

MARINE MAMMAL IMPACT ASSESSMENT (MMIA) FOR THE MULTI-SCALE GEOPHYSICAL INVESTIGATION OF SUBDUCTION TO STRIKE-SLIP TRANSITION (SUBTRANS), NEW ZEALAND

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**TABLE OF CONTENTS**

TABLE OF CONTENTS	3
LIST OF FIGURES	6
LIST OF TABLES	7
LIST OF ACRONYMS/ABBREVIATIONS	7
DEFINITIONS	9
SUMMARY	12
1. INTRODUCTION.....	14
1.1. SUBTRANS	15
1.1.1. Survey aims	16
1.1.2. Survey requirements	17
1.2. 2013 DOC Code of Conduct & status updates	18
1.3. Rationale	19
2. PROJECT ACTIVITIES DESCRIPTION	20
2.1. Timing & location	21
2.2. Navigational safety	22
2.3. Seismic survey	23
2.4. Vessel specifications.....	24
2.5. Survey-design considerations	24
2.5.1. Timing	25
2.5.2. Survey design.....	25
2.5.3. Noise sources	25
2.5.4. Vessel.....	25
3. LEGISLATIVE FRAMEWORK	26
3.1. Marine Mammals Protection Act 1978	26
3.2. Exclusive Economic Zone & Continental Shelf Act 2012.....	26
3.3. Maritime Transport Act 1994	27
4. CONSULTATION & ENGAGEMENT ACTIVITIES	28
5. DESCRIPTION OF OPERATIONAL AREA	28
5.1. Physical oceanography	29
5.1.1. Seafloor morphology & bathymetry	30
5.1.2. Ocean circulation & transport pathways.....	32
5.1.3. Density structure & seasonal stratification	34
5.1.4. Ocean-atmosphere interactions.....	35
5.1.5. Waves, tides & extreme forcing.....	36
5.1.6. Mixing & turbulence	38
5.1.7. Ambient noise & soundscape characterisation	40
5.2. Biological oceanography	41
5.2.1. Plankton.....	43
5.2.2. Invertebrates.....	45
5.2.3. Fish	46
5.2.4. Marine reptiles	49
5.2.5. Seabirds.....	49
5.2.6. Marine mammals.....	52
5.2.6.1. Antarctic & dwarf minke whale (<i>B. bonaerensis</i> & <i>B. acutorostrata</i> ssp.)	54
5.2.6.2. Antarctic blue whale & pygmy blue whale (<i>Balaenoptera musculus intermedia</i> & <i>B. m. brevicauda</i>)	55
5.2.6.3. Fin whale (<i>B. physalus</i>)	56
5.2.6.4. Humpback whale (<i>Megaptera novaeangliae</i>)	57
5.2.6.5. Pygmy right whale (<i>Caperea marginata</i>).....	58
5.2.6.6. Sei whale (<i>Balaenoptera borealis</i>).....	59
5.2.6.7. Southern right whale (<i>Eubalaena australis</i>).....	60
5.2.6.8. Arnoux's beaked whale (<i>Berardius arnuxii</i>)	61

5.2.6.9. Bottlenose dolphin (<i>Tursiops truncatus</i>)	62
5.2.6.10. Common dolphin (<i>Delphinus delphis</i>)	63
5.2.6.11. Dusky dolphin (<i>Lagenorhynchus obscurus</i>).....	64
5.2.6.12. Goose-beaked whale (<i>Ziphius cavirostris</i>)	66
5.2.6.13. Gray's beaked whale (<i>M. grayi</i>).....	67
5.2.6.14. Hector's dolphin (<i>Cephalorhynchus hectori</i>).....	68
5.2.6.15. Killer whale (<i>Orcinus orca</i>)	69
5.2.6.16. Long-finned pilot whale (<i>Globicephala melas</i>)	70
5.2.6.17. Māui Dolphin (<i>Cephalorhynchus hectori maui</i>)	71
5.2.6.18. Pygmy sperm whale (<i>Kogia breviceps</i>).....	72
5.2.6.19. Shepherd's beaked whale (<i>Tasmacetus shepherdi</i>)	72
5.2.6.20. Southern right whale dolphin (<i>Lissodelphis peronii</i>).....	73
5.2.6.21. Sperm whale (<i>Physeter macrocephalus</i>)	74
5.2.6.22. Strap-toothed whale (<i>Mesoplodon layardii</i>)	75
5.2.6.23. Striped dolphin (<i>Stenella coeruleoalba</i>)	76
5.2.6.24. New Zealand fur seal (<i>Arctocephalus forsteri</i>).....	77
5.3. Coastal environment & marine conservation	79
5.3.1. Protected areas	80
5.4. Cultural environment.....	82
5.5. Socio-economic environment.....	83
5.5.1. Recreational fishing	84
5.5.2. Commercial shipping	84
5.5.3. Recreational vessels	84
5.5.4. Oil & Gas (O&G) activities.....	84
5.5.5. Deep-sea mining	84
6. POTENTIAL ENVIRONMENTAL EFFECTS & MITIGATION METHODS	86
6.1. Environmental Impact Assessment methodology.....	86
6.1.1. Scoping.....	86
6.1.2. Mitigation	86
6.1.3. Evaluating residual risks across receptors.....	87
6.1.3.1. Likelihood and severity score	87
6.1.3.2. Population-exposure score.....	88
6.1.3.3. Valuation of receptors	90
6.1.3.4. Residual risk matrix	92
6.2. Results	93
6.2.1. Scoping.....	93
6.2.1.1. Area of biological relevance	94
6.2.1.2. Marine mammal receptors	94
6.2.1.3. Other receptors.....	97
6.2.1.4. Mitigation	97
6.2.2. Impact assessment – marine mammals	99
6.2.2.1. Increased vessel activity	99
6.2.2.2. Collision risk	99
6.2.2.3. Behavioural disturbance	103
6.2.2.4. Displacement from habitat due to vessel presence.....	106
6.2.2.5. Masking from underwater radiated noise from vessel	109
6.2.2.6. Seismic noise	112
6.2.2.7. Physical injury (non-auditory)	113
6.2.2.8. Auditory damage	116
6.2.2.9. Masking	119
6.2.2.10. Behavioural disturbance	123
6.2.2.11. Indirect effects on prey species	127
6.2.2.12. In-combination & cumulative effects	131
6.2.2.13. Unplanned events	132

6.2.2.14. Vessel collision or sinking, and release of hazardous substances	132
6.2.2.15. Equipment loss	132
6.2.3. Impact assessment – other receptors	133
6.2.3.1. Seabirds	133
6.2.3.2. Marine reptiles	134
6.2.3.3. Fish	135
6.2.3.4. Sharks & rays	136
6.2.3.5. Invertebrates	137
6.2.3.6. Zooplankton	139
6.3. Summary	140
7. RESEARCH OPPORTUNITY	142
7.1. Future scientific applications	143
8. CONCLUSIONS	145
9. REFERENCES	146
APPENDIX A – MITIGATION PROTOCOL	173
A.1. Procedures of seismic operations - notification	173
A.2. Observer requirements	173
A.2.1. PAM specifications	173
A.2.2. PAMGuard configuration	175
A.3. Observer duties	175
A.4. Observer effort	176
A.4.1. Pre-start observations	177
A.5. Soft-starts	178
A.6. Acoustic source testing	178
A.7. Delayed or shut down operations - species of concern	178
A.7.1. Other marine mammals (not Species of Concern)	178
A.8. PAM operations	179
A.9. Reporting requirements	179
A.10. Key contacts and communication protocol	179
A.11. Navigational safety	180
APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING	181
B.1. Modelling approach	182
B.1.1. Bathymetry	184
B.1.2. Water column properties	185
B.1.3. Seabed Properties	185
B.2. Results	186
B.2.1. Regional propagation patterns	187
B.2.2. Directional propagation characteristics	189
B.2.3. Mean propagation behaviour	191
B.2.4. Vertical propagation structure	193
B.2.5. Receiver-specific received SEL at mitigation-zone boundaries	196
B.3. Discussion	197
B.3.1. Effect of source location and water depth on propagation behaviour	198
B.3.2. Influence of frequency bandwidth on regional propagation	199
B.3.3. Implications for regional seismic surveys	200
B.4. Conclusions	201
B.4.1. Regional bathymetry & dominant control on acoustic propagation	201
B.4.2. Source location and water depth influence regional propagation behaviour	201
B.4.3. Principal propagation pathways in investigated frequency ranges	201
B.4.4. Numerical propagation modelling & complex acoustic environments	201
B.4.5. Complementary visualisation & interpretation of model behaviour	202
APPENDIX C - SPECIES OF CONCERN	203
APPENDIX D – INACCURATE IMAGE GENERATED BY AI	204

