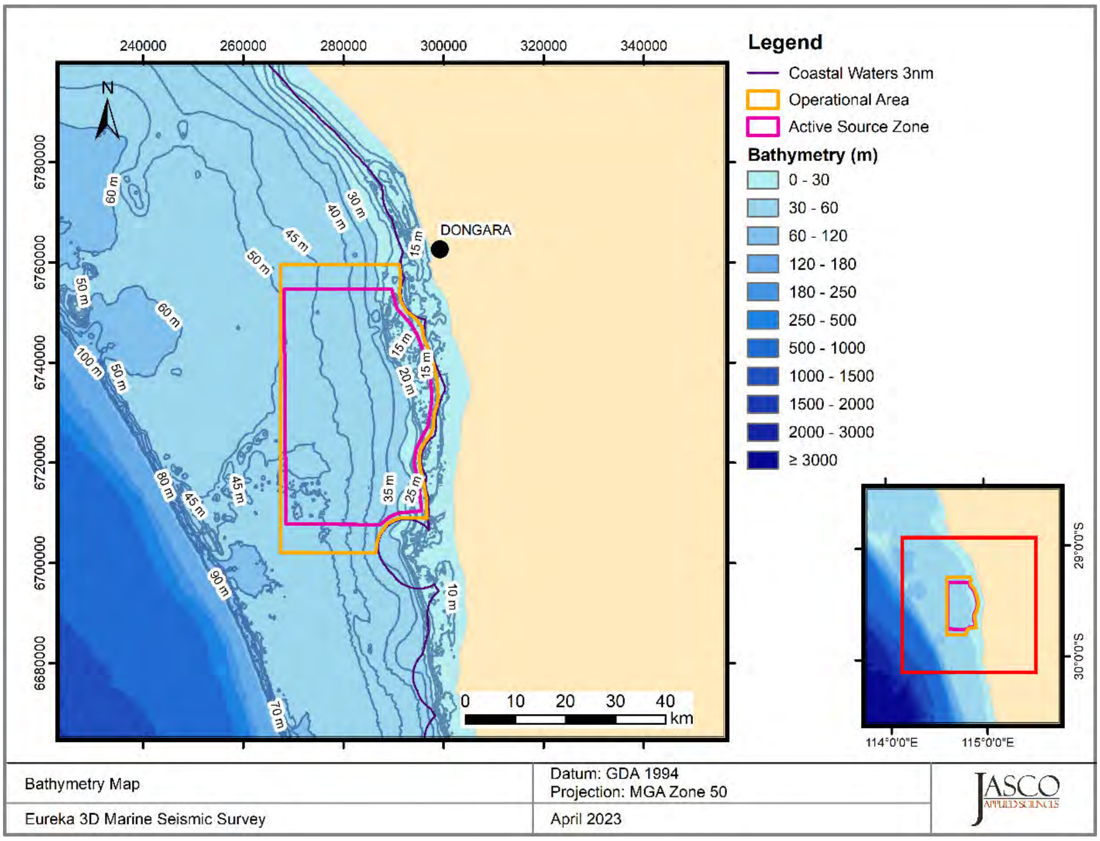

Figure D-4. Bathymetry map of the modelling area for the Eureka Marine Seismic Survey.

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 August sound speed profile is expected to be most favourable to longer-range sound propagation during the proposed survey time frame. As such, August was selected for sound propagation modelling to ensure precautionary estimates of distances to received sound level thresholds. Figure D-5 shows the resulting profile used as input to the sound propagation modelling.

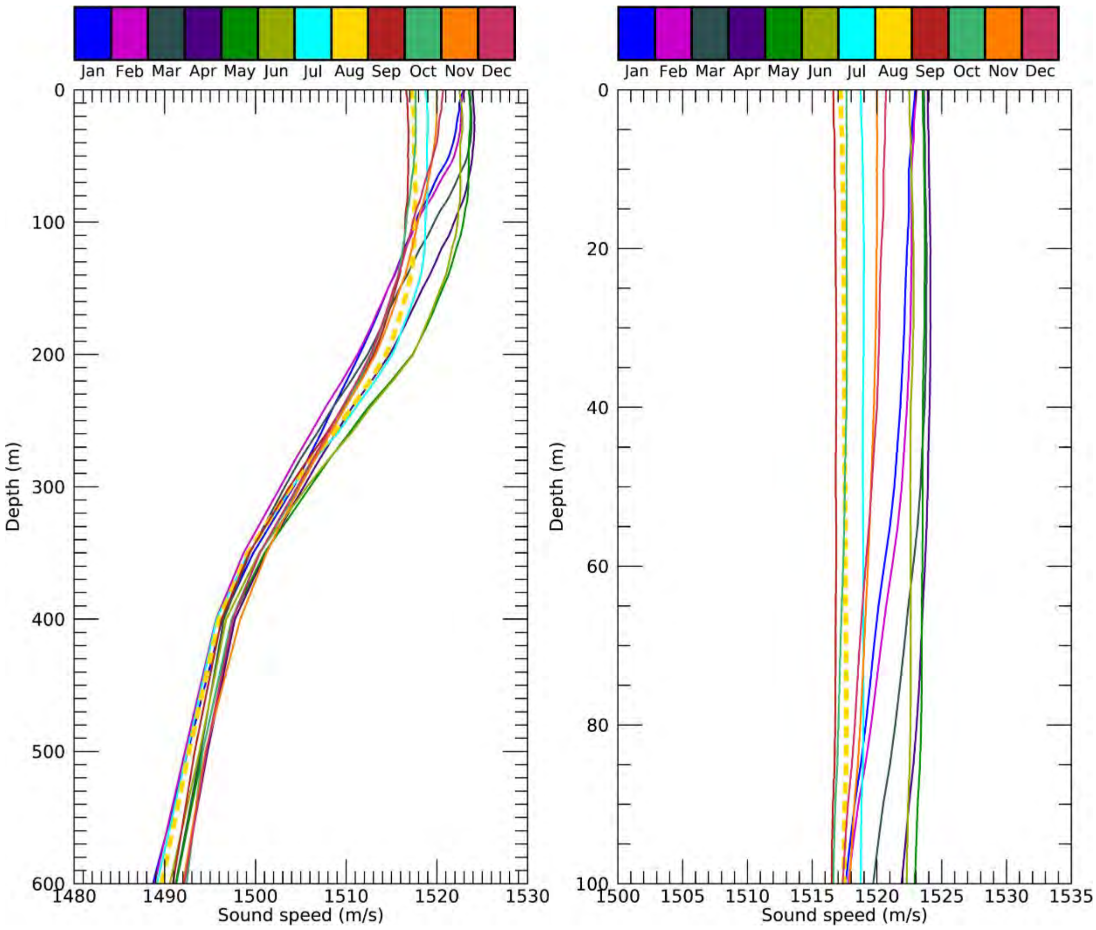

Figure D-5. The sound speed profile used for sound propagation modelling at all sites (August).

D.3.3. Geoacoustics

The propagation models used in this study consider a single geoacoustic profile. Several papers describe a potential geoacoustic models estimated via acoustic inversion (Duncan et al. 2008, Fan et al. 2009). These models consist of a thin sand layer underlain by a semi-cemented limestone/calcarenite bottom. A nominal three-layer representation of the seabed has been proposed based on this information; however, the studies all give slightly different geoacoustic values and layer thicknesses. The seabed model consists of sand/calcarenite/limestone basement where the geoacoustic parameters were averaged and adjusted slightly to obtain representative geoacoustic values. The selected seabed profile is indicative of benthic an environment located on the continental shelf and are consistent with larger scale geological data and interpretations of the Australian continental shelf environment (James and Bone 2010).

Acoustic propagation over calcarenite seabeds generally results in higher rates of loss at distance away from the source as compared to seabeds that contain thick packages of unconsolidated sediments (Duncan et al. 2009), as such additional modelling was conducted to account for the propagation loss associated with a limestone seabed (See Appendix C.3.2). The geoacoustic parameters considered for modelling are provided in Table D-1.

Table D-1. Geoacoustic profile for modelled sites.

Depth below seafloor (m)	Material	Density (g/cm^3)	P-wave speed (m/s)	P-wave attenuation (dB/λ)	S-wave speed (m/s)	S-wave attenuation (dB/λ)
0–1	Sand	1.73	1848	0.43	400	0.5
1–451	Semi-cemented Calcarenite	2.37	2672	0.21		
>451	Limestone Basement	2.40	3550	0.2		

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).

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Technical Memo

DATE: 20 December 2023

FROM: (JASCO Applied Sciences (Australia) Pty Ltd)

TO: RPS

DOCUMENT 03171

VERSION 1.0

Subject: Animal Movement Modelling for the Eureka 3D MSS

JASCO Applied Sciences (JASCO) previously conducted modelling for the Eureka 3D Marine Seismic Survey (MSS) and considered a seismic source array with a volume of 2495 in^3. A change has been requested to include animal movement and exposure modelling for the 2495 in^3 scenario with a shot point interval (12.5 m). Foraging and northbound migrating pygmy blue whales *(Balaenoptera musculus brevicauda)* have been considered. The acoustic and animal movement modelling has been conducted with particular focus on the amount of ensonification of biologically important areas (BIAs) for pygmy blue whales. The migration and known foraging areas for pygmy blue whales are considered herein.

1. Modelling Scenarios

One acquisition scenario was considered using animal movement and exposure modelling. The previous acoustic modelling consisted of both source and propagation modelling, which was conducted at three individual single-impulse sites (Koessler and McPherson 2023). The single impulse sites and the accumulated SEL scenarios were determined based on proposed survey line plans. This study considered a 2495 in^3 seismic source towed in a double array configuration at an assumed speed of ~4.5 knots with an impulse interval (inter-pulse interval) of 12.5 m and a crossline array separation of 50 m.

Table 1 presents the particulars of the scenario and Table 2 presents the sites used in the modelling. Figure 1 presents a map of the spatial extent of the modelled survey lines, sites, and BIAs.

Table 1. Parameters for modelled scenario

Scenario	Source volume (in^3)	Tow depth (m)	Tow direction (°)	Source configuration	Impulse interval (m)	Discharged impulses
2[†]	2495	6	0 & 180	Double	12.5	8558

[†] As presented in Koessler and McPherson (2023).

Table 2. Location details for the single impulse modelled sites

Site	Latitude (°S)	Longitude (°E)	MGA[1] Zone 50		Water depth (m)
			X (m)	Y (m)	
4	29° 23' 08.13"	114° 40' 10.60"	273835	6747035	45.0
5	29° 30' 13.53"	114° 40' 17.24"	274276	6733941	47.0
6	29° 22' 53.53"	114° 38' 08.87"	270544	6747419	48.0

[1] Map Grid of Australia (MGA)

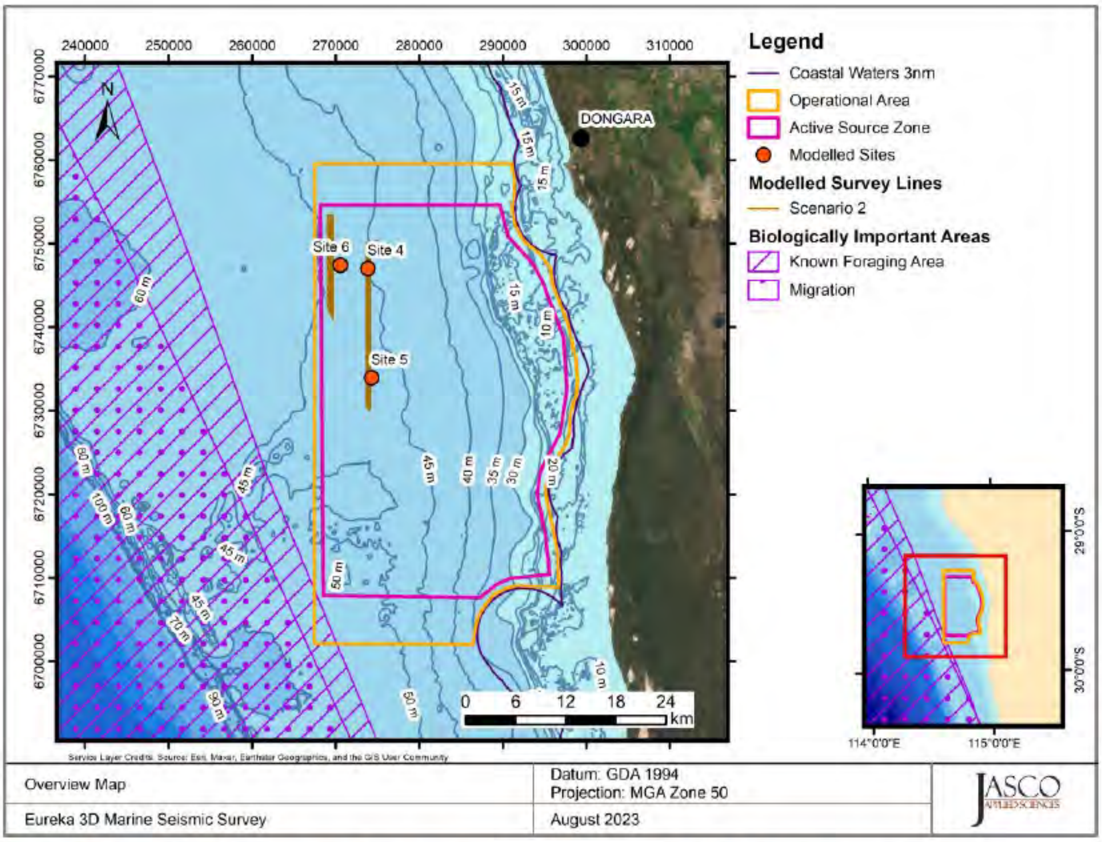

Figure 1. Overview of key survey features, modelled locations, and the survey scenario.

2. Noise Effect Criteria

The perceived loudness of sound, especially impulsive noise such as that 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. 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. (2019). 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 were chosen because they include standard thresholds, thresholds suggested by the best available science:

1. 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 as applied to pygmy blue whales (low-frequency cetaceans, baleen whales).

Further detail on noise effect criteria is provided in Koessler and McPherson (2023).

3. Methods

The methods for acoustic modelling applied herein are the same as presented in Koessler and McPherson (2023). For completeness, the methods employed for animal movement modelling are presented below in Section 3.1.

3.1. Animal Movement and Exposure Modelling

3.1.1. 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. An overview of the exposure modelling process using JASMINE is shown in Figure 2.

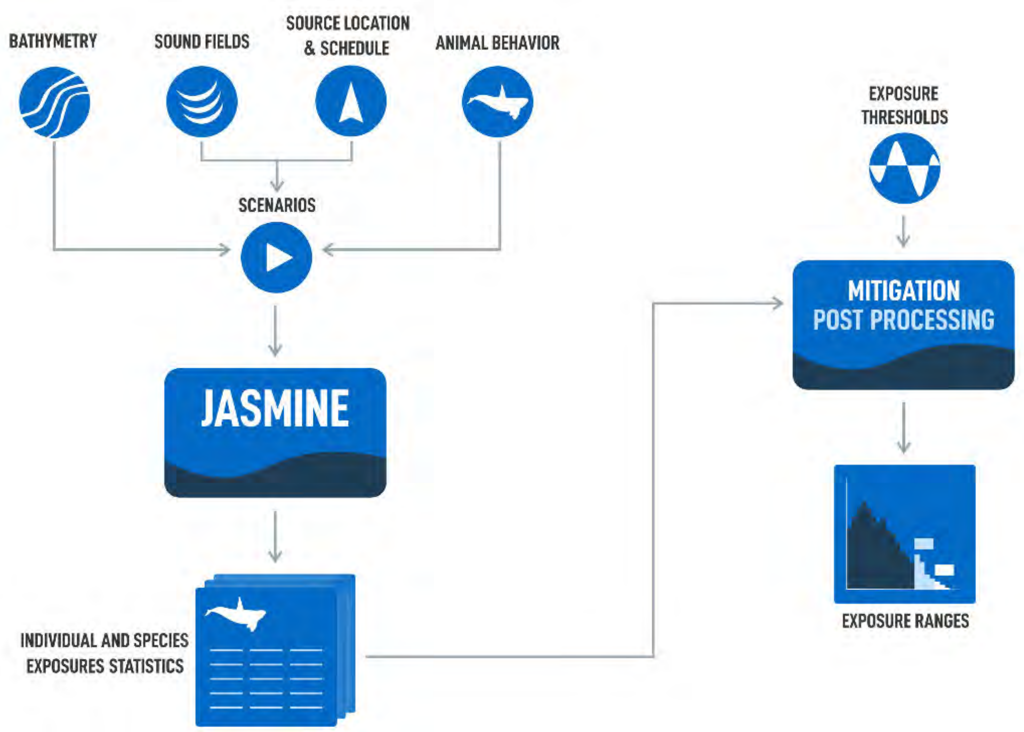

Figure 2. Exposure modelling process overview.

In JASMINE, the sound received by the animats is determined by the proposed seismic operations. As illustrated in Figure 3, 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 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. For additional information on JASMINE, see Appendix A.

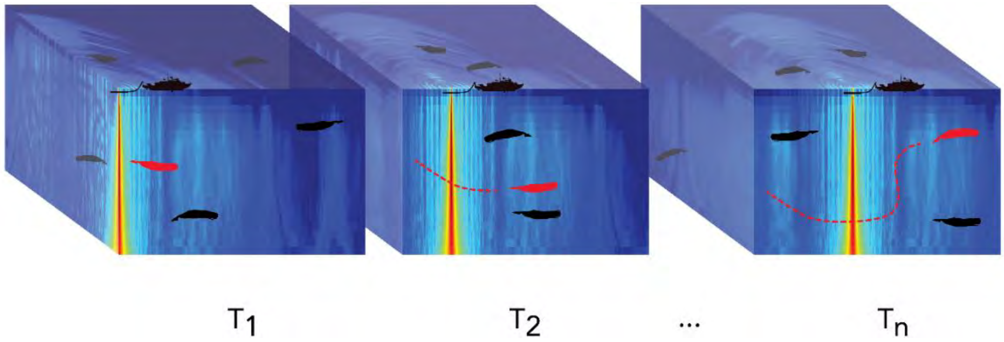

Figure 3. Depiction of animats in a moving sound field. Example animat (red) shown moving with each time step (T_n). The acoustic exposure of each animat is determined by where it is in the sound field, and its exposure history is accumulated as the simulation steps through time.

The exposure criteria for impulsive sounds (described in Koessler and McPherson (2023)) 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 BIAs or known core range area, as the density of animals is not known. To evaluate PTS and TTS, exposure results were obtained using detailed behavioural information for pygmy blue whales (Section 3.1.3.1).

The seismic source was modelled as a vessel towing an airgun array at a speed of 4.5 knots, with an impulse interval of 12.5 m. The simulated source tracks followed a racetrack configuration with no acquisition occurring during 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 4 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.

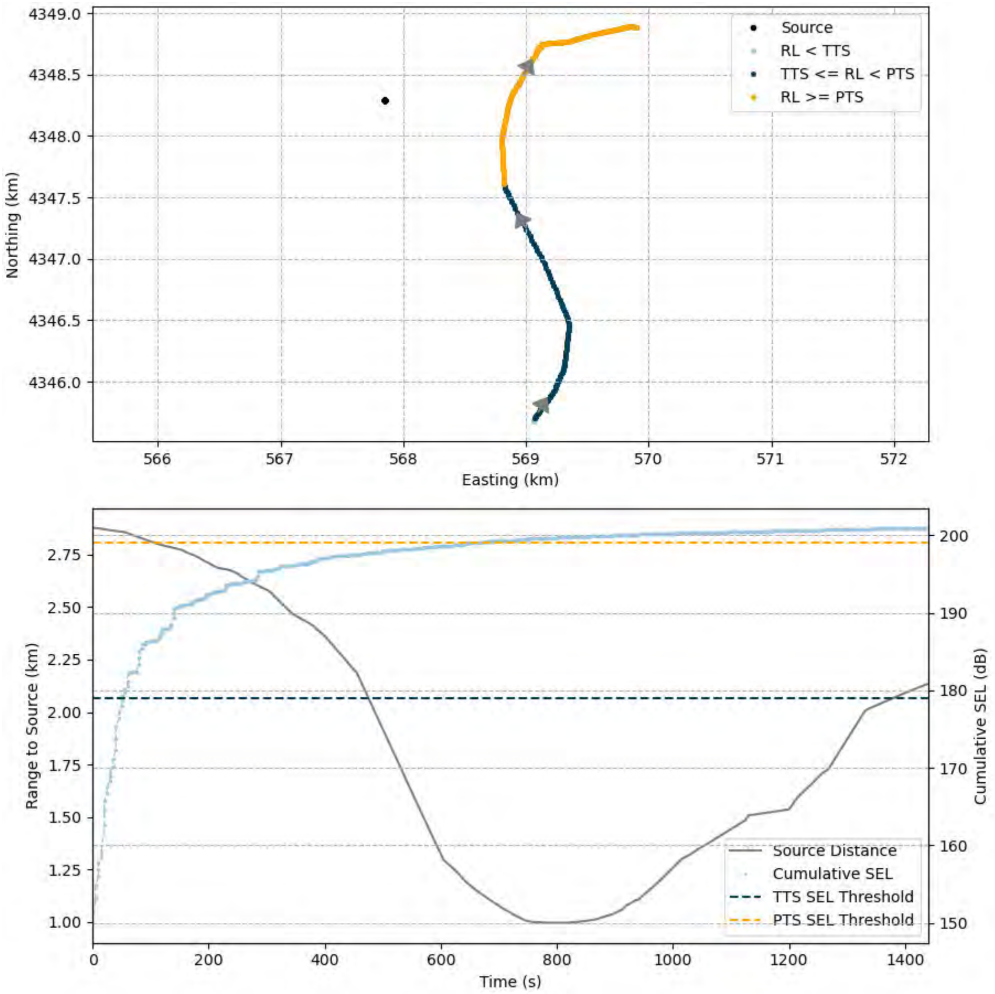

Figure 4. Animat track from an example simulation showing northward movement over a 1400 s duration. The upper panel shows a plan view of both a stationary point source and a foraging animat. Animat steps are coloured to indicate whether the accumulated sound energy at that point has exceeded either 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.

3.1.2. 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. 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 behavioural 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.

Acoustic ranges are reported for both $R_{95\%}$ and R_{max} (see Appendix D, Koessler and McPherson (2023)), however, exposure ranges are reported for $ER_{95\%}$ only since, statistically, ER_{max} is not defined. JASMINE is a Monte Carlo simulation, and the results are probabilistic in nature. This is in contrast with acoustic modelling, where there is a specific maximum isopleth range for a given source/environment setup.

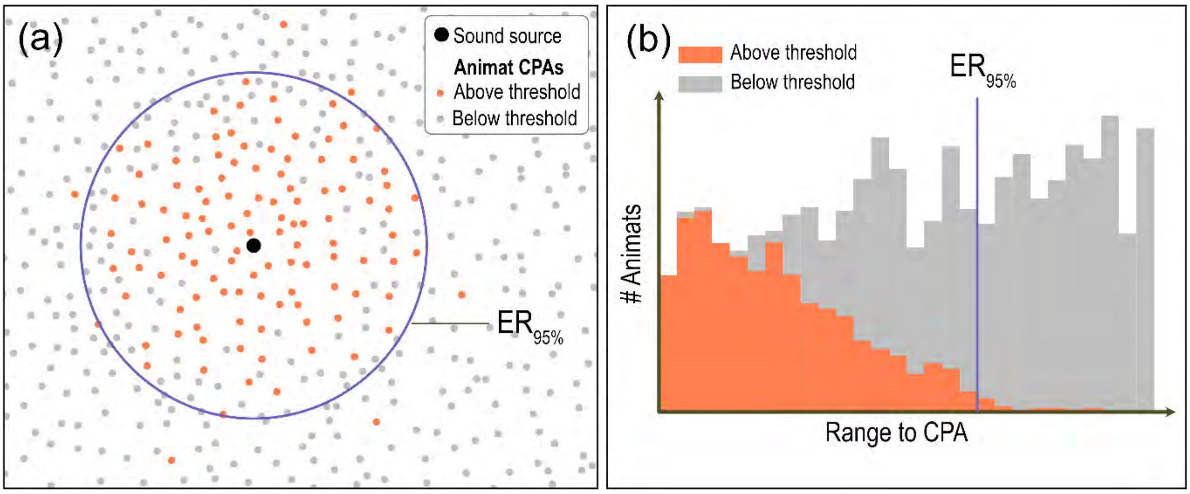

Figure 5. Example distribution of animat closest points of approach (CPAs). Panel (a) shows the horizontal distribution of animats near a sound source. Panel (b) shows the distribution of distances to animat CPAs. The 95% exposure range ($ER_{95\%}$) is indicated in both panels.

3.1.3. Species Specific Behaviour Profile Parameterisation

3.1.3.1. Pygmy Blue Whale Behaviour Profile

The project area is adjacent to the known foraging BIA for pygmy blue whales (DoE (AU) 2015-2025), as well as to the pygmy blue whale migratory BIA (Figure 1). Therefore, animat modelling was undertaken for both foraging and migrating behaviours.

Fine-scale data on foraging behaviour are not currently available for pygmy blue whales. Therefore, data from multi-sensor tags deployed on blue whales (B. musculus) in the North Pacific were used to inform the feeding behaviours. Using intermediate-duration archival tags (SPLASH MK10) attached to eight blue whales off the coast of California, Irvine et al. (2019) determined two primary feeding behaviours: shallow and deep feeding. These two feeding behaviours differed between male and female blue whales, with females generally diving deeper than males during both shallow and deep feeding. In order to account for these differences, foraging female and male pygmy blue whales were modelled separately, with values derived from Irvine et al. (2019). The remaining parameters for feeding behaviour were primarily sourced from Goldbogen et al. (2011b), who deployed 25 multi-sensor suction cup tags (DTAGs) on blue whales off the coast of California. The exceptions were the values for travel speed, which was derived from satellite tags deployed on pygmy blue whales off southern Australia (Möller et al. 2020), and surface interval, which was derived from a satellite tag deployed on a pygmy blue whale off western Australia (Davenport et al. 2022).

The migratory pygmy blue whale behaviour profile was not split by gender as there is no evidence for sex-related differences in migratory behaviour. The migratory profile included both migratory and exploratory dives (i.e., shallow dives with no indication of feeding) based on detailed information from Owen et al. (2016), who equipped a sub-adult pygmy blue whale with a multi-sensor tag off Western Australia. Migrating pygmy blue whales were not modelled undertaking feeding behaviour, as per the findings of Owen et al. (2016). In the migratory profile, the two dive types were modelled together such that the animats were migrating 95% of the time and engaged in exploratory dives 5% 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. Additional parameters regarding pygmy blue whale behaviour were derived from sources that used multi-sensor tags to record fine-scale dive and movement data (Owen et al. 2016, Möller et al. 2020). Where information was unavailable for pygmy blue whales, parameters were derived from blue whale tagging data (Goldbogen et al. 2011a), as per the foraging profile.

The behaviour of migrating pygmy blue whales was modelled to reflect animats transiting through the modelling area on a 334° track during the northbound migration. This represents the animals migrating along the west coast of Australia to 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).

4. Results

Details of the acoustic modelling results can be found in Koessler and McPherson (2023).

4.1. Animal Movement Exposure Ranges

A summary of radial distances to exposure thresholds for pygmy blue whales, along with probability of exposure for each modelled scenario (Section 1) are included below. Table 3 shows results for scenarios for foraging and migrating pygmy blue whale animats. Results include $ER_{95\%}$ exposure ranges calculated for the SEL_{24h} thresholds for both TTS and PTS, and the probability of an animat being exposed above the threshold within the $ER_{95\%}$.

Section 4.1.1 includes histograms of CPA ranges to SEL_{24h} PTS and TTS with results in Table 3.

Table 3. Summary of animat simulation results for pygmy blue whales. 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. The modelled array volume and inter-pulse interval are also provided in brackets below.

Noise Effect Criteria Description	Scenario 2 (2495 in^3, 12.5 m)					
	Foraging				Migrating	
	Female		Male			
	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)
PTS (SEL_{24h})[1]	0.89	63	0.82	66	0.63	54
TTS (SEL_{24h})[2]	14.5	57	13.7	59	8.47	70

[1] LF-weighted SEL_{24h} (183 dB re 1 µPa^2·s) (Southall et al. (2019))
[2] LF-weighted SEL_{24h} (168 dB re 1 µPa^2·s) (Southall et al. (2019))

4.1.1. Exposure Range Histograms: Pygmy Blue Whales

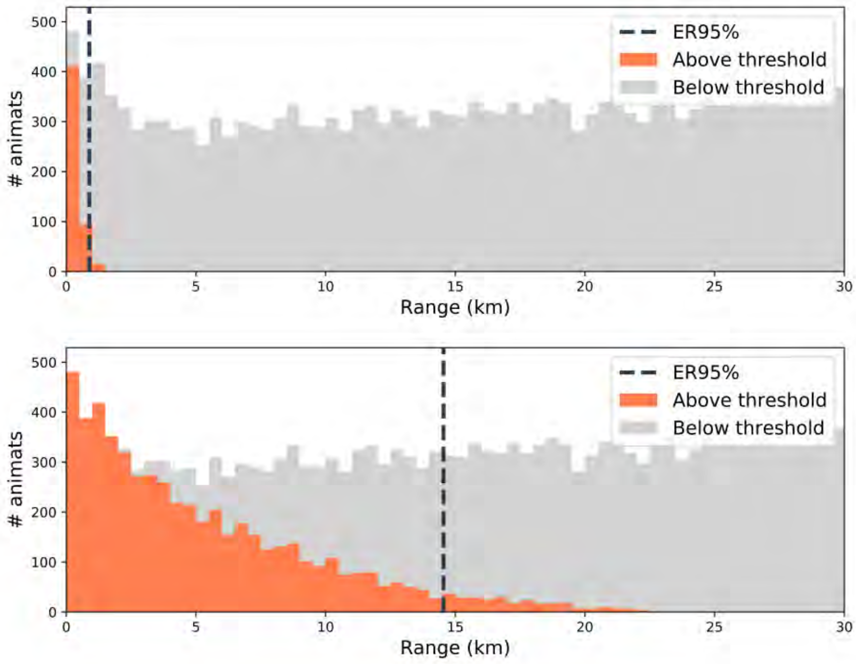

Figure 6. *Scenario 2*, *foraging female pygmy blue whale animats*: CPA range histogram for animats, SEL_{24h} PTS threshold (top panel) and SEL_{24h} TTS threshold (bottom panel).Bar colours indicate whether the animats exceeded the threshold.