LIST OF FIGURES

Figure 1: Survey location operational area	22
Figure 2: Schematic of the 2D seismic system with a 600 m-long streamer.....	23
Figure 3: Vessel <i>RV Sonne</i>	24
Figure 4: Bathymetric contours (in metres) in operational area	32
Figure 5: Bioregions as defined by the NZMEC system.....	43
Figure 6: Major seabird colonies in New Zealand.....	50
Figure 7: Antarctic and dwarf minke whale.....	54
Figure 8: Antarctic blue and pygmy blue whale.....	55
Figure 9: Fin whale.	56
Figure 10: Humpback whale.....	57
Figure 11: Pygmy right whale.	58
Figure 12: Sei whale.	59
Figure 13: Southern right whale.	60
Figure 14: Southern right whale annual distribution in operational area.....	61
Figure 15: Arnoux's beaked whale	61
Figure 16: Bottlenose dolphin.....	62
Figure 17: Bottlenose dolphin annual distribution in operational area	63
Figure 18: Common dolphin.....	63
Figure 19: Common dolphin annual distribution in operational area	64
Figure 20: Dusky dolphin.....	65
Figure 21: Dusky dolphin annual distribution in operational area	66
Figure 22: Goose-beaked whale.	66
Figure 23: Gray's-beaked whale.	67
Figure 24: Hector's dolphin.	68
Figure 25: Killer whale.	69
Figure 26: Killer whale annual distribution in operational area	70
Figure 27: Long-finned pilot whale.....	70
Figure 28: Pygmy sperm whale	72
Figure 29: Shepherd's beaked whale.....	73
Figure 30: Southern right whale dolphin	73
Figure 31: Sperm whale	74
Figure 32: Strap-toothed whale	75
Figure 33: Striped dolphin	76
Figure 34: New Zealand fur seal	77
Figure 35: New Zealand fur seal colonies in operational area	78
Figure 36: New Zealand fur seal annual distribution in operational area.....	78
Figure 37: Current marine protected areas near operational area	82
Figure 38: Customary Marine Title and Protected Customary Rights.....	83
Figure 39: Taiāpure and Mātaitai reserves	83
Figure 40: Example schematic of a towed hydrophone array	174
Figure 41: Schematic of internal PAM system components	174
Figure 42: Standardised cumulative Sound Exposure Level (SEL _{cum}).....	188
Figure 43: Polar representation	190
Figure 44: Comparison of mean.....	192
Figure 45: Vertical standardised SEL _{cum} propagation cross-sections.....	193
Figure 46: Vertical standardised SEL _{cum} propagation cross-sections.....	194
Figure 47: Vertical standardised SEL _{cum} propagation cross-sections.....	195
Figure 48: Vertical standardised SEL _{cum} propagation cross-sections.....	195
Figure 49: Representative broadband received Sound Exposure Level	196
Figure 50: AI-generated image of artificial marine mammal.....	204

LIST OF TABLES

Table 1: MMIA requirements and location of material within the document.....	17
Table 2: Project outline of days at sea	21
Table 3: Specifications of the <i>RV Sonne</i>	24
Table 4: Seabird conservation and breeding status/season.....	51
Table 5: Likelihood score	87
Table 6: Severity score.....	88
Table 7: Population exposure score	90
Table 8: Valuation of marine mammal receptors	91
Table 9: Residual-risk matrix.....	93
Table 10: Marine mammal species considered potentially present	96
Table 11: Marine mammal species scoped out of the impact assessment	97
Table 12: Residual risk of vessel collision	102
Table 13: Residual risk of behavioural disturbance from vessel presence	105
Table 14: Residual risk of displacement from habitat due to vessel presence ..	108
Table 15: Residual risk of auditory masking	111
Table 16: Residual risk of non-auditory physical injury	115
Table 17: Residual risk of auditory effects.....	118
Table 18: Residual risk of auditory masking from the seismic source	122
Table 19: Residual risk of behavioural disturbance from the seismic source...	126
Table 20: Residual risk of indirect effects on marine mammals	130
Table 21: Specifications of hydrophone system.....	175
Table 22: Water-column parameters used in the transmission-loss model.....	185
Table 23: Seabed properties used in the transmission-loss model	186
Table 24: Species of concern.....	203

LIST OF ACRONYMS/ABBREVIATIONS

2D	Two-Dimensional
3D	Three-Dimensional
AI	Artificial Intelligence
AEI	Area of Ecological Importance
AIS	Automatic Identification System
BMBF	Federal Ministry of Education and Research
BPA	Benthic Protected Area
BRT	Boosted Regression Tree
BRASS	Brothers Volcano Seismic Structure
C	Celsius
ca	Circa or approximately
Chl-a	Chlorophyll a
CIEEM	Chartered Institute of Ecology and Environmental Management
CPZ	Cable Protection Zones
COLREGs	Convention on the International Regulations for Preventing Collisions at Sea
CUI	Cubic Inch
dB	DeciBel
DOC	Department of Conservation
DOC Code of Conduct	DOC Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations



EAUC	East Auckland Current
EEZ	Exclusive Economic Zone
EEZ Act	Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012
e.g.	<i>exempli gratia</i> or for example
EIA	Environmental Impact Assessment
E&P	Exploration & Production
EPA	Environmental Protection Authority
EPSG	European Petroleum Survey Group
FEM	Finite Element Method
GCS	Great Cook Strait
GEBCO	General Bathymetric Chart of the Oceans
GEOMAR	Research Centre for Marine Geosciences
G-Gun	Generator-injector Airgun
GPS	Global Positioning System
GT	Gross Tonnage
H	Hydrogen
Hz	Hertz
IBA	Important Bird Area
IR	Infra-Red
ISWSR	Incoming Short-Wave Solar Radiation
IUCN	International Union for Conservation of Nature
IWC	International Whaling Commission
JIP	Joint Industry Programme
km	kilometres
kmh ⁻¹	kilometres per hour
LOA	Length Over All
L	litres
m	metres
MMIA	Marine Mammal Impact Assessment
MMO	Marine Mammal Observer
MOT	Ministry of Transport
MPa	Megapascal
MPI	Ministry for Primary Industries
MPA	Marine Protected Area
MSL	Mean Sea Level
Mw	Magnitude
NBSAP	National Biodiversity Strategy and Action Plan
NIS	Non-Indigenous Species
NIWA	National Institute of Water and Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration
Nucleus+	Nucleus+ Designer seismic-source modelling software
NZ	New Zealand
NZBS	New Zealand Biodiversity Strategy
NZFS	New Zealand Fur Seal
NZMEC	New Zealand Marine Environmental Classification
NZPM	New Zealand Petroleum and Minerals
NZTCS	New Zealand Threat Classification System
O&G	Oil and Gas
OBS	Ocean-Bottom Seismometers
OSC	Ocean Science Consulting Limited
OLWTR	Outgoing Long-Wave Thermal Radiation
PAM(O)	Passive Acoustic Monitoring (Operator)
P-Cable	P-Cable seismic streamer system

PE	Parabolic Equation
pH	Power of Hydrogen
PPE	Personal Protective Equipment
ppt	Parts Per Thousand
PPZ	Pipeline Protection Areas
PSD	Power Spectral Density
PSI	Pounds per Square Inch
PTS	Permanent Threshold Shift
RADAR	Radio Detection And Ranging
RES	Random Effects Smoothing
RMS	Root-Mean-Square
ROV	Remotely Operated Vehicle
SBP	Sub-Bottom Profiler
SEL	Sound Exposure Level
SEL _{cum}	cumulative Sound Exposure Level
SL	Sound Level
SONAR	Sound Navigation And Ranging
SPL	Sound Pressure Level
SST	Sea Surface Temperatures
SSST	Subduction-to-Strike-Slip Transition
STL	Sound Transmission-Loss
STLM	Sound Transmission-Loss Modelling
SUBTRANS	Subduction-to-Strike-Slip Transition
Sv	Sverdrup
SVP	Sound-Velocity Profiling
TTS	Temporary Threshold Shift
URN	Underwater Radiated Noise
UTM	Universal Transverse Mercator
VTS	Vessel Traffic Services
VHF	Very High Frequency
WGS	World Geodetic System
WOA18	World Ocean Atlas 2018
ZOI	Zone of Influence
μPa	microPascal
°	Degrees

DEFINITIONS

Acoustic source activation	The point at which the seismic or other acoustic source begins operating.
Algal turf	Sparse to thick mats of juvenile algae (seaweed) less than 2cm high
Baroclinicity	Variation in density structure causing pressure surfaces and density surfaces not to align, influencing vertical shear and internal motion.
Barotropic flow	Flow that is depth-uniform or governed primarily by pressure gradients independent of density stratification.
Barotropic tides	Large-scale, surface-level ocean waves driven by the gravitational forces of the moon and sun, moving the entire water column in phase.
Bathymetry	Measurement and description of seafloor depth and morphology.

Benthic	Relating to the seabed or organisms living on or within seabed sediments.
Biogenic habitat	Habitat created or structured by living organisms, such as kelp beds, coral thickets, or shellfish reefs.
By-catch	Non-target species caught incidentally during fishing operations.
Continental shelf	Submerged margin of a continent extending from the coast to the shelf break.
Cubic inch	Cubic inch (in ³), common measurement of volume used in seismic research, 1 CUI = 0.016387064 l
Demersal	Relating to or inhabiting the part of the sea close to the seabed
Diapycnal mixing	Mixing across density surfaces in the water column.
Epifaunal	Living on the surface of the seabed or on other organisms.
Euphotic zone	The sunlit upper water column where photosynthesis can occur.
Exclusion zone	A defined area around an acoustic source within which operations are delayed or stopped if specified species are detected.
Hapū	A subtribe or clan which functions as a political unit within Māori society
Heterotrophic	Describing an organism which obtains carbon and energy by consuming organic matter from other organisms
Hydrodynamic forcing	Physical forcing caused by water movement, including tides, waves, currents, and turbulence.
Infaunal	Living within seabed sediments.
Internal tide	Internal wave generated when tidal currents interact with stratified water and bathymetry.
Internal wave	Wave occurring within the water column along density gradients, rather than at the sea surface.
Inverted barometer effect	Sea-level response to changes in atmospheric pressure.
Isotropic	Having physical properties which do not vary when measured in different directions
Iwi	Largest social groups in Māori society, often translated as tribe
Kelp forest	Dense habitat-forming assemblage of large brown algae.
Level 1 survey	An operational acoustic source capacity of >427 CUI (in ³) (>7.0 L)
Level 2 survey	An operational acoustic source capacity of 151–426 CUI (in ³) (2.47–6.98 L)
Level 3 survey	An operational acoustic source capacity of <150 CUI (in ³) (<2.46 L)
Macroalgal reef	Seaweed bed
Māori	Indigenous Polynesian people of New Zealand
Mātaitai	Reserves provided for customary fishing use and management practices.
Mitigation zone	A defined monitoring area around an activity where mitigation actions are applied.
Mixotrophic	Capable of obtaining energy through both photosynthesis and consumption of organic material.