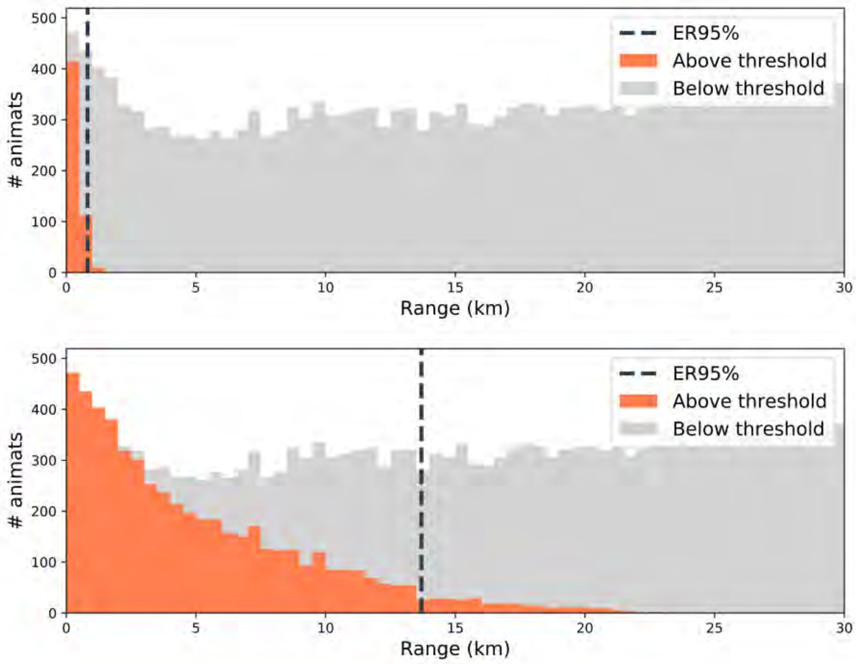

Figure 7. *Scenario 2, foraging male pygmy blue whale animats*: CPA range histogram for animats, SEL_{24h} PTS threshold (top panel) and SEL_{24h} TTS threshold (bottom panel).Bar colours indicate whether the animats exceeded the threshold.

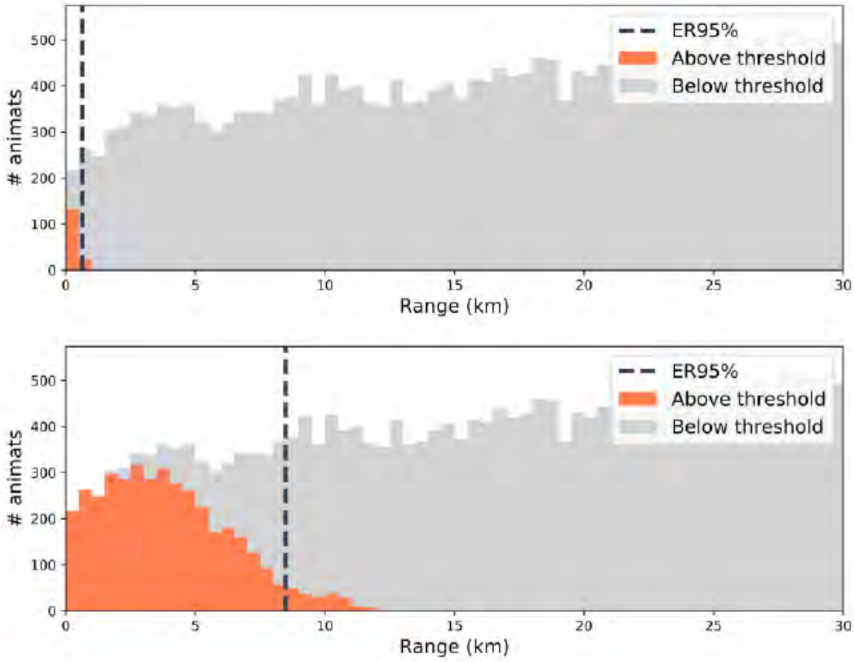

Figure 8. *Scenario 2, migrating pygmy blue whale animats*: CPA range histogram for animats, SEL_{24h} PTS threshold (top panel) and SEL_{24h} TTS threshold (bottom panel).Bar colours indicate whether the animats exceeded the threshold.

5. Discussion

5.1. Animal Movement Modelling

The estimated sound fields produced by source and propagation models for the planned Eureka MSS were incorporated into an animat sound exposure model for pygmy blue whales to estimate the radial distance within which 95% of exposure exceedances occur ($ER_{95\%}$), along with the probability that an animat with its closest point of approach within that distance would be exposed above the relevant threshold (P_{exp}).

For this exposure analysis, one nominal acquisition scenario with an impulse interval of 12.5 m was run for foraging and northbound migrating pygmy blue whales. The nominal acquisition scenario is located approximately 13.5 and 18.5 km outside of the known core range area and the migrating BIA, respectively. Animats were not restricted to the known core range area or BIA.

Section 5.1.1 summarises the PTS and TTS exposure range results, with the summarised results presented in Table 4.

Table 4. Summary of animat simulation results for PTS and TTS criteria for pygmy blue whales. Maximum exposure ranges show $ER_{95\%}$ (km) first and probability of exposure of animats travelling within the $ER_{95\%}$ (P_{exp} (%)) in parentheses.

Species	Scenario	TTS (SEL_{24h})[2]	PTS (SEL_{24h})[2]
		168[1]	183[1]
Pygmy blue whale	2 (2495 in^3,12.5 m)	14.5	0.89

[1] LF-weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)

[2] Southall et al. (2019) criteria for marine fauna.

5.1.1. 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 moving animats generally accumulate sound energy over a shorter time ('dwell time'). In this study, PTS and TTS exposure ranges were substantially shorter than acoustic ranges to threshold.

All considered scenarios with unrestricted animat seeding resulted in exposures above the PTS and TTS thresholds. The maximum $ER_{95\%}$ for PTS and TTS were 0.89 and 14.5 km, respectively, with corresponding exposure probabilities for animats travelling within that range of 63% and 57%, indicating that 37% and 43% of animats that travelled within the 95th percentile range were not exposed above threshold. This is because the modelled animats move in and out of the ensonified area and change their vertical position in the water column, thereby influencing 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 sound exposure, or they may spend more time at depths where sound levels are lower.

The animal movement and exposure modelling presented herein is a more realistic estimate of the dosimetric impact potential for accumulated sound exposure compared to static receiver accumulated sound exposure modelling scenarios presented in Koessler and McPherson (2023) .

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Appendix A. Animal Movement and Exposure Modelling

Animal movement and exposure modelling considers the movement of both sound sources and animals over time. Acoustic source and propagation modelling are used to generate 3-D sound fields that vary as a function of 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 events 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 typically much higher than real-world animal density to ensure good representation of the PDF. The resulting PDF can be scaled using real-world density when such data are available.

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 animats 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 (FRAWM) 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.

A.1.1. 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 animats 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 animats 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 animats 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 animats rate of travel in the vertical plane during the ascent portion of a dive.
- **Descent rate**–defines an animats rate of travel in the vertical plane during the descent portion of a dive.
- **Depth**–defines an animats 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.

A.1.2. Exposure Integration Time

The interval over which acoustic exposure (LE) should be integrated and maximal exposure (Lp) 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.

A.1.3. 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 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 impulsive sounds were used to determine the number of animats exceeding exposure thresholds. To generate statistically reliable probability density functions, all simulations were seeded with an animat density of 4 animat/km^2 over the entire simulation area. The modelling results are not related to real-world animal densities as this data is not available, and the number of real-world animals potentially exposed could not be calculated.

Technical Memo

DATE: 9 May 2025

FROM: Matthew Koessler (JASCO Applied Sciences (Australia) Pty Ltd)

TO: Pennie Ginn, Matt Fraser (Klarite)

DOCUMENT 03816

VERSION 1.0

Subject: Acoustic Modelling for the Eureka 3D MSS with seabed nodes

JASCO Applied Sciences (JASCO) previously conducted modelling for the Eureka 3D Marine Seismic Survey (MSS). A change has been requested to investigate the underwater noise emissions considering a 1440 in^3 source with a shot point interval of 50 m. The use of this source will be used with seabed seismometer nodes. The acoustic modelling has been conducted with particular focus when the survey is in operations over shallow coastal waters.

1. Modelling Scenarios

A single acquisition scenario was considered using acoustic modelling. Acoustic modelling consisted of both source and propagation modelling, which was conducted at two individual single-impulse sites. The single impulse sites and the accumulated SEL scenarios were determined based on proposed survey line plans. This study considered a 1440 in^3 seismic source towed in a double array configuration at an assumed speed of ~5 knots with an impulse interval (inter-pulse interval) of either 50 m and a crossline array separation of 50 m. For comparison purposes refer the other scenarios, parameters, and results from Koessler and McPherson (2023), which consider a 12.5 m inter-pulse interval and a 2495 in^3 array.

Table 1 presents the particulars of the scenarios and Table 2 presents the sites used in the modelling. Figure 1 presents a map of the spatial extent of the modelled survey lines, sites, and BIAs.

Table 1. Parameters for modelled scenarios

Scenario	Source volume (in³)	Tow depth (m)	Tow direction (°)	Source configuration	Impulse interval (m)	Discharged impulses
1-A	1440	5	0 & 180	Double	50	3455

Table 2. Location details for the single impulse modelled sites.

Site	Latitude (°S)	Longitude (°E)	MGA[1] Zone 50		Water depth (m)
			X (m)	Y (m)	
1-A	29° 24' 10.17"	114° 51' 16.44"	291825	6745469	14.7
2-A	29° 29' 31.85"	114° 51' 24.52"	292225	6735569	26.9

[1] Map Grid of Australia (MGA)

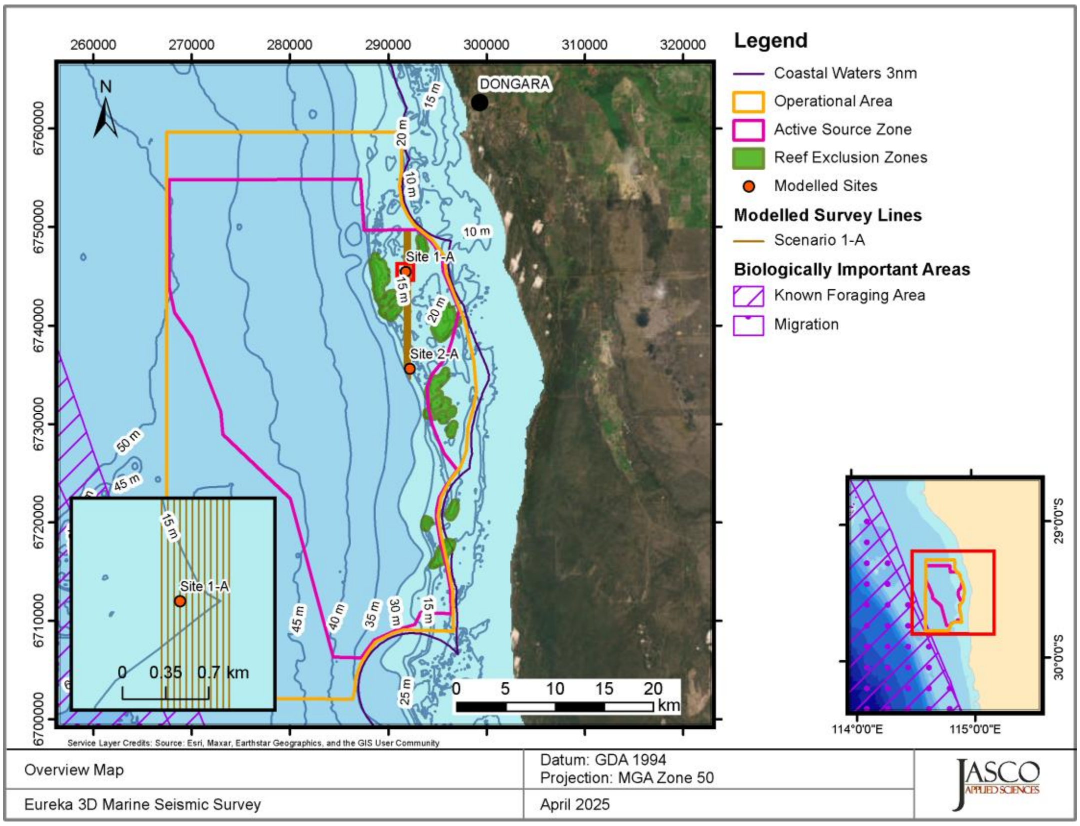

Figure 1. Overview of key survey features, modelled locations, and the survey scenario.

2. Noise Effect Criteria

The perceived loudness of sound, especially impulsive noise such as that 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. 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. (2019). 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 were chosen because they include standard thresholds, thresholds suggested by the best available science:

- 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.
- 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.
- Sound exposure guidelines for fish, fish eggs and larvae (including plankton) (Popper et al. 2014).
- Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from Finneran et al. (2017) for the onset of permanent threshold shift (PTS) and temporary threshold shift (TTS) in turtles.
- Sea turtle behavioural response threshold of 166 dB re 1 µPa (SPL; L_p) for impulsive noise, along with a sound level associated with behavioural disturbance 175 dB re 1 µPa (SPL; L_p) (McCauley et al. 2000).
- Peak-peak pressure levels (PK-PK; $L_{pk\text{-}pk}$) and peak particle acceleration magnitude (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).
- A sound level of 226 dB re 1 µPa (PK; L_{pk}) reported for comparing to Heyward et al. (2018) for sponges and corals.
- A startle (inking) response sound level of 162 dB re 1 µPa^{2}s per–pulse SEL (L_E) for squid from Fewtrell and McCauley (2012).
- An SPL human health assessment threshold of 145 dB re 1 µPa (SPL; L_p) for sound exposure to people swimming and diving derived from Parvin (2005), and considering Ainslie (2008).

Further detail on noise effect criteria is provided in Koessler and McPherson (2023).

3. Methods

The methods for acoustic modelling applied herein are the same as presented in Koessler and McPherson (2023).

4. Results

4.1. Acoustic source levels and directivity

Table 3 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 seismic array considered (1440 in^3 array with 5 m tow depth). The broadside, endfire, and vertical overpressure signature and corresponding power spectrum levels for the array are provided in Appendix A.

Table 3. Far-field source level specifications for the 1440 in^3 array with a 5 m tow depth. Source levels are for a point-like acoustic source with equivalent far-field acoustic output in the specified direction. Sound level metrics are per-pulse and unweighted.

Total Volume (in^3)	Direction	Peak source pressure level ($L_{S,pk}$; dB re 1 µPa m)	Per-pulse source SEL ($L_{S,E}$; dB 1 µPa^{2}m^{2}s)	
			10-2000 Hz	2000-25000 Hz
1440	Broadside	247.1	222.6	181.9
1440	Endfire	245.0	221.7	180.1
1440	Vertical	253.2	225.4	187.1

4.2. 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.
- 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 µPa2·s, relevant for the EPBC Act Policy Statement 2.1 (DEWHA 2008).
- Per-pulse SEL sound fields to determine the distances to the level associated with squid startle (inking) response (Fewtrell and McCauley 2012).
- 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)
- PK metrics at the seafloor are relevant to guidelines for fish, fish eggs and larvae 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.

Seafloor sound levels were assessed at eight different representative depths and Tables 7– 8 present the PK and PK-PK results. At these same water depths particle motion was also calculated and presented in Table 9

4.2.1.1. Entire Water Column

Table 4. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the seismic source to modelled maximum-over-depth (also maximised over tow modelled tow direction) 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-A (14.7 m)		Site 2-A (26.9 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	0.08	0.06	0.06	0.05
180	0.30	0.26	0.26	0.22
170	0.84	0.70	0.86	0.72
162[1]	2.30	1.90	2.56	2.10
160[2]	1.94	1.59	2.14	1.74
150	5.05	4.21	5.87	4.99
140	7.61	6.40	12.1	10.2
130	21.2	15.4	34.3	29.6

[1] Startle response level for squid (Fewtrell and McCauley 2012).
[2] Low power zone assessment criteria DEWHA (2008).

Table 5. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the seismic source to modelled maximum-over-depth (also maximised over tow modelled tow direction) 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-A (14.7 m)		Site 2-A (26.9 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.08	0.06	0.06	0.05
190	0.28	0.22	0.24	0.18
180	0.74	0.62	0.72	0.62
175[1]	1.28	1.04	1.28	1.06
170	2.06	1.67	2.22	1.80
166[2]	2.96	2.37	3.37	2.80
160[3]	4.94	4.06	5.53	4.75
150	7.26	5.99	11.1	9.48
145[4]	10.2	7.91	19.8	15.9
140	18.9	12.5	30.9	26.5
130	46.6	39.1	66.3	53.8

1 Threshold for turtle behavioural disturbance from impulsive noise.
2 Threshold for turtle behavioural response to impulsive noise (NSF 2011).
3 Marine mammal behavioural threshold for impulsive sound sources (NOAA 2019).
4 Human health assessment threshold derived from (Parvin 2005).

Table 6. Maximum (R_{max}) horizontal distances (in km) from the seismic source to modelled maximum-over-depth (also maximised over tow modelled tow direction) peak pressure level (PK) thresholds based on Southall et al. (2019) for marine mammals, and Popper et al. (2014) for fish and Finneran et al. (2017) for sea turtles, Sites 3 and 5), with water depth indicated.

Hearing group	PK threshold (L_{pk}; dB re 1 µPa)	Distance R_{max} (km)	
		Site 1-A (14.7 m)	Site 2-A (26.9 m)
Low-frequency cetaceans (PTS)	219	0.06	0.03
Low-frequency cetaceans (TTS)	213	0.11	0.09
High-frequency cetaceans (PTS)	230	–	–
High-frequency cetaceans (TTS)	224	–	–
Very-high-frequency cetaceans (PTS)	202	0.45	0.34
Very-high-frequency cetaceans (TTS)	196	0.82	0.85
Other Carnivores in Water (PTS)	232	–	–
Other Carnivores in Water (TTS)	226	–	–
Sea Turtles (PTS)	232	–	–
Sea Turtles (TTS)	226	–	–
Fish: No swim bladder (also applied to sharks)	213	0.11	0.09
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae	207	0.28	0.20

A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).

4.2.1.2. Seafloor

Ranges presented at the seafloor (50 and 5 cm above the interface) provided in Tables 7 and 8 are different to those for the maximum-over-depth modelling results presented in Table 6. 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 7. 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 two water depths within the Active Source Area.

Hearing group/animal type	PK threshold (L_{pk}; dB re 1 µPa)	Water Depth 10 m	Water Depth 15 m
		Distance R_{max} (m)	
Sound levels for sponges and corals[1]	226	2	4
Fish: No swim bladder (also applied to sharks)	213	45	44
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae	207	94	72

[1] Heyward et al. (2018)
An asterisk indicates that the sound level was not reached.

Table 8. 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 two water depths within the Active Source Area. Results included in relation to benthic invertebrates.

PK-PK ($L_{pk\text{-}pk}$; dB re 1 µPa)	Water Depth 10 m	Water Depth 15 m
	Distance R_{max} (m)	
213[1,2,3]	70	66
212[2,3]	75	69
210[1,2]	93	85
209[1,2]	103	91
202[4]	183	212

[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

4.2.1.2.1. Particle Motion Metrics

Table 9. Maximum (R_{max}) horizontal distances (in m) from the seismic source to particle motion threshold: Peak acceleration magnitude level (m/s^2) threshold for benthic invertebrates 5 cm above the seafloor, with water depth indicated.

Hearing group/animal type	Peak Acceleration Magnitude (m/s^2)	Water Depth 10 m	Water Depth 15 m
		Distance R_{max} (m)	
Benthic invertebrates	37.57	42	35

4.2.2. Sound Level Contour Maps

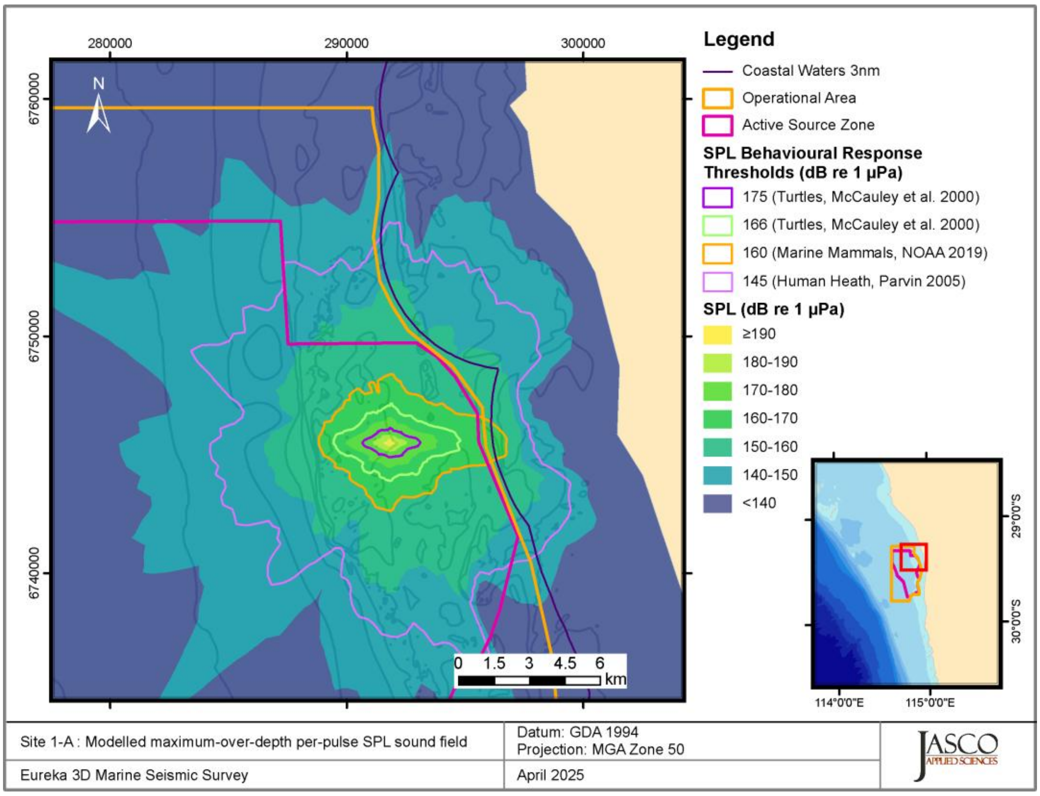

Figure 2. *Site 1-A, SPL, 1440 in³ source, tow azimuth 0*°: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

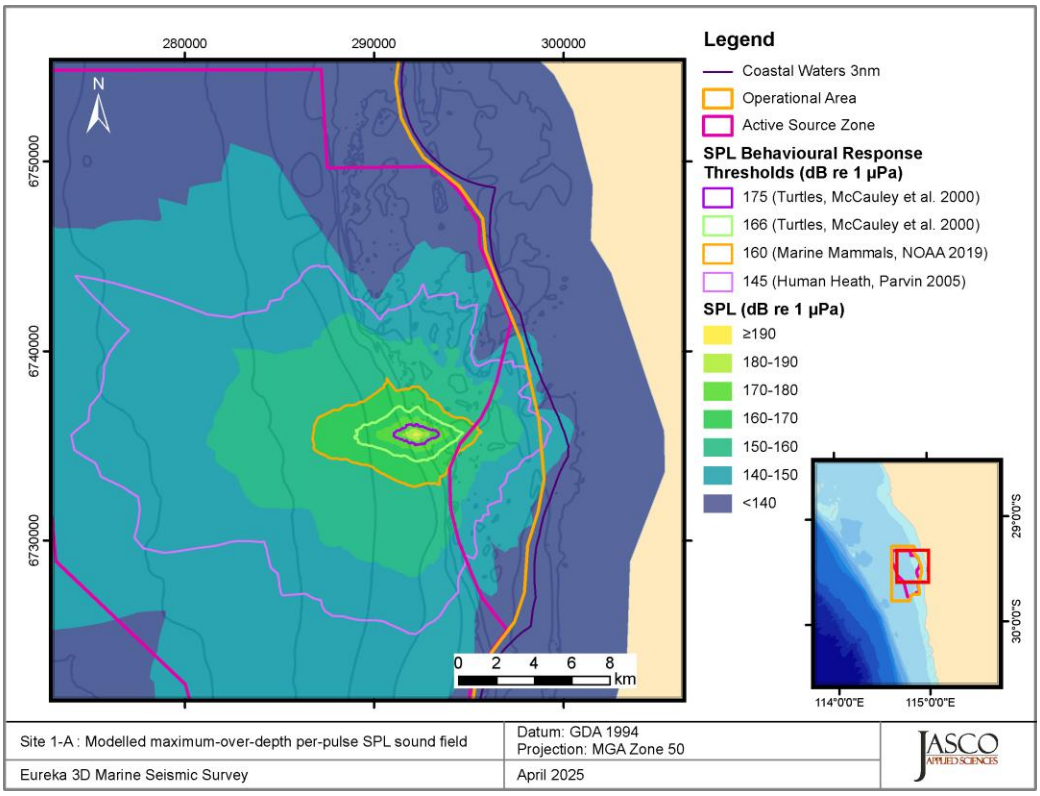

Figure 3. *Site 2-A, SPL, 1440 in³ source, tow azimuth 0°*: Sound level contour map of unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural response thresholds for marine mammals and turtles.

4.3. Multiple Source Fields

This section presents the sound fields in terms of SEL accumulated over 24 hours of survey, for the modelled scenarios. Frequency-weighted SEL_{24h} sound fields were used to estimate the maximum horizontal distances (R_{max}) to low frequency cetacean PTS and TTS thresholds.

The SEL_{24h} sound fields are presented as contour maps in Figure 4, it present's the unweighted SEL_{24h} in 10 dB steps, as well as the isopleths corresponding to thresholds for which R_{max} is greater than 20 m.

4.3.1. Tabulated Results

Table 10. Marine mammal criteria as applied to pygmy blue whales: Maximum (R_{max}) horizontal distances (in km) and ensonified area (km^2) from the survey lines to permanent threshold shift (PTS) and temporary threshold shift (TTS) thresholds considering 24 hours of survey activity (maximum-over-depth). The modelled array volume and inter-pulse intervals are also provided in brackets below each scenario number.

Hearing group	Weighted SEL thresholds ($L_{E,24h}$; dB re 1 µPa²·s)	Scenario 1-A	
		R_{max} (km)	Area (km^2)
PTS			
Low-frequency cetaceans	183	1.72	50.3
High-frequency cetaceans	185	–	–
Very-high-frequency cetaceans	155	0.07	2.78
Pinnipeds	203	–	–
Sea Turtles	204	0.07	2.78
TTS			
Low-frequency cetaceans	168	11.9	351.2
Low-frequency cetaceans	168	0.05	0.44
High-frequency cetaceans	170	0.10	10.3
Very-high-frequency cetaceans	140	0.07	2.53
Pinnipeds	188	0.98	31.9
Sea turtles	189	1.72	50.3

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 11. *Fish criteria*: Maximum horizontal distances (R_{max}, in km) from the survey lines and area (km^2) to injury and temporary threshold shift (TTS) thresholds considering 24 h of survey activity.

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 $\mu Pa^2 \cdot s$)	Scenario 1-A	
		R_{max} (km)	Area (km^2)
Mortality and potential mortal injury			
I	219	0.06	1.33
II, fish eggs and larvae	210	0.07	2.78
III	207	0.07	2.78
Fish recoverable injury			
I	216	0.07	2.78
II, III	203	0.07	5.33
Fish TTS			
I, II, III	186	2.46	65.0

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 sound level was not reached.