Otolith	Dense inner-ear structure used by fish to detect particle motion and balance.
Particle motion	Oscillatory displacement, velocity, or acceleration of water particles in a sound field.
Pelagic	Relating to the open water column rather than the seabed or coast.
pH	Power of Hydrogen, a measure of the acidity or basicity (alkalinity) of an aqueous solution
Phototrophic Plankton	Using light as an energy source. Organisms suspended in the water column, including phytoplankton and zooplankton.
Pycnocline	Layer in the water column where density changes rapidly with depth.
Raukawa Moana Receptor	Cook Strait Ecological feature or species group that may be affected by a project activity.
Residual circulation	Net flow remaining after short-period oscillatory motions, such as tides, are averaged out.
Residual risk	Risk remaining after mitigation measures have been applied.
Sessile	Fixed in place and unable to move freely.
Sound channel	Water-column layer where sound can propagate efficiently because of sound-speed structure.
Sound speed profile	Vertical profile of sound speed in seawater, controlled mainly by temperature, salinity, and pressure.
Subtidal	Below the low-tide level or relating to processes occurring below the tidal range.
Taiāpure	Traditional Māori fishing grounds in estuarine or littoral coastal areas that also include areas of special spiritual or cultural significance
Takutai moana	The marine and coastal area starting from the mean high-tide mark and ending 12 nautical miles (22.2 km) out to sea
Tangata whenua	A specific group of people with historical claim to a certain district (or Māori people as a whole)
Te Tai o Marokura	Kaikōura
Trophic pathway	Ecological pathway through which energy or effects are transferred through food-web interactions.
Turbulence	Irregular, chaotic water motion that promotes mixing.
Water column	The vertical body of water between the sea surface and seabed.
Wave-current interaction	Modification of waves by currents or currents by waves, affecting sea state and turbulence.
Whānau	Extended family group which is formed of several generations and forms the political version below hapū

SUMMARY

The Subduction-to-Strike-Slip Transition (SUBTRANS) survey is a multidisciplinary geophysical investigation designed to improve understanding of the tectonic transition between the Hikurangi subduction margin and the Marlborough Fault System within central New Zealand. This Marine Mammal Impact Assessment (MMIA) was prepared for GEOMAR Helmholtz Centre for Ocean Research Kiel to evaluate the potential environmental effects of a 23-day offshore survey programme scheduled within Cook Strait and the southern Hikurangi Margin in February and March 2027. The proposed activities comprise approximately 15 days of Level 1 seismic operations using a 5,420 in³ (approximately 90 L) G-Gun airgun array, deployment and recovery of 42 Ocean Bottom Seismometers (OBS), vessel operations, and associated scientific activities. The MMIA was undertaken in accordance with the Marine Mammals Protection Act 1978, the Exclusive Economic Zone and [Continental Shelf](#) (Environmental Effects) Act 2012, and the 2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations.

The assessment was developed through integration of physical oceanography, bathymetry, habitat characterisation, species-distribution data, published literature, acoustic modelling, and structured environmental risk assessment. The area of biological relevance encompasses one of the most tectonically and oceanographically complex marine environments globally, characterised by water depths ranging from approximately 50 m on the continental shelf to >2,700 m within adjacent offshore basins, strong tidal currents exceeding 3 ms⁻¹ in constricted regions, steep bathymetric gradients, submarine canyon systems, and highly heterogeneous habitats. Baseline characterisation identified at least 27 marine mammal species with potential occurrence within the wider area of biological relevance, including blue whale (*Balaenoptera musculus*), minke whale (*Balaenoptera acutorostrata*), potentially (although less likely), Hector's and Māui dolphin (*Cephalorhynchus hectori* and *C. h. maui* respectively), sperm whales (*Physeter macrocephalus*), beaked whales, and New Zealand fur seals (*Arctocephalus forsteri*).

A site-specific sound transmission-loss assessment was undertaken using a range-dependent Parabolic Equation propagation model to characterise regional acoustic propagation under representative shallow-water (approximately 25 m water depth) and deep-water (approximately 2,372 m water depth) scenarios. Broadband simulations were conducted across frequency bands of 12.5–250 Hz and 12.5–1,000 Hz. The modelling demonstrated that water depth, bathymetry and propagation direction strongly influence acoustic propagation within the study area, producing highly directional and spatially heterogeneous sound fields. The representative deep-water scenario produced a substantially broader propagation domain than the shallow-water scenario, with propagation strongly influenced by basin geometry, shelf-break morphology and submarine canyon systems. The standardised 3,600-s SEL_{cum} fields used for these analyses provide a common basis for comparing regional propagation behaviour and should not be interpreted as operational cumulative exposure experienced by an individual receptor. For the separate comparison with the 2013 Code of Conduct, representative 1-s received SELs at 200 m, 1 km and 1.5 km remained below the corresponding Code criteria; the screening assessment therefore does not indicate a requirement to expand the prescribed mitigation zones on the basis of these modelled receiver levels.

Potential environmental effects were evaluated for marine mammals, seabirds, marine reptiles, fish, elasmobranchs, marine invertebrates and zooplankton, benthic habitats, commercial fisheries, tangata whenua interests, other marine users, and cumulative environmental values. For marine mammals, the principal potential effects considered included vessel collision, behavioural disturbance, displacement, acoustic masking, physical and auditory effects associated with seismic exposure, and indirect effects mediated through prey. The revised species-specific assessment incorporated updated population-exposure and receptor-valuation parameters, while other ecological receptors were assessed qualitatively at broad taxonomic-group level. Physical or auditory effects are principally associated with comparatively high exposures close to the active seismic source, whereas behavioural disturbance and masking may occur at lower received levels and potentially over greater distances. Persistent population-level effects are not predicted on the basis of the available evidence and proposed mitigation.

Mitigation measures include implementation of the 2013 Code of Conduct, use of dedicated Marine Mammal Observers (MMOs) and Passive Acoustic Monitoring Operators (PAMOs), 24-hour acoustic monitoring capability, pre-start observations, soft-start procedures, prescribed mitigation and shutdown requirements, vessel-speed controls, and detailed reporting protocols. The revised assessment indicates that implementation of these measures reduces the likelihood and potential consequences of close-range exposure of marine mammals, while qualitative assessment of other ecological receptors does not predict persistent population- or community-level effects. No significant adverse effects on marine mammal populations, critical habitats, ecosystem functioning, commercial activities, or cultural values are anticipated on the basis of the information available and implementation of the applicable mitigation and regulatory requirements.

Overall, the assessment indicates that the proposed SUBTRANS survey can be undertaken while maintaining a high level of environmental protection. Potential effects are expected to be predominantly temporary and context-dependent, and implementation of the applicable regulatory requirements, mitigation measures and monitoring programme is expected to reduce the likelihood and consequences of significant adverse effects on marine mammals and other ecological receptors. The survey will provide important new information on one of the world's most complex subduction-to-strike-slip transition zones while remaining consistent with New Zealand's environmental management and marine-mammal protection requirements.

1. INTRODUCTION

Globally, many whale and seal populations were hunted to near extinction by commercial whalers and sealers in the 19th and 20th centuries before the International Whaling Commission (IWC) enacted a moratorium on commercial whaling (Clapham and Baker, 2002; Leaper *et al.*, 2008; Richards, 2009); however, many populations are now on the rise, benefiting from regulations and protections of countries worldwide. Many marine mammal species remain threatened or endangered, facing pressures from climate change, habitat degradation, and **by-catch** or entanglement in commercial fisheries. Anthropogenic noise represents an additional and increasingly significant stressor for these species.

Marine mammals, and in particular cetaceans, use different sound frequency bands for a number of activities, which include, but are not limited to: communication, navigation, foraging, and a range of activities within the wider social group such as cohesive actions, warnings, and maternal relationships (Southall *et al.*, 2007; André *et al.*, 2010; Erbe *et al.*, 2018; Southall *et al.*, 2019; NMFS, 2024). Sound perception and production is also an important sensory modality for pinnipeds – eared seals and sea lions (Schusterman and van Parijs, 2003; Reichmuth *et al.*, 2013; Mikkelsen *et al.*, 2019; Vincenzi *et al.*, 2019; Sills *et al.*, 2025). Given that effects of noise on marine mammals are variable and depend greatly on noise characteristics (e.g. source level/type of noise), weather conditions, nearby vessels, local sound propagation conditions, and receiver characteristics with regards to sensitivity and bandwidth of hearing, determining the extent of impact is challenging (Todd, 2016; Merchant *et al.*, 2018; Benda-Beckmann *et al.*, 2019).

Anthropogenic noise can impact marine mammals in several ways, including:

1. Masking of important sounds (including communication signals, echolocation, sounds associated with finding prey or avoiding predators, and human threats such as shipping);
2. Alterations in behaviour (including displacement from feeding/breeding/migration habitat);
3. Hearing loss (temporary or permanent);
4. Chronic stress; and,
5. In extreme cases may cause death (Richardson *et al.*, 1995; Nowacek *et al.*, 2007; Wright *et al.*, 2007; Andersen *et al.*, 2012; Johnston *et al.*, 2012; Todd *et al.*, 2015; Nabi *et al.*, 2018; NMFS, 2018; Southall *et al.*, 2019).

Anthropogenic noise can also affect marine mammals indirectly through impact to both adult and juvenile/larval stages of prey, such as fish and invertebrates (e.g. Packard *et al.*, 1990; Simpson *et al.*, 2010; Radford *et al.*, 2011; Holles *et al.*, 2013; de Jong *et al.*, 2018; Wale *et al.*, 2019). Considered together, there is little doubt operationally noisy activities (such as seismic surveys) are detrimental to marine mammal species at both the individual and population level (Todd, 2016) as it has potential to induce possible ecological impacts on local marine mammal species *via* both direct and indirect effects (Todd *et al.*, 2015).