4.3.2. Sound Level Contour Maps

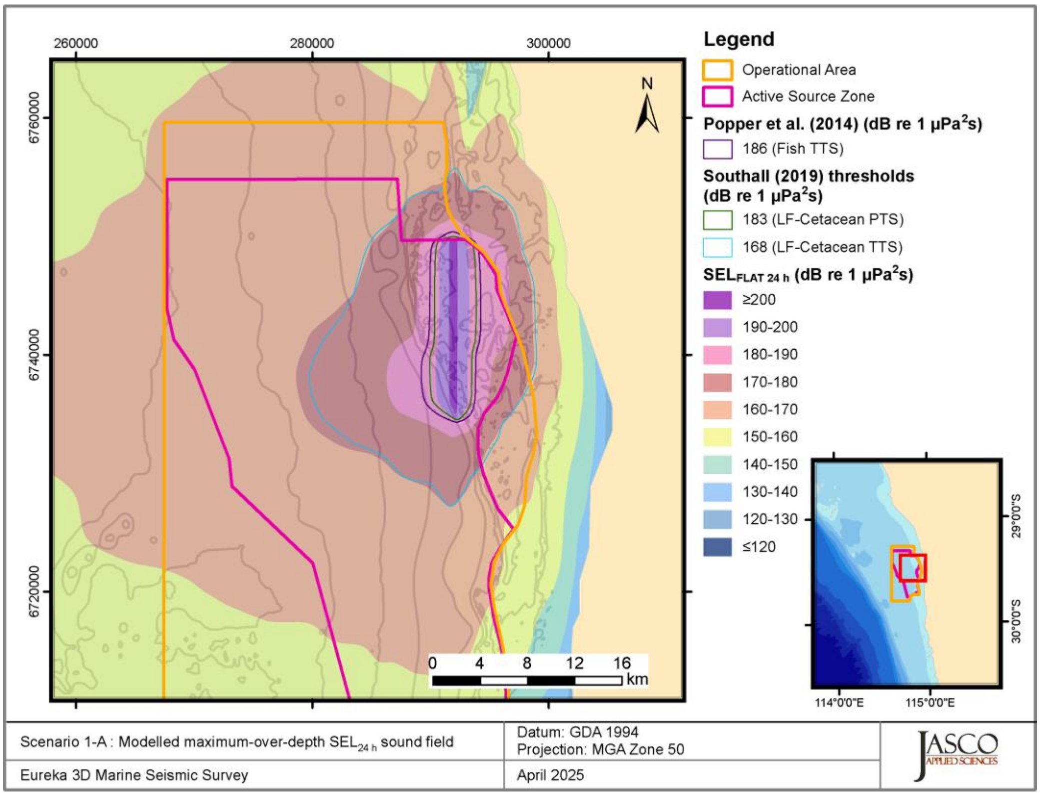

Figure 4. *Scenario .1-A, 1440 in³ with 50 m inter-pulse interval*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h}, along with thresholds for LF-cetaceans. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 10 for tabulated radii.

5. Discussion

5.1. Multiple Pulse Sound Fields

The accumulated SEL over 24 hours of seismic source operation was modelled considering representative scenarios with realistic acquisition patterns for shallow sections of the Eureka 3D MSS. The footprints and range maxima for SEL_{24h} criteria are substantially influenced by the number of impulses discharged. Compared to the original acoustic modelling, a smaller array volume and larger inter-pulse intervals reduced the maximum ranges to all relevant SEL_{24h} thresholds.

For the accumulated sound exposure scenarios, the SEL_{24h} is a cumulative metric that reflects the dosimetric effect of noise levels within 24 hours. It assumes a receiver (e.g., an animal) is consistently exposed to the noise at a fixed position. More realistically, marine animals would not stay in the same location for 24 hours. Therefore, a radius for the SEL_{24h} criteria does not mean that marine fauna within this radius will be impaired, but rather that the animal could be exposed to the sound level associated with impairment, either Permanent Threshold Shift (PTS) or Temporary Threshold Shift (TTS), if it remained at that location for 24 hours. The animal movement and exposure modelling discussed below presents a more realistic estimate of the dosimetric impact potential for accumulated sound exposure.

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Appendix A. Seismic Source

The layout of the seismic source used for modelling in this study is provided in Figure A-1 and details of the airgun parameters are provided in Table A-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.

Table A-1. Layout of the modelled 1440 in^3 array. Tow depth is 5 m. Firing pressure for all guns is 2000 psi. Also see Figure A-1.

String	Gun	*x* (m)	*y* (m)	*z* (m)	Vol (in^3)	String	Gun	*x* (m)	*y* (m)	*z* (m)	Vol (in^3)
1	1	6.25	-5.35	6.0	60	2	13	6.25	4.65	6.0	60
	2	6.25	-4.65	6.0	60		14	6.25	5.35	6.0	60
	5	1.25	-5.35	6.0	150		17	1.25	4.65	6.0	150
	6	1.25	-4.65	6.0	150		18	1.25	5.35	6.0	150
	7	-1.25	-5.35	6.0	60		19	-1.25	4.65	6.0	60
	8	-1.25	-4.65	6.0	60		20	-1.25	5.35	6.0	60
	9	-3.75	-5.35	6.0	60		21	-3.75	4.65	6.0	60
	10	-3.75	-4.65	6.0	60		22	-3.75	5.35	6.0	60
	11	-6.25	-5.35	6.0	60		23	-6.25	4.65	6.0	60

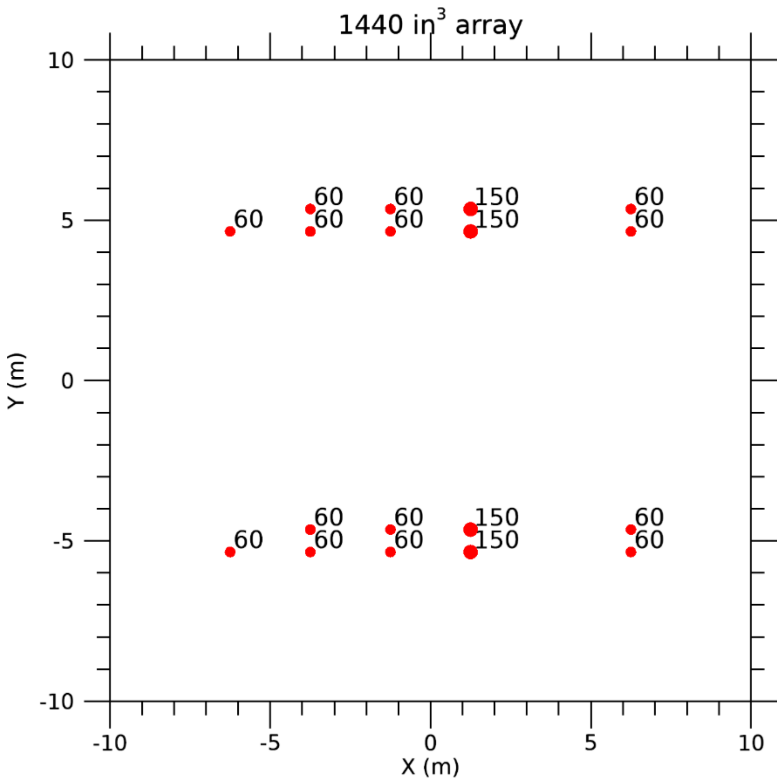

Figure A-1. Layout of the modelled 1440 in³ seismic array where the plotted layout is such that the array is centred on the origin and vessel travel direction is in the positive x-direction. Tow depth is 5 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table A-1.

A.1. Array Source Levels and Directivity

Figure A-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 seismic source. Horizontal decidecade-band source levels are shown as a function of band centre frequency and azimuth in Figure A-3.

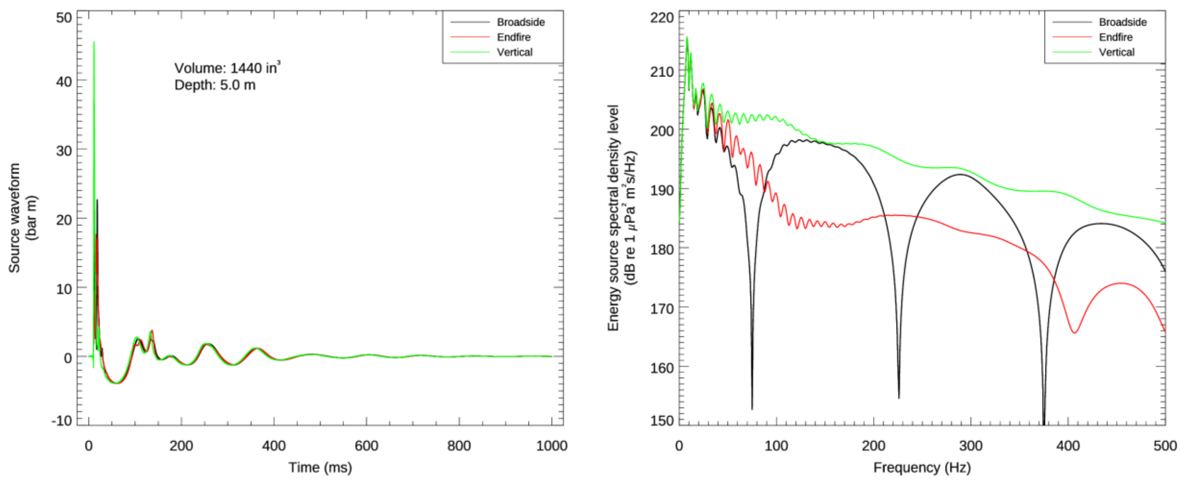

Figure A-2. Predicated source level details for the 1440 in³ array at 5 m tow depth. (Left) overpressure signature and (right) the power spectrum for in-plane horizontal (broadside), perpendicular (endfire), and vertical directions (no surface ghost).

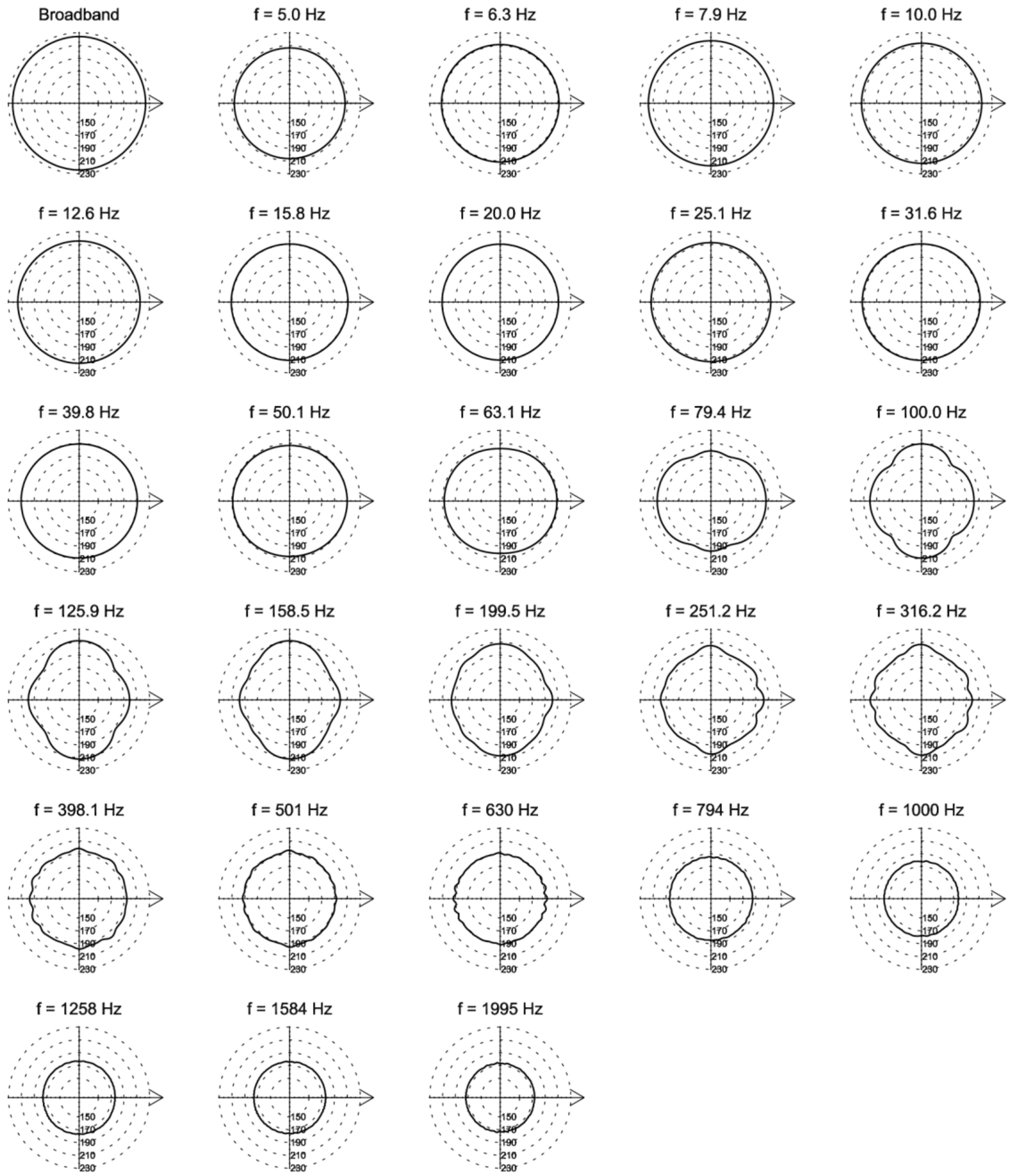

Figure A-3. Directionality of the predicted horizontal source levels for the 1440 in^3 seismic source, 5 Hz to 2 kHz. Source levels (in dB re 1 μPa^2·s m^2) are shown as a function of azimuth for the centre frequencies of the decidecade bands modelled; frequencies are shown above the plots. The vessel travel direction is to the right of frame. Tow depth is 5 m.

Appendix B. 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 B-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 B-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 B-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.

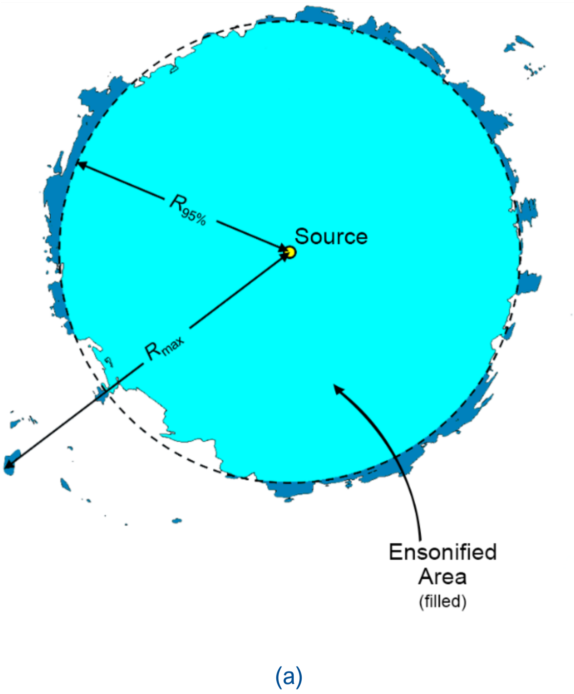

Figure B-1. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified areas bounded by $R_{95\%}$; darker blue indicates the areas outside this boundary which determine R_{max}.

APPENDIX H: UTAS ROCK LOBSTER TRANSFERABILITY OF KNOWLEDGE STUDY

UNIVERSITY of TASMANIA

IMAS

Institute for Marine and Antarctic Studies

Transferability of knowledge between Southern Rock lobster (*Jasus edwardsii*) and Western rock lobster (*Panulirus cygnus*)

P. Peinado, R.D. Day, & J.M. Semmens

April 2024

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Contents

1. Background

Pilot Energy is seeking approval to carry out the Eureka 3D Marine Seismic Survey in Commonwealth waters off the mid-west coast of Western Australia, where Western rock lobster (WRL; *Panulirus cygnus*) inhabit and concern has been raised over potential impacts to the WRL fishery by this seismic survey.

Consultation with WRL fisheries stakeholders in the region has indicated that they believe that the research on the effects of seismic signals on Southern Rock Lobsters (SRL; *Jasus edwardsii*) has limited relevance for understanding the potential impacts of seismic exposure on WRL, based on their experience that WRL are less robust and resilient than SRL. On the other hand, Pilot Energy believe that, despite some distinct differences in their biology, ecology, and distribution, the two species overall share a great deal of similarities in their taxonomy, habitat utilisation, size, appearance, life cycle, diet, and economic importance, which makes the research conducted on SRL relevant. To better understand the significance of these similarities and differences and to evaluate whether there are any indicators to suggest a difference in their resilience or sensitivity to seismic exposure, a review of the extant literature was conducted to compare the two species to identify similarities and differences to examine the potential transferability of knowledge between SRL and WRL.

Specific topics requested to be included in the report:

- Present a background on Southern Rock Lobster and Western Rock Lobster, including their taxonomy, distribution, and ecological characteristics. This is covered.
- Describe the current scientific understanding of both species, highlighting any significant differences or similarities between them in relation to the range of effects from seismic sound. This is covered.

- Briefly identify the impact of environmental factors on the biology and ecology of both species, including temperature, salinity, habitat availability, and food sources. This is covered.
- Identify key findings and research gaps regarding the biology, ecology, habitat preferences, behaviour, and life history of both species. This is covered.
- Identify any existing studies that have investigated the transferability of scientific knowledge between closely related lobster species. There are no existing studies.
- Assess the extent to which environmental conditions influence the transferability of scientific knowledge between Southern Rock Lobster and Western Rock Lobster in relation to seismic sound. This is covered.
- Assess the applicability and transferability of the scientific knowledge obtained from Southern Rock Lobster to Western Rock Lobster. This is covered.
- Identify any limitations or constraints associated with transferring scientific findings between the two species. This is covered.

2. Southern rock lobster (*Jasus edwardsii*)

Jasus edwardsii (Hutton, 1877), a crustacean of the order Decapoda, is a species of spiny lobster, which belongs to the Palinuridae family and genus *Jasus*.

Southern rock lobster (SRL) is a large benthic species inhabiting coastal reefs where they play an important ecological role in rocky reef ecosystems (Pinkerton et al. (2008) and are targeted by a socioeconomically important fishery across their distribution. They are omnivorous, feeding mostly at night. Ontogenetic changes in southern rock lobster feeding habits have been found, with juveniles feeding on ophiuroids, isopods and bivalves and adults on bivalves, crabs and other crustaceans, urchins, and gastropods (Edmunds, 1995)

Distribution and habitat:

SRL are native along the southern coast of Australia and around New Zealand (Figure 1)(Phillips and Kittaka, 2008). The Australian range extends from southern Western Australia to New South Wales, with the bulk of the population found in the southeastern states of South Australia, Victoria and Tasmania, where they occur to depths from 1 to around 200 m, experiencing water temperatures from 6 to 23 °C (McKoy, 1985).

Across their distribution, SRL generally inhabit rocky bryozoan or aeolianite limestone reefs but are also found on outcrops of igneous rocks such as granite (Phillips and Kittaka, 2008). Within coastal ecosystems, SRL are not evenly distributed but are often more abundant in complex habitats such as algal-dominated reef that provide daytime shelter and a variety of microhabitats for nocturnal foraging (MacDiarmid et al., 2013; Phillips et al., 2013).

Figure 1: Distribution of Southern rock lobster (SRL) in Australia (Linnane, 2020).

Life history:

Stock structure:

Previous studies based on mitochondrial DNA analysis, suggested that SRL encompass a single genetic stock, with little evidence of population sub-structuring across mainland Australia, Tasmania and New Zealand (Brasher et al., 1992; Ovenden et al., 1992). However, a more recent study found small levels of genetic differentiation across southern Tasmania, with significant levels of differentiation between Tasmania and New Zealand (Morgan et al., 2013). Furthermore, larval transport models via ocean currents suggest that population structure is likely to be complex (Stephen et al., 2003; Bruce et al., 2007).

Growth:

SRL individuals' carapaces can grow up to 230 mm in length and can exceed 8 kilogram in weight with a life span of over 20 years.

Water temperature and diet appear to be key factors affecting growth in SRL (Hooker et al., 1997; Radford et al., 2007). In the southwest of Tasmania, the population is characterized by slow growing, small individuals with relatively small size at onset of maturity, by contrast, in the north and east of the state, growth is faster, individuals grow larger and they have a larger size of onset of maturity (Gardner and Van Putten, 2008; McLeay et al., 2019). Consequently, size at maturity in southern rock lobster is directly correlated with environmental temperature (McLeay et al., 2019).

Moulting is a complex process in which lobster shed their carapace to facilitate growth. SRL demonstrate sexual asynchrony in moult cycles, with males moulting between October and November and females late April to June. MacDiarmid (1989) also found that moulting occurred predominantly at night in shallow water and that the timing of moulting and the number of eggs produced was correlated to lobster size. It has been suggested that spatial differences in the time of moult in SRL might be due to variation in temperature and photoperiod, with latitudinal trends in reproduction and time of moult similar (Quackenbush and Herrnkind 1983, Nelson 1986, Lipcius and Herrnkind 1987).

Reproduction

Sexual maturity in female SRL is reached 3-7 years post-settlement at a size ranging from 60-120 mm carapace length, depending on locality (Phillips and Kittaka, 2008).

Mature SRL usually move into deeper offshore water to breed. Reproduction occurs between April and July, depending on location. Immediately following the moulting of females, males deposit a spermatophore on the sternal plates of females, then females extrude their egg mass and external fertilization occurs (Phillips and Booth, 1994). The females then brood the eggs for approximately 3-4 months over the winter season until hatching which usually peaks in September through October (MacDiarmid et al., 2013).

Life cycle

After hatching, SRL larvae (called phyllosoma) have a pelagic phase with a duration of at least 12 to 24 months (Chiswell and Booth, 2017). During this phase, the larva undergo 11 moult cycles in the open ocean (Phillips and McWilliam, 1986), then the phyllosoma moult into the puerulus stage, in which they actively swim from the deeper ocean to a costal reef to settle into near-shore habitats (Phillips, 2008). It is not clear how SRL find the coast, with a range of possible mechanisms suggested including orientation towards nearshore sources of underwater sound, water chemistry, electromagnetic fields and hydrodynamic cues (Jeffs et al., 2005). The puerulus is a short-lived, transitional stage between planktonic phyllosoma and the bottom-living juvenile. Once the puerulus is settled, individuals moult into a pigmented juvenile (approx. 5 cm in carapace length) within two weeks (Pecl et al., 2009). A young immature lobster will moult about 25 times per year with the time between moults (known as moult increment) increasing with each moult.

During the juvenile phase, SRL are susceptible to high predation mortality due to their small size and extended planktonic duration, then when individuals reach large sizes (“size refuge”) they tend to aggregate more with conspecifics (Buttler et al., 2016). SRL undertake predictable seasonal movements between depths, with adult males and females moving up and down the reef at different times of the year with these patterns seemingly related to the annual timing of moulting, reproduction and feeding activities (MacDiarmid1991).

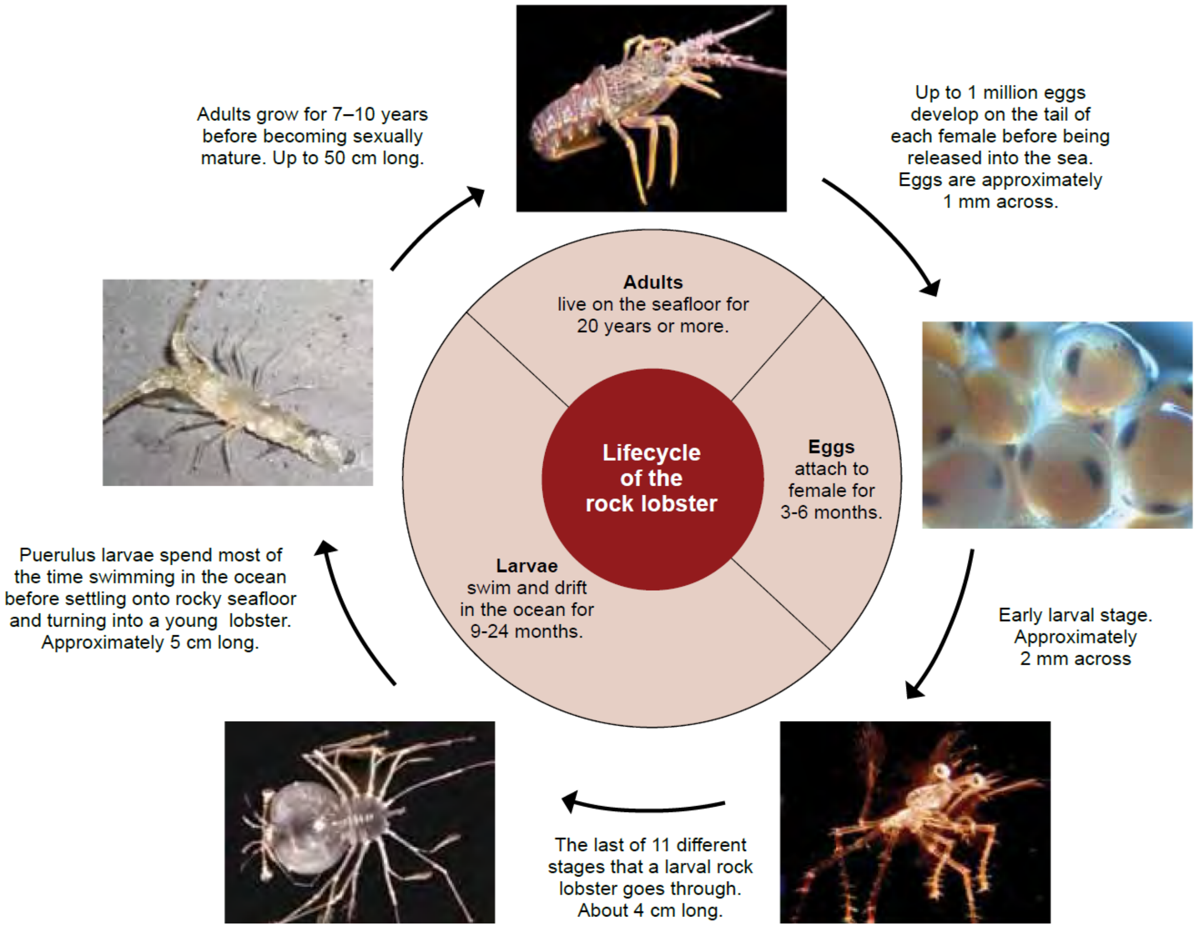

Figure 2: Life cycle of Southern rock lobster (Jasus edwardsii). Figure from (Pecl et al., 2009).

Anthropogenic impacts

Environmental condition

Warming water temperatures will affect SRL directly and indirectly into the future. Temperature has a controlling effect on the biology of ectothermic species, affecting their physiology and therefore behaviour. For example, temperature effects physiological processes such as aerobic scope, the amount of energy available to individual lobsters to perform non-essential body processes as well as survival, growth, feeding, metabolism, cardiac performance, reproduction and predator avoidance (Fitzgibbon et al., 2012; Fitzgibbon et al., 2014; Fitzgibbon et al., 2017b; Oellermann et al., 2020; Twiname et al., 2020). In SRL, high temperature has been associated with a decrease in growth due to a reduction in intermolt period, i.e. more frequent moulting (Thomas et al., 2000). Temperature also affects the survival of SRL, with mortality increasing at temperatures above 24°C. Changes in temperature will affect these processes differently across the range of the SRL population, with climate change modelling of SRL in Tasmania indicating that current declines in recruitment will likely continue, with the rate of these declines dependent on the level of warming (Pecl et al., 2009). In the short term, declines in recruitment will be masked by increases in biomass of SRL due to warming effects on growth rates. However, in the long term, decreases in recruitment as well as effects of temperature on growth will result in a decline in the biomass of SRL in Tasmania. This will occur first, and be most pronounced, in the north of the state, where temperatures are already close to the thermal limits of SRL.

Kelp habitat provides food, and refuge for many species, including southern rock lobster, but coverage has reduced over the last few decades around Tasmania due to climate change. The presence or absence of kelp has been found to influence settlement and the overnight predation of early life stages, suggesting that kelp habitat promotes SRL recruitment and survival against predators (Hinojosa et al., 2014). Consequently, the decline in kelp habitat due to climate change may potentially affect lobster recruitment and productivity.

Seismic impacts

The impacts of seismic surveys and air gun signals in southern rock lobster has been investigated across several different life stages. In adults, exposure to a single air gun has shown impairment of immune function, nutritional condition (Fitzgibbon et al., 2017a), and dorsoventral righting reflex, as well as the persistent damage to the mechanosensory statocyst organ (Day et al., 2019). Egg-bearing (berried) female South rock lobster exposed to air gun signals did not show any impact in the number or quality of offspring, with hatched larval lobster not showing any impact from exposure early in the embryonic period (Day et al., 2016).

In juveniles and puerulus, no mortality was observed when exposed to a full commercial seismic array, however, air guns signals caused righting impairments to at least 500m from the source (Day et al., 2022), suggesting statocyst damage as found for the adults with a single airgun (Day et al., 2019). Day et al. (2022) also found that the intermoult duration significantly increased in juveniles exposed at 0 m from the seismic source, suggesting the potential for slowed development, growth, and physiological stress.

A statistical analysis of catch-per-unit-effort (CPUE) data collected over nearly 30 years in the Victorian southern rock lobster fishery showed no influence of historical seismic survey activity, through the authors noted a lack of sensitivity due to the preponderance of surveys conducted in deep water away from fishing areas and suggested that catch rates would have had to decrease by around 50% to detect an impact (Perry & Gason, 2006).

3. Western rock lobster (*Panulirus cygnus*)

The western rock lobster (WRL), *Panulirus cygnus* (George, 1962), is a decapod crustacean of the family Palinuridae (spiny lobster) and genus *Panulirus*.

They are opportunistic omnivores, with a diet composed of different variety of plants and animals, such as crabs, molluscs, small crustaceans, bivalves, coralline algae, or sponges (Joll and Phillips, 1984; Edgar, 1990; Jernakoff et al., 1993; MacArthur et al., 2008). In shallow inshore areas, WRL forage throughout the night in seagrass meadows surrounding reef, moving distances of up to 300 m (Jernakoff, 1987). Studies suggest that western rock lobster are primary carnivorous and act as a secondary consumers, changing their diet from omnivorous in shallow inshore areas to a primarily carnivorous diet when they migrate to deep waters (de Lestang et al., 2012).