New Zealand has a broad and rich fauna of marine mammals, including almost half of the world's cetaceans being reported in the waters around the islands (DOC, 2025). Important species include Hector's dolphin (*Cephalorhynchus hectori*) and Māui's dolphin (*Cephalorhynchus hectori maui*), both of which are endemic to New Zealand, rare beaked whales, New Zealand fur seal (*Arctocephalus forsteri*), and

southern right whale (*Eubalaena australis*). To protect New Zealand's vibrant array of marine mammals from noise from seismic surveys, the Department of Conservation (DOC) enacted the '2013 Code of Conduct for minimising acoustic disturbance to marine mammals from seismic survey operations' (hereafter '2013 Code of Conduct'; DOC, 2013), which applies to the 200 nautical mile (370.4 km) Exclusive Economic Zone (EEZ) of New Zealand's continental waters. The main purpose of the 2013 Code of Conduct is to mitigate the impact to marine mammals from seismic surveys (**Section 1.2**). All provisions of the 2013 Code of Conduct must be complied with, in order to undertake a seismic survey as a permitted activity in New Zealand's EEZ.

A Marine Mammal Impact Assessment (MMIA) is a requirement under the 2013 Code of Conduct for seismic surveys. The purpose of a MMIA is to identify, quantify, and evaluate potential impacts to marine mammals in the operational area from a seismic survey. MMIAs must also include descriptions of the existing environment, including details of marine mammals and other marine megafauna, e.g. fish, sharks, seabirds, etc. Additionally, transmission-loss modelling of underwater noise is undertaken to assess whether the mitigation zone distance specified in the code is sufficient for the seismic airgun in use, and to characterise long-range propagation and its potential overlap with critical habitat. Additional requirements under the 2013 Code of Conduct include a consultation (**Section 4**) and a Marine Mammal Mitigation Plan (**APPENDIX A – MITIGATION PROTOCOL**).

1.1. SUBTRANS

The Subduction-to-Strike-Slip Transition (SSST) in central New Zealand describes the geo-dynamically complex region in which plate boundary deformation transitions from subduction to strike-slip faulting ¹ along the Pacific-Australian plate boundary. This transition occurs across the southern Hikurangi margin, the Cook Strait region, and into the Marlborough Fault System, forming one of the clearest global examples of along-strike variation in plate boundary style (Wallace *et al.*, 2012). In the North Island, convergence is accommodated primarily by subduction of the Pacific Plate beneath the Australian Plate at the Hikurangi margin. Southwards, the relative plate motion is transferred progressively from the subduction interface onto upper-plate faults, resulting in predominantly strike-slip deformation within the South Island (Power *et al.*, 2016).

The SSST is distributed spatially rather than abruptly, involving partitioning of plate motion across multiple tectonic structures. Geodetic and geological datasets demonstrate that convergence rates decrease southwards along the Hikurangi margin, with deformation accommodated increasingly by crustal strike-slip faults within the upper plate (Wallace *et al.*, 2012). This transfer of motion is facilitated through a system of oblique and strike-slip faults, including those of the Marlborough Fault System, which act to redistribute strain across the transition zone. The result is a coupled system in which subduction processes persist at depth while strike-slip deformation dominates in the upper crust, producing a mechanically complex and multi-layered plate boundary (Power *et al.*, 2016).

¹ A subduction-to-strike-slip transition is where the plate boundary changes from 'one plate going under' to 'plates sliding sideways'.

The SSST region is characterised by:

- Spatially variable coupling along the subduction interface, including areas of strong inter-seismic locking and slow-slip behaviour;
- Distributed crustal deformation expressed through multiple active faults, rather than a single discrete plate boundary;
- Temporally variable seismic behaviour, including interactions between megathrust and crustal fault systems; and,
- Complex three-dimensional plate geometry, with changes in slab dip, fault orientation, and deformation style across relatively short spatial scales (Wallace *et al.*, 2012; Power *et al.*, 2016).

These characteristics underpin the high seismic hazard of the region and confer a capacity for multi-fault rupture, as demonstrated in recent large earthquakes (e.g. 2016 Mw 7.8 Kaikōura) within central New Zealand. Consequently, the SUBTRANS experiment has significant implications for both seismic hazard assessment and applied marine geoscience. The coexistence of subduction and strike-slip processes facilitates complex rupture propagation pathways, including interactions between megathrust earthquakes and upper-plate fault systems (Power *et al.*, 2016).

From an applied perspective, including offshore survey and environmental assessment contexts, the tectonic complexity of the SUBTRANS region influences:

- Seafloor morphology and sediment pathways;
- Spatial distribution of active faults and associated geohazards;
- Temporo-spatial patterns in seismicity and ground motion propagation; and,
- Structural heterogeneity that may affect acoustic propagation and subsurface imaging.

These interactions are linked mechanistically, with active tectonics driving geomorphological evolution and structural complexity, which in turn influence physical and acoustic processes in the marine environment.

1.1.1. Survey aims

The aim of the SUBTRANS seismic survey is to test three hypotheses concerning geophysical construction of the sea floor within the Cook Strait. These hypotheses are:

1. Spatial variability in upper-plate structure, elastic-properties and degree of deformation, control the frictional properties and slip behaviour along the megathrust underlying SSST zones.
2. Structural inheritance relating to plate boundary evolution strongly influences the kinematics of current deformation and how strain is distributed throughout SSST zones.
3. Pronounced changes in upper plate fault connectivity and strike direction, expected in SSST zones, limit the dimensions of upper-plate fault ruptures.

To explore these hypotheses, onshore, offshore, and ocean-bottom seismic activities will be conducted to examine the structural and geophysical properties of the SSST zone. This will be followed up by dense seismic surveying to observe fault configurations at depth. Wide angle reflections will also be used to assess the geometry of the megathrust and characteristics between domains of different plate boundary configuration and earthquake behaviour.

Records of marine mammals potentially present in the operation zone have been collated and are described in **Section 5.2.6**. Key species include blue whales (*Balaenoptera musculus*), common dolphin (*Delphinus delphis*), Hector's dolphins (*Cephalorhynchus hectori*), and Māui's dolphins (*Cephalorhynchus hectori maui*) who are considered particularly vulnerable to seismic activity. As use of seismic equipment may disturb marine mammals, mitigation must be undertaken to minimise the risk to marine mammals under the 2013 Code of Conduct (DOC, 2013).

1.1.2. Survey requirements

This MMIA, required as part of the planning process for the SUBTRANS survey, will be made available to all personnel involved in observational roles. It will be submitted to the Director-General at the earliest opportunity, and no later than one month prior to commencement of the survey, in accordance with regulatory requirements.

Requirement	Location in MMIA
Describe the activities related to the proposed marine seismic survey	2. PROJECT ACTIVITIES DESCRIPTION
Describe the state of the local environment in relation to marine species and habitats, with particular focus on marine mammals, prior to activities being undertaken	5. DESCRIPTION OF OPERATIONAL AREA
Identify the actual and potential effects of the activities on the environment and existing interests, including any conflicts with existing interests	6. POTENTIAL ENVIRONMENTAL EFFECTS & MITIGATION METHODS
Identify the significance, in terms of risk and consequence, of potential negative impacts and define criteria used in making each determination	6. POTENTIAL ENVIRONMENTAL EFFECTS & MITIGATION METHODS
Identify persons, organisations, or <i>tangata whenua</i> with specific interests or expertise relevant to the potential impacts on the environment	4. CONSULTATION & ENGAGEMENT ACTIVITIES
Describe any consultation undertaken with persons described above and specify those who have provided written submissions on the proposed activities	4. CONSULTATION & ENGAGEMENT ACTIVITIES
Include copies of any written submissions from the consultation process	4. CONSULTATION & ENGAGEMENT ACTIVITIES
Specify any possible alternative methods for undertaking the activities to avoid, remedy or mitigate any adverse effects	6. POTENTIAL ENVIRONMENTAL EFFECTS & MITIGATION METHODS
Specify a monitoring and reporting plan	APPENDIX A – MITIGATION PROTOCOL
Specify means of coordinating research opportunities, plans, and activities relating to reducing and evaluating environmental effects	7. RESEARCH OPPORTUNITY

Table 1: MMIA requirements and location of material within the document.
Source: OSC (2026).

1.2. 2013 DOC Code of Conduct & status updates

Developed by the New Zealand Government's Department of Conservation (DOC), in conjunction with detailed input from Ocean Science Consulting and other experts, and in force from 29 November 2013, the '*2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations*' (DOC, 2013) superseded the '*2012 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations*'. It must be read in conjunction with the '*2012 Code of Conduct: reference document*' (DOC, 2012b; DOC, 2012a). Its primary purpose is to mitigate impacts on marine mammals arising from seismic survey operations.

The 2013 Code of Conduct applies to all marine seismic survey operations within New Zealand continental waters, from the coast to the outer edge of the 200 nautical mile (370.4 km) EEZ, including the [continental shelf](#). The 2013 Code of Conduct is mandatory in these areas. It is also given regulatory effect in some marine mammal sanctuaries and in parts of the territorial sea via regional coastal plans developed by regional councils under the Resource Management Act. Elsewhere, outside the EEZ, marine mammal sanctuaries and territorial sea areas where the Resource Management Act has been used to give the Code regulatory effect, application of the Code is voluntary.

The primary objectives of the 2013 Code of Conduct are:

- To minimise disturbance to marine mammals from seismic surveys;
- Minimise noise in the marine environment created from seismic surveys;
- Contribute findings on the physical and behavioural impacts of seismic surveys on marine mammals to scientific body of knowledge, which will help improve standardising observations and reporting;
- Allow environmentally responsible and sustainable seismic surveys to take place in New Zealand continental waters; and,
- Build working relationships between government, research, and industry stakeholders.

The 2013 Code of Conduct incorporates in-built mitigation measures designed to reduce both the physical and behavioural risks posed by seismic surveys. The 2013 Code of Conduct has slightly different mitigation procedures based on the level of acoustic source output. The levels are:

- **Level 1**: an operational acoustic source capacity of >427 [Cubic Inches](#) (CUI; in³, >7.0 L). These tend to be large-scale geophysical investigations (often oil & gas);
- **Level 2**: 151–426 CUI (in³, 2.47–6.98 L). Lower scale investigations (often scientific); and,
- **Level 3**: <150 CUI (in³, <2.46 L). Small scale survey technologies. Not subject to provisions of the Code.

A comprehensive MMIA is required to be submitted to the DOC for any projects that are *Level 1* or *Level 2*. The MMIA assesses potential effects of the seismic survey on marine mammal species in the operational area and can specify further mitigation measures if required.

At the time of this MMIA, the '*Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations*' (DOC, 2013) remains the current operative guidance administered by DOC, and no formal updated or

replacement version has been published. The Code continues to be incorporated explicitly within the regulatory framework governing seismic survey activities in New Zealand, and compliance with its provisions remains mandatory for permitted activities undertaken within the EEZ (New Zealand Parliamentary Counsel Office, 2012). The primary statutory framework underpinning these requirements is provided by the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012, which establishes the overarching regime for managing environmental effects of activities within the EEZ and continental shelf. This Act enables the development of specific regulations, including activity classifications and compliance requirements applicable to seismic surveying. The Exclusive Economic Zone and Continental Shelf (Environmental Effects - Permitted Activities) Regulations 2013 further define seismic surveying as a permitted activity, subject to compliance with the DOC Code of Conduct. These regulations form the principal legal mechanism by which the Code is operationalised within the marine consenting framework (New Zealand Parliamentary Counsel Office, 2012).

Additional regulatory developments have occurred within the broader legislative framework, including amendments to Marine Mammal Sanctuary regulations (e.g. 2020), which introduce further spatial and activity-specific restrictions on seismic surveying. Notwithstanding these developments, such provisions continue to require compliance with the 2013 Code of Conduct. Accordingly, for the purposes of this MMIA, the 2013 DOC Code of Conduct remains the primary and current standard for mitigation of acoustic disturbance to marine mammals, operating within an evolving but consistent legislative framework defined by the EEZ Act 2012 and its associated regulations.

Full details for all these amendments can be sourced on the following websites:

- Department of Conservation (DOC) – 2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations: [View DOC Code of Conduct overview](#).
- Environmental Protection Authority (EPA) – Marine seismic survey requirements: [View EPA marine seismic survey guidance](#).
- New Zealand Legislation – Exclusive Economic Zone and Continental Shelf (Environmental Effects): [View EEZ Act \(current consolidated version\)](#).
- Ministry for the Environment – Regulations under the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012: [View EEZ regulations overview](#).
- New Zealand Legislation – Marine Mammals Protection Act: [View Marine Mammals Protection Act 1978](#)

1.3. Rationale

This Marine Mammal Impact Assessment (MMIA) has been prepared for the multi-scale geophysical investigation of the Subduction-to-Strike-Slip Transition, New Zealand (SUBTRANS), planned within the Cook Strait onshore and offshore region, New Zealand, which is recognised as an Area of Ecological Importance for marine mammals by the Department of Conservation (DOC), , in addition the proposed survey area encompasses two marine mammal sanctuaries: The Clifford and Cloudy Bay Marine Mammal Sanctuary and The West Coast North Island Marine Mammal Sanctuary. The survey is scheduled to occur over a 23-day period in February and March 2027, comprising of ca. 15-day seismic acquisition programme using Ocean-Bottom Seismometers (OBSs) and associated Sound Velocity Profiling (SVP), undertaken from the research vessel RV Sonne, operated by the Federal

Republic of Germany through the Federal Ministry of Education and Research (BMBF).

Ocean Science Consulting Limited (OSC) was contracted by GEOMAR to undertake this MMIA in accordance with the New Zealand DOC's '2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations' (DOC, 2013). The primary purpose of this assessment is to identify, quantify, and plan for effective mitigation of the potential impacts of the SUBTRANS survey on marine mammals within the operational area, while also characterising the receiving environment, including the physical setting and other ecological receptors such as fish, marine reptiles, and seabirds. Potential environmental effects are assessed in **Section 6**.

This MMIA is required to ensure that the SUBTRANS survey is designed and implemented in a manner that is scientifically robust, environmentally responsible, and compliant with regulatory requirements, specifically:

1. Regulatory compliance: the 2013 Code of Conduct (DOC, 2013) mandates an assessment for any *Level 1* or *Level 2* seismic survey activity to ensure that seismic activities do not adversely affect marine mammal populations;
2. Environmental protection: the study aims to examine the structure of SSST zones to understand the along-strike track and its non-extension into Cook Strait; however, the use of seismic equipment can disturb marine mammals, and this assessment identifies, quantifies, and evaluates these potential impacts to mitigate adverse effects;
3. Scientific insight: findings from this survey will provide unprecedented insight into how upper plate changes have affected the variability of after-slips following the Kaikōura earthquake, the manifestation of deformation in ancestral faults through Cook Strait, and the impact of upper plate fault connectivity on the deflection of the Kaikōura earthquake trajectory; and,
4. Stakeholder engagement: the MMIA includes information on the physical environment and marine life in the survey area, ensuring that all relevant ecological factors are considered. This holistic approach helps in engaging various stakeholders, including regulatory bodies, environmental organisations, and the scientific community; and,
5. Mitigation strategies: by identifying potential impacts and proposing mitigation measures, the MMIA aims to minimise disturbance to marine mammals and other vulnerable species, ensuring that the survey is conducted in a responsible and sustainable manner.

Accordingly, this assessment provides a comprehensive, evidence-based framework to balance the scientific objectives of the SUBTRANS programme with the protection of marine mammals and their habitats, ensuring that survey activities are undertaken in accordance with best practice and regulatory expectations.

2. PROJECT ACTIVITIES DESCRIPTION

This section provides information on the activities that will be undertaken during the project. **Section 2.1** outlines the operation schedule and the area to be surveyed. **Section 2.2** includes the navigation safety measures which will be affected throughout the project. **Section 2.3** outlines the materials used including the airgun system specifications and ROV equipment. **Section 2.4** outlines the

vessels that will be used during the project and their relevant specifications. **Section 2.5** will discuss the survey design considerations, including the need for the survey, how this will affect the environment and what timing measures are in place.

2.1. Timing & location

The survey will be undertaken from the dedicated *RV Sonne* (**Section 2.4**) over a period of 23 days (**Table 1**) in the Great Cook Strait (GCS), New Zealand, in the area bounded by 173°E to 177°E and 40.5°S to 43.5°S (**Figure 1**), in February and March 2027.

Area, activity	Station(s)	Duration	Transit
Central NZ, Sound-velocity profile	01	2	
Central NZ, OBS deployments	02-43	21	34
Central NZ, Seismic deployment		8	
Central NZ, Seismic Survey 1	44-67 (Lines 01 – 12)	221	
Short transit: Survey 1 to Survey 2			1
Central NZ, Seismic Survey 2	68-79 (Lines 13 – 18)	143	
Central NZ, Seismic recovery		3	
Central NZ, OBS recovery	80-121	84	34
Hours in total		482 h	69 h

The total hours on station and in transit between stations (excluding the transit to and from port) are: **482 + 69 = 551 hours = 23 days**.

Table 2: Project outline of days at sea. *Source:* GEOMAR (2025).

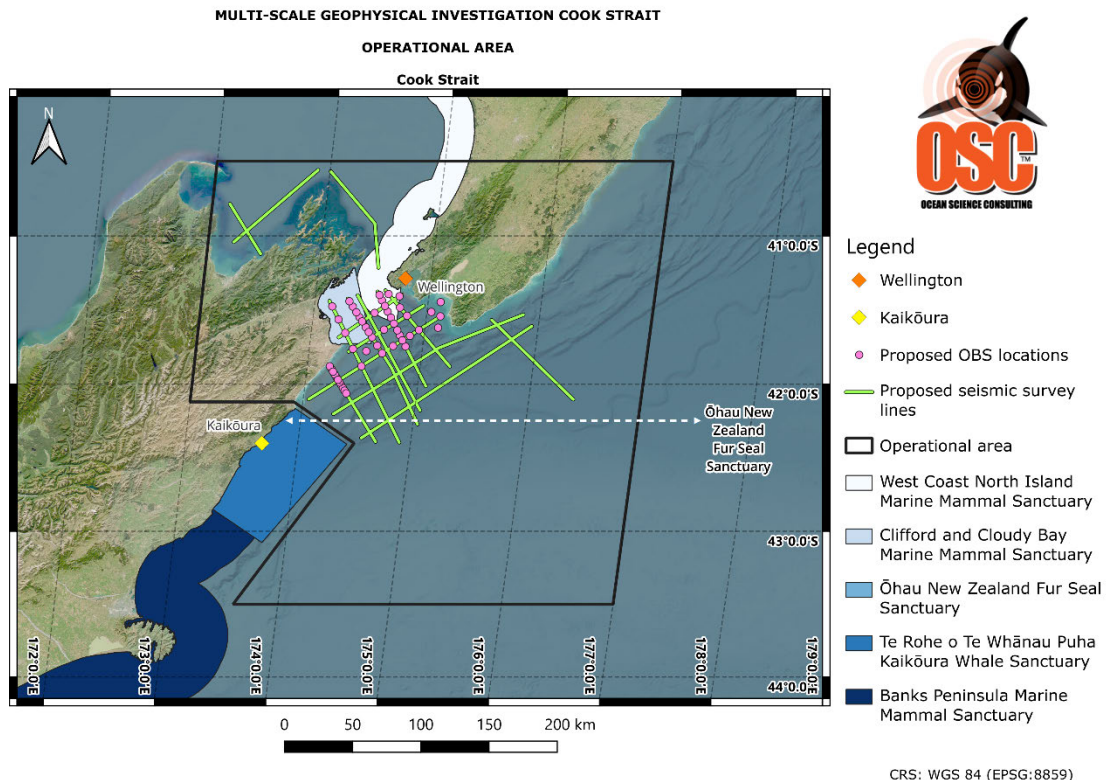


Figure 1: Survey location operational area in relation to marine mammal sanctuaries. The precise locations of seismic survey lines and OBS locations is subject to reasonable modifications as new scientific insight evolves leading up to the voyage, and as conditions on board (weather, logistics) require changes in survey priorities. *Source:* OSC (2026).