Distribution and habitat:

The western rock lobster is a temperate species distributed along the Western Australia coast, ranging from Exmouth to Albany (Figure 2) (Phillips, 2008). The greatest abundance of WRL is found in the mid-west coast (Geraldton to Perth) region relative to the northern and southern extents of the distribution (Bellchambers et al., 2012). Across their distribution, WRL experience a large range of temperatures which vary between 16°C to 27° C due the contrasting oceanic conditions created by the Leeuwin and the Capes Currents (Bellchambers et al., 2012).

The habitat of WRL is dominated by shallow water limestone reef and adjacent seagrass beds with the majority of the population occurring from the coast out to 40 to 60km seaward on the continental shelf, with some utilization of unvegetated areas during migration (Newman et al., 2023).

The western rock lobster has a spatially segregated life-cycle, where juveniles (1-5 years) inhabit inshore reefs (< 40 m depth), while adults (> 80 mm carapace length) migrate towards deep-water offshore habitats (> 40 m depth) (Bellchambers et al., 2012).

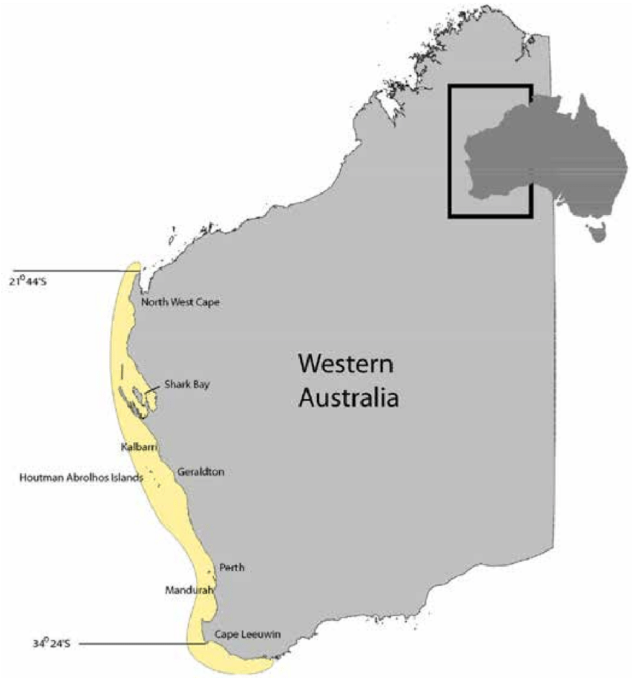

Figure 3: Distribution of the western rock lobster (Panulirus cygnus) along the Western Australian coastline (Bellchambers et al., 2012).

Life history:

Stock structure:

Previous analysis of molecular variance indicated no significant population structure along 960 km of coastline or genetic differentiation among temporal samples, suggesting that *P. cygnus* is a single, and panmictic population (Thompson et al., 1996; Kennington et al., 2013).

Growth:

Individuals can live for over 20 years and weigh up to 5.5 kg, though a 10 to 15 year lifespan, weight of less than 3 kg with a maximum carapace of 150 mm length is typical (Bellchambers et al., 2012; de Lestang et al., 2012; How et al., 2022).

The growth rate in WRL in both males and females is categorized by rapid juvenile growth, followed by a rate reduction after sexual maturity. de Lestang (2018) found that sex, temperature, population density and geographical position significantly impact growth rate in WRL. For example, growth had a significant negative correlation with increased population density throughout the species distribution and a significant positive correlation with the warmer water temperatures experienced in the northern end of the distribution (de Lestang et al. 2009), attributed to increased moult frequency rather than larger moult increments (Chittleborough 1975).

In juveniles, growth rates do not differ between sexes (Chittleborough, 1976), however, in females a reduction in growth becomes increasingly more pronounced with sexual maturity, resulting in larger maximum sizes in males overall (Bellchambers et al., 2012), and often a relatively large size at first maturity (Melville-Smith and De Lestang, 2006).

Temperature is also directly correlated with the size and age of maturity, evident in the decreasing size of lobsters from south to north (Chittleborough, 1976; Chubb, 1991; Melville-Smith and De Lestang, 2006), as individuals become mature at about 5-7 years or 90 mm carapace length (CL) in the south whereas in warm northern waters, individuals mature at smaller sizes around 70 mm CL (Melville-Smith and De Lestang, 2006).

Reproduction:

Mature WRL individuals 6-7 years of age mate in late winter and early spring between August to September. First, males attach their spermatophores to the sternums of a receptive female. Then external fertilization takes place when the female releases eggs and scratches the spermatophoric mass to release motile sperm (Chittleborough, 1976). The eggs are thus fertilized as they are swept backwards from the female and become attached to the 'seatae' on the tail of the lobster, for a 5-to-8-week period depending on water temperature. The number of eggs produced by a particular female during a spawning period depends on the size of an individual lobster (Chubb, 1991), with large females capable of producing up to a million eggs and having a greater probability of spawning twice in a season (Morgan, 1972; Melville-Smith and De Lestang, 2006).

Life cycle:

WRL has a complex life cycle, including an oceanic larval phase followed by a longer benthic one (Figure 3). Individuals hatch as a 2 mm long planktonic phyllosoma larvae which drift offshore as far as 1500 km helped by winds and currents. At this stage, the larvae spend between nine to 11 months in a planktonic state growing through a series of moults (estimated 15 instars) until they reach approximately 35 mm long (Braine, 1979; Phillips et al., 1979). Phyllosoma then undergo one last moult, changing into a translucent puerulus (post-larvae) lobster at around 25 mm long (Figure 3, stage 6). The pueruli swim across the continental shelf toward the shore and settle in shallow reefs, which can occur thought the year with peaks from late-winter to mid-summer, with environmental factors driving this considerable variation (Caputi et al., 2010). The settled pueruli then go thought a series of moults, and individuals grow to become juvenile rock lobster.

Juvenile WRL concentrate mainly in shallow reefs where they spend between 4 to 5 years feeding and growing (Chittleborough, 1976). When they reach a size of 65 – 85 mm carapace length, individuals congregate and undergo a synchronized moult event over a three-to-four week period in late spring, changing colour from red to pale pink (Melville-Smith et al., 2003; Wade et al., 2008). Moulting is followed by a mass migration between late-November to mid-January each year to deeper water to reach spawning/breeding grounds which is generally referred to as a “white” migration (Bellchambers et al., 2012). Once there, white lobster gradually return to their normal red coloration and become sexually mature (Melville-Smith et al., 2003). Early juvenile spiny lobster trend to be solitary but as they grow they become gregarious (Phillips et al., 2013). In western rock lobster, Fitzpatrick et al. (1989) found that over 95% of newly settled pueruli and post-pueruli were solitary but less than 20% of lobsters were solitary after a year post-settlement.

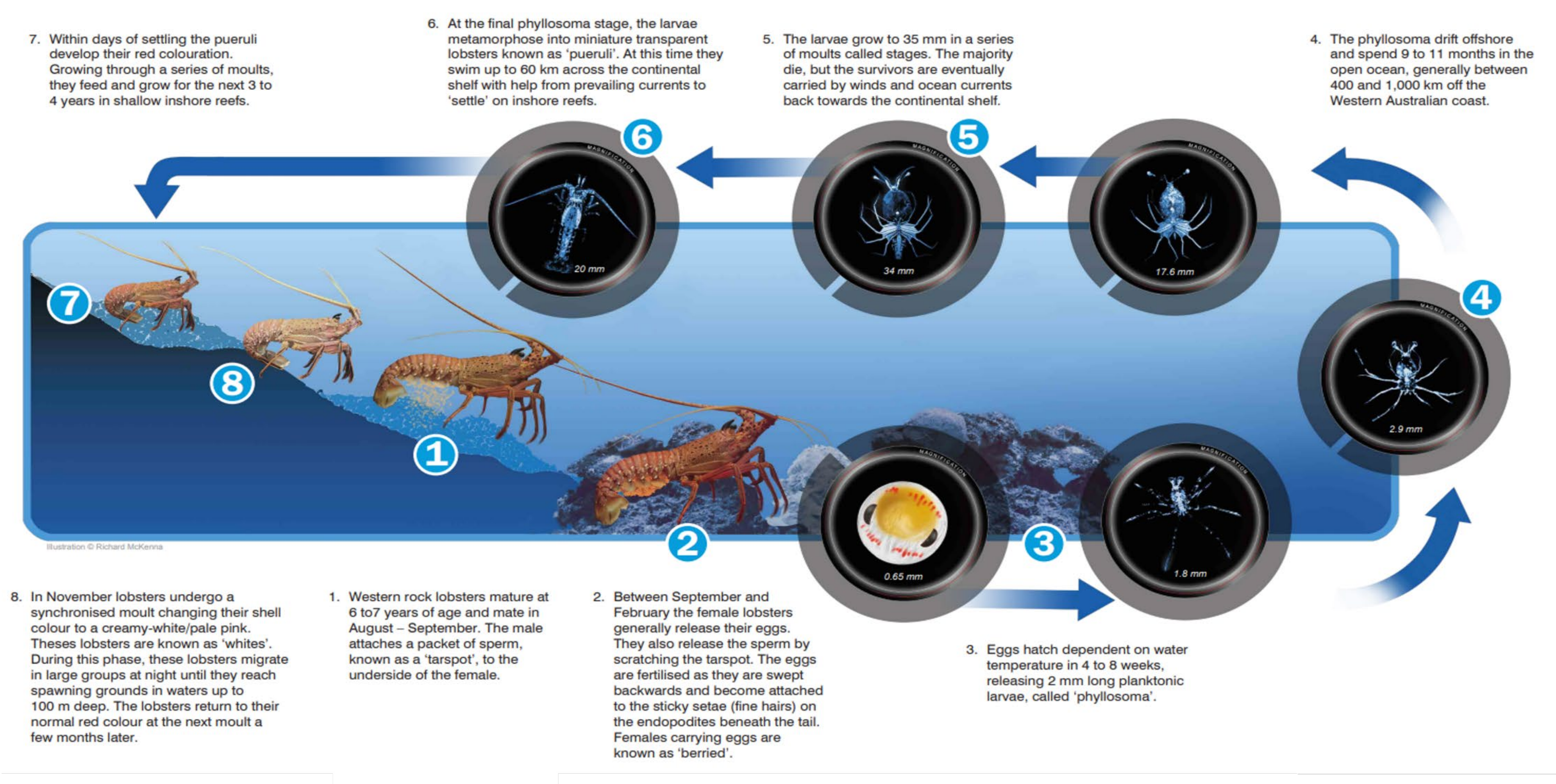

Figure 4: Life cycle of Panulirus cygnus (Western rock lobster). Diagram form the Western Australian Department of Primary Industries and Regional Development.

Anthropogenic impacts

Environmental conditions

Shifts in environmental conditions have been shown to influence different aspects of the WRL life history and stock populations (Caputi et al., 2010; Caputi et al., 2013). For instance, water temperature and storm activity are among the environmental parameters affecting puerulus settlement and timing, reducing the migration of white lobsters to northern breeding grounds, and decreasing the size at maturity within populations (Caputi et al., 1995; Caputi et al., 2001; Melville-Smith and De Lestang, 2006). Furthermore, significant changes in the size and age at sexual maturity of WRL over the past 35 years have been linked to climate change (Caputi et al., 2010).

Future changes are also predicted to affect the spatial distribution of western rock lobster as a result of the strength of the Leeuwin current which influences the large-scale migration of this species (de Lestang and Caputi, 2015). The Leeuwin Current, which brings warm, nutrient-poor waters southward along the edge of the West Australian continental shelf, is correlated with WRL puerulus settlement along the coast, with higher temperatures at the time of spawning correlated to below average WRL puerulus settlement (de Lestang et al., 2015). The timing of spawning is negatively correlated with temperature, and warmer temperatures may result in an earlier spawning which may cause a mismatch with other environmental factors such as peaks in ocean productivity and/or storms that assist the larvae returning to the coast and offshore water temperatures that help the early stage larval growth resulting in indirect impact to the larval settlement (de Lestang et al., 2015).

An extreme marine heat wave occurred along the Western Australia coast during 2011 and its impacts on marine ecosystems continue to linger, with the WRL population showing evidence of impact and incomplete recovery (Caputi et al., 2019). Survival and growth of the juveniles may been impacted by the changes in the habitat and prey availability caused by the extreme event (Smale et al. (2017).

In previous studies under laboratory conditions, the effects of temperature had been examined in early stages of the WRL. Elevated temperatures resulted in reduced intermoult periods and post-moult sizes (Liddy et al., 2004) despite reports of faster growth (Johnston et al., 2008). Additionally, Johnston et al. (2008) also found that survival was higher at ambient temperature (around 19 °C) in stage 1 and 2 phyllosoma. There was an interaction effect of temperature and feeding frequency on post-pueruli where weight and carapace length were significantly higher at ambient temperatures (around 19 °C) when post-pueruli were fed three times a day, whereas at 23°C weight and carapace length were significantly greater when fed once per day (Johnston et al., 2008). Liddy et al. (2004) also measured the effects of food density, finding no significant effect on either the intermoult period or the size of the larvae.

Environmental variables were also linked to morbidity and mortality of western rock lobster during live transport, as holding time in export cartons, ambient temperature in the internal carton and chilling period before packing the lobster were found to have the greatest impact on survivability (Spanoghe and Bourne, 1998). Furthermore, previous studies have found that under stressful conditions, such as hot and windy conditions, when individuals are removed from the ocean or when encountering hypersaline conditions, WRL are particularly susceptible to leg loss due to their natural autonomy reflex (Davidson, 2004).

Seismic impacts

To date there has been only one study on the impact of seismic signals on WRL (de Lestang et al., 2024). In this study, tagged WRL collected from within the centre of the fishery were housed in cages and exposed to a shallow (~ 5m) commercial seismic survey before being released back into the fishery. The air gun array consisted of an 80 CUI inch sleeve gun array (four 20-CUI guns) towed at 2 m depth, with an operating pressure of 2000 PSI and the maximum SPLpk – pk recorded from the four deployed hydrophones was 190, 216, 223, and 204 dB re 1 μPa.

Neither lobster mortality nor blood protein concentrations were affected immediately after exposure. Most lobsters examined retained all their legs; however, when focusing on lobsters with missing legs, a significant difference was found, with more legs missing in the exposure group. Additionally, lobsters exposed to air guns took significantly longer to right themselves, and their release behavior was slower compared to the control group.

In the first month following the seismic survey, exposed lobsters were less likely to be recaught in commercial lobster pots, with de Lestang et al. (2024) estimating an initial mortality of around 22% (0.06 – 0.68% CI) in this period. This differential recapture rate persisted over the subsequent two years, suggesting no further mortality beyond the first month after the survey.