OSC will also provide Marine Mammal Observers (MMOs) and Passive Acoustic Monitoring Operators (PAMOs), who will be responsible for monitoring, mitigation, and the collection of information (where available) on marine mammals and other species of interest within the region. MMOs and PAMOs are authorised to implement the requirements of the 2013 Code of Conduct, including the cessation of survey activities where necessary. Further details on mitigation requirements and MMO/PAMO protocols are provided in **APPENDIX A – MITIGATION PROTOCOL**. Survey activities will also be conducted in accordance with the applicable restrictions and regulatory requirements associated with the two Marine Mammal Sanctuaries established under the Marine Mammals Protection Act 1978 that overlap with the survey area.

2.2. Navigational safety

The vessel will transit from Aotea Quay, Wellington Harbour through Cook Strait to conduct seismic operations. The transit is expected to last approximately eight hours from Aotea Quay. During transit and survey operations, the vessel will comply with all applicable maritime navigation requirements, including the Convention on the International Regulations for Preventing Collisions at Sea (COLREGs) and relevant New Zealand maritime legislation. Operations will be undertaken in accordance with the statutory framework established under the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 (New Zealand Parliamentary Counsel Office, 2012), and associated regulations

governing offshore activities, including the Exclusive Economic Zone and Continental Shelf (Environmental Effects - Permitted Activities) Regulations 2013, which apply to seismic survey activities within the EEZ (EPA, 2026). A continuous bridge watch will be maintained, and vessel operations will adhere to recognised navigation practices, including operation within established shipping routes and compliance with any applicable Vessel Traffic Services (VTS) and harbour authority requirements. Navigational lighting, signalling, and Automatic Identification System (AIS) transmission will be maintained throughout transit and operational phases to ensure visibility and situational awareness to other sea users. Appropriate notifications will be issued to relevant authorities prior to commencement of operations, and communication will be maintained with nearby vessels to minimise navigational risk. During survey operations, the presence of towed equipment and any associated restrictions on vessel manoeuvrability will be clearly communicated in accordance with regulatory requirements.

2.3. Seismic survey

A sound velocity profile will be conducted over two hours in relatively deep water (ca. 2580 m) to support multibeam calibration and seismic-reflection data processing. Following this, 42 Ocean-Bottom Seismometers (OBSs) will be deployed over ca. 55 hours within GCS. These OBS nodes will remain on the seabed for the duration of the seismic acquisition and will support the development of a Three-Dimensional (3D) tomographic model of the SSST zone, providing constraints on upper-plate and fault-zone structure, as well as the physical properties of the upper plate and megathrust. The survey will then be conducted over a period of approximately 15 days, with variation depending on the time required to deploy and recover the OBS instruments. The survey operational area is shown in **Figure 1**. The exact survey configuration is subject to change, as new scientific insights developed prior to the survey may be used to optimise the location of survey activities. Any revised survey lines will remain entirely within the operational area defined for the survey.

The multichannel seismic system, shown in **Figure 2** will consist of a 600 m-long streamer towed behind an array of six G-Guns with a combined volume of ca. 5,400 CUI in³. A dominant frequency of ca. 10-30Hz will enable deep penetration of ca. 5 km. Deployment of the streamer is estimated to take eight hours. Shot intervals are spaced at 10-15 seconds (subject to water depth), to create shot spacing of ca. 20-30 m travelling at 3.5 knots. Multibeam bathymetry data and Parasound² Sub-Bottom Profiler (SBP) data will be collected in tandem with seismic acquisition.

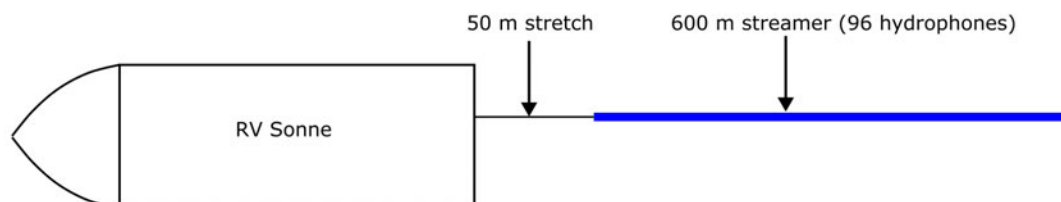


Figure 2: Schematic of the 2D seismic system with a 600 m-long streamer. *Source:* GEOMAR (2025).

² A ParaSound SBP is a special profiler manufactured by Teledyne RESON. It is used widely to image sediment layers and geological structures beneath the seabed.

2.4. Vessel specifications

Operations will be undertaken aboard *RV Sonne*, a research vessel, which has a Length Over All (LOA) of 116 m and a width of 20.6 m (**Figure 3**). Vessel specifications are found in **Table 3**.



Figure 3: Vessel *RV Sonne* Source: Marine Traffic (2026).

Specifications *RV Sonne*

Owner	Federal Ministry of Education and Research (BMBF)
Year of construction	2014
Home port	Wilhelmshaven
Tonnage	8,554 GT
Draft	6.4 m max
Dimensions	Length: 116 m, width: 20.6 m
Maximum speed	15 knots (27.8 kmh ⁻¹)
Operating range	7,500 nautical miles (13,890 km)
Time at sea	50 days
Crew	Ship: 35, science: 40
Scientific facilities	17 laboratories, 521 square metres

Table 3: Specifications of the *RV Sonne*. Source: GEOMAR (2025).

2.5. Survey-design considerations

During survey planning, GEOMAR's survey design was guided primarily by the scientific objectives of the project. Investigation of the deep-seated fault networks in central New Zealand is necessary to provide better understanding of earthquake hazard. The survey design has been planned to avoid the Kaikōura Marine Mammal Sanctuary, while still meeting the core science objectives of the voyage.

2.5.1. Timing

It is not possible to adjust the duration or timing of the survey due to the personnel involved and the requirements for data acquisition. The cruise schedule has been determined in advance to minimise logistical constraints associated with coordinating an international research programme involving multiple institutions and countries. The *Level 1* seismic survey component of the cruise will comprise approximately 15 days of airgun operations; this amount of time is the minimum required for good 3D imaging required to meet the scientific objectives.

2.5.2. Survey design

Equipment deployment locations will be determined *in situ* to ensure that data acquisition objectives are met. The survey design, including line spacing, equipment configuration, and deployment parameters is dictated by the distribution of active and earthquake producing faults and our survey has been designed to image these with the required spatial resolution and data quality. Any major deviation from these parameters would compromise data integrity, reduce interpretability, and potentially render the dataset unsuitable for its intended scientific and operational purposes. Consequently, major modification of survey design is not practicable. The design therefore represents the minimum configuration necessary to obtain robust, defensible, and scientifically valid results within the constraints of the survey objectives.

2.5.3. Noise sources

No alternative acoustic sources were considered, as the selection of seismic-source parameters is defined by the specific scientific requirements of the survey. The airgun arrays have been selected to provide the necessary energy levels and frequency content to achieve the required depth of penetration and imaging resolution for the survey objectives.

The *Level 1* seismic source (*ca.* 5,420 CUI) is required for all 2D seismic lines, where deeper crustal structure and fault architecture (e.g. the subduction megathrust) must be resolved. Lower-energy sources would not provide sufficient signal strength to image these targets at the required depths and spatial resolution and would therefore compromise the scientific validity of the dataset. Use of the *Level 1* source is restricted to the acquisition phase (*ca.* 15 days), representing the minimum operational period necessary to obtain these data.

2.5.4. Vessel

The *RV Sonne* is a purpose-built, modern oceanographic research vessel equipped with specialist geophysical survey systems and supported by experienced technical and scientific personnel. It provides the integrated infrastructure required for successful acquisition of high-resolution seismic, bathymetric, and ocean-bottom instrumentation datasets, including deployment, recovery, and real-time data monitoring capabilities. The vessel's sensor suite, deck-handling systems, and onboard laboratories enable safe and efficient operation of large airgun arrays, seismic streamers, and OBS, together with precise navigation and positioning systems required for geophysical survey accuracy. In addition, the vessel accommodates the technical expertise necessary to operate, calibrate, and quality-control advanced geophysical equipment throughout the survey programme.

Given the technical requirements of the proposed survey, including deep-water operations, high-energy seismic acquisition, and coordinated multi-instrument deployment, the use of a vessel with equivalent capabilities and configuration is necessary. Consequently, selection of an alternative platform is not considered practicable without compromising operational safety, data quality, and survey objectives. Moreover, from an environmental perspective, *RV Sonne* operates as a standard oceanographic research vessel, with no characteristics that would result in disturbance levels exceeding those associated with comparable vessels undertaking similar activities. Vessel-related effects are therefore limited to typical underwater radiated noise and physical presence, which are transient and consistent with established scientific survey operations.

3. LEGISLATIVE FRAMEWORK

Section 3 describes the legislation in place in the GCS for the protection of marine mammals, the environment and maritime traffic. In addition to the 2013 Code of Conduct (DOC, 2013), there are other important legislative requirements to consider when completing a seismic survey. These include the *Marine Mammals Protection Act 1978* (Department of Conservation, 1978) (**Section 3.1**), *Exclusive Economic Zone & Continental Shelf Act 2012* (New Zealand Parliamentary Counsel Office, 2012) (**Section 3.2**), and *Maritime Transport Act 1994* (New Zealand Parliamentary Counsel Office, 1994) (**Section 3.3**). The Resource Management Act 1991 is also relevant to the placement of Ocean-Bottom Seismometers (OBSs), where deployment must comply with the applicable regional coastal-plan provisions and may require resource consent where permitted-activity conditions are not met.

3.1. *Marine Mammals Protection Act 1978*

The Marine Mammals Protection Act 1978 (Department of Conservation, 1978) is the primary legislative instrument governing the protection, conservation, and management of marine mammals within New Zealand waters, and is administered by DOC. The Act applies to all marine mammals, including whales, dolphins, seals, and sea lions, and establishes a strict legal framework under which it is an offence to kill, injure, harass, or disturb these species without lawful authority. The Act provides for development and implementation of conservation management strategies and plans, including population management measures where required, and establishes mechanisms for regulating activities that may affect marine mammals. Of relevance to seismic survey operations, the Act enables designation of Marine Mammal Sanctuaries under Section 22, within which activities that may adversely affect marine mammals can be restricted or prohibited within these sanctuaries, subject to a limited number of exemptions. Where the proposed survey overlaps Marine Mammal Sanctuaries, approval from the relevant Ministers will therefore be required before seismic operations can proceed. Any such operations must also comply with the applicable sanctuary conditions; the 2013 Code of Conduct and any additional mitigation or operational requirements identified during regulatory review.

3.2. *Exclusive Economic Zone & Continental Shelf Act 2012*

The Exclusive Economic Zone and Continental Shelf Act 2012 (New Zealand Parliamentary Counsel Office, 2012) establishes the statutory framework for environmental management within New Zealand's EEZ and continental shelf. The Act promotes the sustainable management of natural resources by regulating their use, development, and protection, ensuring that economic activities are

undertaken while maintaining the life-supporting capacity of the environment, sustaining resources for future generations, and minimising adverse environmental effects.

Under the Act, activities within the EEZ and continental shelf are classified according to their potential environmental effects and level of regulatory control required. These classifications are defined as follows:

- Permitted activities that may be undertaken without a marine consent, provided they comply with all applicable regulations and conditions; and, where required, notification must be made to the Environmental Protection Agency (EPA) prior to commencement;
- Discretionary activities that require a marine consent from the EPA, with applications subject to public notification and a statutory assessment period of up to 140 working days;
- Prohibited activities are those for which a marine consent cannot be sought or granted; and,
- Non-notified discretionary require a marine consent from the EPA but are not subject to public notification and are assessed within statutory timeframes of up to 60 working days.

Classification of activities is informed by consideration of potential environmental effects, the need to protect sensitive or vulnerable ecosystems, and the economic and societal benefits associated with the activity.

Within this regulatory framework, marine seismic surveying is designated as a permitted activity under the EEZ and Continental Shelf (Environmental Effects – Permitted Activities) Regulations 2013, if operations comply with the DOC's 2013 Code of Conduct. Compliance with the Code is overseen by DOC, including through implementation of MMOs and PAMOs, while the EPA retains responsibility for regulatory oversight and enforcement in the event of non-compliance. The placement and recovery of OBSs within the EEZ may also be subject to applicable requirements under the EEZ Act as permitted marine structures to carry out the seismic surveying.

3.3. Maritime Transport Act 1994

The Maritime Transport Act 1994 (New Zealand Parliamentary Counsel Office, 1994) establishes the legislative framework governing maritime safety, pollution prevention, and the protection of the marine environment from vessel-related activities. Within the context of offshore operations, the Act places clear obligations on vessel operators to prevent environmental harm arising from routine operations and unplanned incidents.

A central provision of the Act is prohibition of discharge of harmful substances into the marine environment. This includes discharges into the sea within the EEZ, as well as releases onto or into the seabed. Harmful substances are defined broadly and encompass fuels, oils, chemicals, waste materials, and any other substances that may cause contamination or adverse effects on marine ecosystems. In addition to discharge prohibitions, the Act establishes requirements for:

- Prevention of marine pollution through adherence to operational controls, vessel management practices, and internationally recognised standards;
- Contingency planning and response, including requirement for vessels to maintain appropriate procedures and equipment to minimise environmental impacts in the event of accidental discharges or spills;

- Reporting obligations in relation to marine pollution incidents, ensuring that any discharge or release with potential environmental consequences is notified to relevant authorities; and,
- Enforcement and compliance mechanisms, including inspection, investigation, and penalties for non-compliance.

In the context of the proposed seismic survey, compliance with the Maritime Transport Act 1994 ensures that vessel operations, including fuel management, waste handling, and routine discharges, are conducted in a manner that minimises risk to the marine environment. Consequently, potential impacts associated with vessel-derived pollution are low, provided that established operational and regulatory controls are implemented effectively throughout the survey programme.

4. CONSULTATION & ENGAGEMENT ACTIVITIES

Section 4 describes OSC's engagement with local stakeholders and key individuals within the GCS communities to obtain information on the operational area and how operations might affect local environmental, cultural and socio-economic interest and species.

Contact is being planned with the *Iwi* via an information sheet with project specifics outlined. This connection is being made by [REDACTED], a research lead involved in the Ngā Ngaru Wakapuke project that focuses on central New Zealand earthquake hazards. The aim of the Ngā Ngaru Wakapuke research project is to provide further insight into the Transition Zone earthquakes to accurately forecast economic, societal and environmental hazards posed by large earthquake sequences within the boundary faults. The Ngā Ngaru Wakapuke project aligns with potential data collection in GCS as part of the SUBTRANS seismic. Through Tapuke, OSC has engaged [REDACTED], head of Te Kotahi o Te Taihū, the Charitable Trust established by the eight *iwi* (Ngāti Kuia, Rangitāne, Ngāti Apa ki te Rā Tō, Ngāti Koata, Ngāti Rārua, Ngāti Toa Rangitira, Te Atiawa, Ngāti Tama) across the top of the South Island. The SUBTRANS information sheet has been provided to Te Taihū, and engagement is ongoing to identify a mana whenua representative who may participate in the SUBTRANS experiment and join the voyage onboard R/V *Sonne*.

Further engagement will include *iwi* and *rūnanga* representing areas not covered through Te Kotahi o Te Taihū, particularly *iwi* of the Wairarapa region and the relevant Ngāi Tahu *rūnanga* in the Kaikōura area. Other stakeholders identified for consultation include commercial fishing representatives, recreational diving groups, Project Jonah, and Kaikōura-based marine tourism operators, including Whale Watch Kaikōura and Dolphin Encounter.

Tapuke is also working alongside local *kura* to identify and provide opportunities for tamariki to engage in the SUBTRANS experiment, either through participation in fieldwork, visiting the vessel while in port, or engaging with the scientists pre, during and post voyage.

5. DESCRIPTION OF OPERATIONAL AREA

Section 5.1 presents a detailed description of the bathymetric structure of Cook Strait and the geological and oceanographic processes that have shaped it. Additionally, it covers ocean circulation in the Cook Strait region, from basin-scale circulation around New Zealand to local dynamics within the strait itself. **Section 5.2** explores species present within the Cook Strait, including species of considered

vulnerability such as marine mammals. **Section 5.3** describes the coastal environments involved and expands into marine conservation taking place in surrounding areas, including protected areas. **Section 5.4** delves into the cultural environment present and the impact this could have on operations. Finally, **Section 5.5** explores anthropological factors in the operational area, from fishing to shipping activities and other industrial activities.

5.1. Physical oceanography

Physical oceanography provides the framework for understanding how seabed morphology and external forcing combine to produce complex, energetic-flow regimes and associated patterns of transport, exchange, and variability. This section concerns the study of the physical processes and properties that govern ocean behaviour, including circulation, tides, waves, temperature, salinity, density structure, and mixing, and seeks to understand how these processes interact to regulate ocean dynamics and variability across a range of temporo-spatial scales.

The GCS lies between New Zealand's North and South Islands. Its position at the convergence of the Pacific and Indo-Australian tectonic plates results in complex bathymetry, characterised by an adjacent shallow continental shelf, a deep ocean trench, numerous intersecting faults, and a highly irregular shoreline. The two main islands of New Zealand (North and South Islands) present a formidable north-south oriented barrier of approximately 1,400 kilometres to the prevailing west to southwest winds and oceanic currents, with the GCS presenting the only gap in the bathymetry and topography. The GCS is wider and larger on the western side comprising Golden Bay, Tasman Bay and the South Taranaki Bight, leading through the Narrows (only 24 kilometres wide) and widening again on the eastern side, especially beyond Cape Palliser and Cape Campbell (Walters *et al.*, 2010).

Within the GCS, circulation, tides and mixing represent internal ocean dynamics that are shaped fundamentally by underlying bathymetry and pronounced constriction of flow between the two islands. Density structure and stratification modify the propagation of momentum and energy within the [water column](#), regulating vertical exchange and influencing both mean circulation and short-term variability. Superimposed on these internal dynamics, ocean-atmosphere interactions provide the dominant external forcing, primarily through wind stress, air-sea heat exchange, and atmospheric pressure gradients. Atmospheric forcing directly modulates circulation strength, stratification, wave climate, and short-term variability, particularly in the near-surface ocean. The acoustic environment of the GCS arises as an emergent property of this integrated system, reflecting the combined influence of bathymetry, circulation, stratification, mixing, and surface forcing.

From an acoustic perspective (**Section 5.1.7**), bathymetric structure exerts a primary control on sound propagation by governing reflection, refraction, and scattering processes at the seabed and along steep gradients. Abrupt depth changes, canyon systems, and shelf-slope transitions introduce strong spatial variability in acoustic boundary conditions, influencing transmission-loss, multipath propagation, and the distribution of acoustic energy within the water column. Accurate representation of seabed morphology is therefore fundamental to understanding spatial variability in the acoustic environment.

In summary, in the operational area overall, these processes are dominated by strong tidal currents interacting with complex bathymetry, resulting in a highly energetic flow regime characterised by strong spatial heterogeneity and tight

coupling between physical and biological systems (Bowman *et al.*, 1983; Walters *et al.*, 2010). The physical environment is therefore best described as an integrated dynamical system in which circulation, stratification, and mixing jointly regulate transport pathways, residence times, and vertical exchange.

5.1.1. Seafloor morphology & bathymetry

This section covers basin-scale and local bathymetry, shelf-slope transitions, canyon systems, tectonic controls, and relevance to flow steering, [turbulence](#) generation, and sound propagation.