4. Similarities and differences between SRL and WRL

SRL, *Jasus edwardsii* and WRL, *Panulirus cygnus* form the basis of two of the largest and most lucrative fisheries in Australia. Both species belong to the same spiny lobster family (Palinuridae) but not the same genus (i.e., *Jasus* vs. *Panulirus*). In Australia, SRL have a temperate distribution across the entirety of southern Australia, whereas WRL is endemic to Western Australia (Figure 5). Although also inhabiting temperate waters, WRL experience warmer water temperatures between 16 – 27°C, meanwhile SRL inhabit waters as cool as 6°C, reaching a maximum of 23°C (Figure 5). Both species usually seek shelter in cervices beneath rocks, corals or sponges, and under ledges or edges of vegetation.

Figure 5: Australian distribution of Southern rock lobster (red) and western rock lobster (blue).

In spiny lobsters (Palinuridae), there is a fivefold difference in size of the antennular plate, on which a sound producing apparatus, the plectrum, is located, such that the antennular plate reaches 38% of carapace length in some sound producers (Stridentes) compared to only 4% carapace length in non-sound producing spiny lobsters (Silentes) (Patek and Oakley, 2003). WRL are members of the Stridentes (Meyer-Rochow and Penrose, 1976; Patek and Oakley, 2003) and SRL the Silentes (Patek, 2002; Patek and Oakley, 2003). The Stridentes produce sound during interactions with predators, which most likely increases their chances of escape by causing the predator to pause momentarily (Meyer-Rochow and Penrose, 1976; Patek and Oakley, 2003; Staaterman et al., 2010). Antennae are spiny lobsters' primary weapons against predators and larger antennae are stronger and have the capacity to produce more force without structural failure (see review in Patek and Oakley, 2003), however, the Stridentes also have a secondary predator deterrent, i.e., sound.

Another key parameter in which the two lobsters vary is size, as WRL are usually smaller (maximum of 150 mm in carapace) than SRL which can reach 230 mm in carapace length. Furthermore, size at maturity are different between both species and within species due to spatial variation (Melville-Smith and De Lestang, 2006). In WRL in cooler waters individuals become mature around 90 mm carapace length (CL), yet, in warm waters individuals mature at smaller sizes around 70 mm (Melville-Smith and De Lestang, 2006). In SRL in the warmer north of Tasmania, individuals grow at up to 20 mm per year and mature at 115 mm CL, whereas in the south they grow as slowly as 1 mm per year and mature at very small sizes of 60 mm CL (Gardner et al., 2006).

The early life history of both SRL and WRL follows the general trend of other palinurids, characterized by a long-lived, widely dispersed oceanic phyllosoma larval phase, followed by a briefer post larval puerulus transitional stage. Still, notable differences exist in the development of the two species, such as the time the phyllosoma larvae spend in the plankton, as *WRL* have a pelagic larval duration between 9 to 11 months, which is markedly shorter than that of SRL (12 to 24 months). The duration of the pueruli stage is also shorter in WRL, lasting about 2 weeks, in comparison to SRL, which may remain as pueruli for up to 70 days (Table 1).Regarding differences in their behaviour, WRL undertake large-scale mass migrations as juveniles (de Lestang, 2014), whereas SRL is restricted to more localised movement.

Table 1: Life history parameters for Jasus edwardsii and Panulirus cygnus.

	Jasus edwardsii (Southern rock lobster)	*Panulirus cygnus* (Western rock lobster)
Max. life span (year)	20	20 (usually 10 to 15)
Max. carapace	250	150
Max. Weight	8	< 3
Maturity (year)	3-7	6-7
Broods per year	1	1-2
Egg size index	300	400

Incubation period (months)	4-6	0.5-2
No. of instars	15-17	15
phyllosoma period (months)	12-24	9-11
Puerulus period (days)	70	15

While there is significantly less information available for WRL on the potential impacts of seismic signals compared to SRL, one similarity is that air guns signals cause righting impairments for both species (Day et al., 2019; Day et al., 2022; de Lestang et al., 2024) suggesting that like SRL (Day et al., 2019), airgun signals can damage the mechanosensory statocyst organ of WRL. The statocyst is a mechanoreceptive organ responsible for spatial orientation and equilibrium. In crustaceans, the basic structure of the statocyst is similar across species, consisting of a sac-like epidermal invagination of the cuticle (Finley and MacMillan, 2000). However, the location of the statocyst varies between groups; for example, in lobsters, it is in the basal segment of each antennule. To the best of our knowledge, the statocyst in WRL has not yet been examined. However, due to the similarities across different crustacean species, as well as the similarities between lobsters, it is likely that the WRL and SRL statocysts are similar. This suggests that the seismic impact observed on the SRL statocyst could be extrapolated to WRL. Reflex impairment and significant damage to the sensory hairs of the statocyst in SRL persist up to a year post-exposure to a single airgun (150 in^3) (Day et al., 2019), with the exposure calculated as equivalent to a 3065 in^3 commercial survey array passing at an estimated range of 100-500 meters.

Although ecological impacts of the chronic impairment of the righting reflex observed in exposed SRL and WRL have yet to be evaluated but the impairment suggests some impact on the ability of an exposed lobster to function in the wild. Lobsters use input from the statocysts, leg proprioception receptors, and eyes in conjunction to identify and modulate their position (Neil, 1985), and removal of one of these inputs forces a greater reliance on the others (Schöne et al., 1983). Given the observed sensitivity of the SRL statocyst receptors to aquatic noise (Day et al., 2019), whether these other inputs are affected requires study, as they control a range of behaviours in lobsters, including the movement of the eyes, movement of the antennae, and coordination of the tail (Schöne et al., 1983; Neil, 1985; Newland and Neil, 1987). Indeed, removal of the statocyst entirely compromises the ability to modulate tail flip-mediated swimming to maintain correct body position (Newland and Neil, 1990) and to return to the substrate in an upright position (Newland and Neil, 1987) a posture necessary to initiate any further escape responses. de de Lestang et al. (2024) suggest that the impaired righting reflex in the WRL exposed to seismic signals in their study may have led to greater predation in these animals compared to the controls, thus explaining the suggested higher rate of mortality for exposed lobsters in the first month after the survey. The authors do note, however, that alternatively airgun exposure may have directly resulted in mortality that occurred after the lobsters were released but before they were first resampled (de Lestang et al., 2024).

In lobsters, overall, early benthic phase juveniles have high natural mortality levels and are the most vulnerable stages to predation, suffering high mortality from an array of fishes and motile invertebrates (e.g. crabs and octopus), despite mitigating adaptations including use of physical refuges, camouflage, cryptic behaviour, and nocturnality (Phillips, 2008). Estimates of WRL mortality occurring during the first year after settlement (from ages 1-2 years) were as high as 97-98%, with at least 80-84%, where only 0.9 to 6.4% survive from settlement until recruitment to the fishery at about 4.5 years of age (Phillips et al., 2003).These results clearly indicate that WRL experience very high natural mortality between the time of puerulus settlement in coastal reefs and when the lobsters move offshore and recruit into the fishery, with predation identified as the primary cause of this natural mortality (Miller et al., 2023). To the best of our knowledge, no natural mortality rates have been published for SRL, however, P. Breen (National Institute of Water and Atmospheric Research, pers. Comm, in Phillips et al., 2003) indicates that conservative estimates of mortality rates are 75 % for the first year after settlement, 25% for 2 and 3 year and 10 % for subsequent years. In both species of lobster, natural mortality rates are higher during the first year after settlement and decrease as the lobsters age. These elevated early mortality rates could be more impactful if external stressors directly affect these early stages, potentially having a detrimental effect on population recruitment.

Fishing induce mortality has not been studied in WRL or SRL, however, mortality within pots due to predatory behaviour has been estimate for SRL. (Briceño et al., 2016) demonstrated that lobster mortality by predation in pots varies considerably across stock assessment areas and can follow seasonal cycles of fishing effort and lobster abundance. For example, in Tasmania, SRL mortality by octopus is estimated to represent an average of 2.35% of the total lobster harvest per year (Briceño et al., 2016), while in South Australia the mortality rate associated with octopus predation is 4% (Brock and Ward, 2004).

de Lestang et al. (2024) estimated that exposure to seismic surveys might cause up to 22% mortality in WRL, based on the lower number of recaptures observed in their study. As the survey was conducted in juvenile and shallow habitat, they suggested that a detectable and significant deleterious impact on WRL occurred, but only on lobster in approximately four year-classes. Yet, on a wider stock level, they suggested that the increase in mortality would be undetectable. However, if the survey was to be conducted in a deeper water area of the fishery, dominated by mature breeding individuals, any increased levels of mortality have the potential to reduce subsequent reproductive success, potentially having much broader implications.

Transferability of knowledge between lobster species:

While there have been published compilations about the biology of different groups of lobster (Phillips et al., 1992; Phillips and Booth, 1994; Phillips, 2008; Phillips et al., 2013; Wahle et al., 2021), no studies have previously investigated the potential transferability of scientific knowledge between related lobster species.

A recent review conducted by Peinado et al. (2021) on the potential transferability of knowledge between the effect of seismic surveys on crustaceans in general to Giant Crab (*Pseudocarcinus gigas*) specifically, suggested that if significant biological differences exist between species, extrapolation of the results might not be reliable, potentially even underestimating the potential severity of any impact. SRL and WRL differ in key biological parameters directly affecting survival and population dynamics (e.g., settlement time, duration of larval stages, growth). As such, the ability to draw specific conclusions around the potential risk of seismic surveys to WRL without sufficient species-specific information and predominately using SRL data is difficult and should be avoided where possible.

In the case of SRL and WRL, to the best of our knowledge only one study (Crear, 1998) has examined both species, in which a physiological investigation into methods of improving the post-capture survival of both species was undertaken. Crear (1998) shows clear differences between both species, with standard oxygen consumption, aerobic scope, and oxygen consumption at night almost twice as high in western rock lobster than in southern rock lobster. Ammonia excretion of WRL was generally also twice as high as that of SRL (Crear, 1998). Crear (1998) suggested that the differences between the species probably indicate that WRL have a higher capacity for activity than SRL. (Crear, 1998). Importantly, Crear (1998) did not discuss the potential use of one species as a model of the other, rather, only observed differences between the species.

Given that air guns signals cause righting impairments for both SRL (Day et al., 2019; Day et al., 2022) and WRL (de Lestang et al., 2024) (de Lestang et al., unpublished), it is possible that there can be transferability of knowledge around potential impacts of seismic surveys between the species, but more research is needed to confirm this, given only one study has been undertaken for WRL. Given the current paucity of impact of seismic survey research for WRL, it is difficult to determine the extent to which environmental conditions may influence the transferability of scientific knowledge between SRL and WRL in relation to seismic sound. However, the fact that WRL inhabit seagrass meadows (Newman et al., 2023), along with limestone reef, whereas SRL are restricted to rocky reefs (limestone) and outcrops (igneous rocks such as granite) (Phillips and Kittaka, 2008), may influence how WRL are impacted by seismic signals, as these signals will attenuate more effectively through sediment (seagrass meadows) compared to rock. Note, however, that similar impacts were seen for SRL exposed on both limestone reef (Day et al., 2019) and sediment (Day et al., 2022), but the seismic sources and water depths were different between the studies. As such, direct comparison between potential impacts of seismic surveys across different habitats used by WRL may be worthwhile.

5. Discussion

Spiny lobster, including SRL and WRL, represent some of the most iconic and valuable species around the world, which have been subject to intensive fishing worldwide as they are generally shallow water species. Although grouped in a common category, there are substantial differences between the spiny lobster species, including aspects of growth, breeding, recruitment (Jeffs et al., 2013; Phillips et al., 2013), and noise production (Patek and Oakley, 2003), with further spatial variation due to differences in major ocean currents, temperature, depth and habitats (Plagányi et al., 2018).

The early stages of a lobster's life are essential for its development and survival, playing a key role in determining the overall population dynamics and resilience of lobster populations. A major difference between the life cycle of SRL and WRL is the length of the phyllosoma larval stage, which is much longer in SRL (12-24 months vs. 9-11 months). As a result, an impact to SRL at the phyllosoma stage might have a larger effect at the population level compared to WRL.

SRL and WRL have a distinctly different thermal niche. The variation in temperatures along the distribution in both species is a key factor to consider as ectotherms are highly dependent on external temperature for internal regulation. Thus, critical biological parameters have been identified to differ not only between SRL and WRL but also within each species across their geographical ranges, such as growth rates or size at maturity which are key population parameters (Phillips et al., 2013; McLeay et al., 2019). WRL are smaller in size and mature at a smaller size compared to SRL, so if there was an impact to subadult sizes, it might be more harmful to a SRL population than to that of a WRL population.

In lobster species, increases in water temperatures can accelerate growth and development, yet the nature of the relationship between fluctuation in temperature and size at maturity is not consistent among species (Chittleborough, 1975; Johnston et al., 2008; McMahan et al., 2016), with WRL and SRL showing opposite trends. In WRL, size at maturity is inversely correlated to temperature conditions experienced during growth (Melville-Smith and De Lestang, 2006), meanwhile in SRL, size at maturity is positively correlated with temperature (Linnane et al., 2008) (Hobday and Ryan, 1997; Gardner et al., 2006). Such divergent responses between species are thought to reflect species-specific adaptations in physiology that mediate the way that temperature influences different essential processes such somatic growth or reproductive development.

Crustaceans in general are sensitive to changes in their local thermal environment, yet the impact of ocean warming on population traits are not yet well documented (McLeay et al., 2019). In Australia, both SRL and WRL are influenced by long term increases in water temperature which are projected to continue, resulting in variation of size at maturity or migrations patterns, which highlight the vulnerability of lobster stocks to climate change due to their long larval phase (Caputi et al., 2010; Caputi et al., 2013). Consequently, environmental factors are important drivers of fisheries recruitment variation, and they have become increasingly important under changing environmental conditions. Previous studies found direct effects on WRL and SRL under warming temperatures, such as reduced intermoult period (Thomas et al., 2000; Liddy et al., 2004) or survival (Thomas et al., 2000; Johnston et al., 2008). Furthermore, for both species an indirect impact on the population resulted from a change in habitat, e.g., decrease in kelp or algal coverage) (Hinojosa et al., 2014; Smale et al., 2017).

In regard to potential impacts of seismic surveys on crustaceans in general, previous studies have examined the effect of anthropogenic noises on sensory systems (Day et al., 2019), moulting (Day et al., 2022), behavioural responses (Cote et al., 2020), nutrition (Fitzgibbon et al., 2017a), immune function ((Fitzgibbon et al., 2017a) and physiological responses (Wale et al., 2013; Aimon et al., 2021), with research to date showing inconsistent results between species, parameters, and life history stages (Peinado et al., 2021; Solé et al., 2023). With major discrepancies/contradictions in the current literature across crustacean species, along with limited standardisation of sound source types or levels and inconsistent measuring and reporting of sound pressure, particle-motion, and ground vibration levels from these studies, it is extremely difficult to make any clear determination on what the impact of a seismic survey on any species and its population may be. As such, until we have a better general understanding, species and life stages should be assessed individually where feasible.

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