Overall, the Cook Strait has a highly variable seafloor shaped by active tectonics, extremely strong tidal currents, and long-term sediment transport between the continental shelf and the deep ocean. A strong contrast exists across the strait, from a broad, shallow continental shelf in the north-west to rapid deepening and a canyon-dominated margin in the south-east, where the Cook Strait Canyon system links the shelf directly to the Hikurangi Trough. This bathymetric complexity strongly influences sediment pathways, seabed habitats, and tidal dynamics.

The bathymetry of Cook Strait is highly asymmetric and spatially heterogeneous, reflecting the combined influence of active plate boundary tectonics, extreme tidal forcing, and long-term sediment transfer between the continental shelf and deep ocean basins. The strait occupies a critical position at the transition between the obliquely convergent Pacific–Australian plate boundary and the Hikurangi subduction margin, and its present-day morphology records both tectonic deformation and vigorous hydrodynamic reworking over Quaternary timescales (Lewis, 1980; Lewis *et al.*, 1994; Mountjoy, 2009).

Water depths vary strongly across the strait, from shallow shelf regions of <100 metres on the northwestern side to >2,000–3,000 metres where the Cook Strait Canyon system descends into the Hikurangi Trough on the southeastern margin. This abrupt bathymetric step reflects the juxtaposition of a broad, low-gradient continental shelf against a deeply incised, tectonically controlled canyon system that funnels sediment directly from the shelf edge into the deep Pacific basin (Lewis, 1980; Mountjoy, 2009; Micallef *et al.*, 2014).

The northwestern sector of Cook Strait, encompassing the South Taranaki Bight and extending into Tasman and Golden Bays, is characterised by a wide, gently sloping shelf with subdued bathymetric gradients. Early regional syntheses of shelf morphology and sedimentation recognised this region as a relatively lower tidally-induced bottom-stress domain outside the main Narrows jet, favouring fine-sediment deposition and reworking under changing sea level and forcing relative to the southeastern strait, dominated by reworked Holocene and late Pleistocene sediments and punctuated by broad, low-relief bedforms (Lewis, 1980; Proctor and Carter, 1989; Carter, 1992; Mountjoy, 2009; Walters *et al.*, 2010).

Regional geological and oceanographic studies indicate that the northwestern approaches to Cook Strait, including the South Taranaki Bight and the entrances to Tasman and Golden Bays, comprise broad, low-gradient continental shelf areas. During late Quaternary sea-level rise, these shelf regions functioned as relatively low-stress sedimentary domains compared with the southeastern strait, with sediment accumulation during lowered sea levels followed by reworking under strong tidal forcing after strait opening (Lewis, 1980; Proctor and Carter, 1989; Lewis *et al.*, 1994; Mountjoy, 2009). In contrast, the southeastern sector of Cook

Strait exhibits abrupt bathymetric deepening across the Narrows and offshore of Cape Palliser and Cape Campbell, where the shelf edge is incised by the multibranched Cook Strait Canyon system. High-resolution bathymetric analyses demonstrate that these canyons are deeply cut into bedrock, with steep longitudinal profiles and canyon walls, reflecting strong structural control in combination with active erosional processes (Lewis, 1980; Mountjoy, 2009; Micallef *et al.*, 2014). The canyon system extends approximately 40 kilometres landward into the continental shelf and descends to depths of about 2,700 m where it merges with the Hikurangi Trough (Lewis, 1980; Mountjoy, 2009; Lamarche *et al.*, 2012).

The morphology and evolution of the Cook Strait Canyon system are tightly coupled to regional tectonics. Primary studies demonstrate that major active faults and folds exert first-order control on canyon alignment, sinuosity, and knickpoint development, producing a transient, non-equilibrium canyon morphology that responds to ongoing uplift and deformation of the (Lewis, 1980; Mountjoy, 2009; Micallef *et al.*, 2014). Earthquake-triggered slope failures and sediment gravity flows further contribute to canyon deepening and sediment export, highlighting the role of tectonic forcing in maintaining efficient shelf-to-basin sediment transfer pathways.

Strong tidal currents within Cook Strait interact directly with its complex bathymetry, particularly in the Narrows where depth contrasts and constricted geometry amplify near-bed shear stresses. Depth-averaged tidal currents in and near the Narrows are modelled to reach $ca. 2.5 \text{ ms}^{-1}$ with spring-tide peaks exceeding 3 ms^{-1} reported in observational studies, promoting persistent seabed scour and inhibiting sediment accumulation on steep bathymetric slopes (Lewis, 1980; Proctor and Carter, 1989; Mountjoy, 2009; Walters *et al.*, 2010). The coupling between bathymetry and tidal dynamics reinforces the long-term maintenance of the canyon heads and prevents infilling of the southeastern shelf break despite high sediment supply from adjacent basins.

Overall, the bathymetric structure of Cook Strait reflects the superposition of tectonic segmentation, canyon incision, and tidally driven reworking, producing one of the most morphologically complex straits globally. This combination of processes results in a sharp spatial contrast between a broad, sediment-dominated shelf in the northwest and a tectonically sculpted, canyon-dominated margin in the southeast, with important implications for sediment transport, benthic habitat distribution, and regional oceanographic dynamics. Further reading can be found in: (Micallef *et al.*, 2014; Stevens, 2014; NIWA, 2016b; Stevens, 2018; Hadfield and Stevens, 2021).

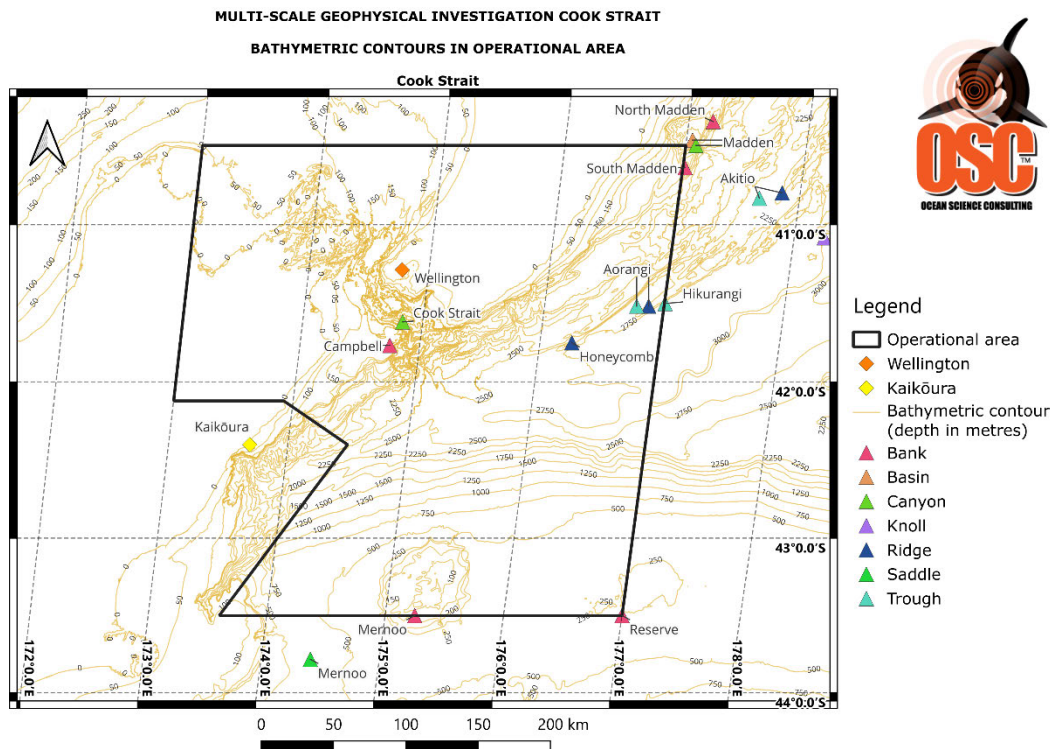


Figure 4: Bathymetric contours (in metres) in operational area. Coordinate reference system: WGS 84/Equal Earth Asia-Pacific (EPSG:8859). *Source:* OSC (2026), modified from National Institute of Water and Atmosphere (NIWA, 2016a).

5.1.2. Ocean circulation & transport pathways

This section covers regional boundary currents versus local dynamics, tidal dominance, [residual circulation](#), and exchange between basins.

At the broadest scale, circulation around New Zealand reflects the separation of the subtropical gyre into boundary currents that flow predominantly northward on the western side of the country and southward on the eastern side. These basin-scale currents establish the background conditions upon which Cook Strait dynamics operate, but they do not dominate transport through the strait itself. Instead, transport is highly episodic and strongly modulated by tides, local pressure gradients, and wind forcing over short temporal scales (Chiswell *et al.*, 2015a); therefore, in the operational area overall, ocean circulation is constrained strongly by bathymetry, with tidal dynamics dominating instantaneous flow rather than persistent advective boundary currents (Bowman *et al.*, 1983; Walters *et al.*, 2010). Strong oscillatory tidal flows interact with steep and irregular seabed topography, generating vigorous horizontal and vertical mixing (**Section 5.1.6**) and limiting the development of long-lived, coherent mean flow (Stevens, 2014). Residual circulation is comparatively weak, variable spatially, and superimposed on energetic tidal motion, resulting in rapid exchange and short water-mass residence times rather than sustained unidirectional transport.

Large-scale and regional ocean circulation in the Cook Strait region is governed by interaction between strong barotropic tidal forcing, complex bathymetry, and the convergence of broader southwest Pacific water-mass pathways around New Zealand. The strait occupies a unique dynamical position as the sole deep-water

connection between the Tasman Sea and the southwest Pacific Ocean and consequently acts as both a conduit and a filter for momentum, mass, and tracers exchanged between these basins. A good overview is found in Stevens *et al.* (2021a).

The Cook Strait is recognised widely as one of the most tidally energetic straits globally, although representative astronomical tidal ranges are relatively low, ranging from 0.7–2.0 metres during perigean ‘king’ tides. The constricted geometry of the Narrows, combined with pronounced depth gradients and adjacent shelf-slope transitions, accelerates tidal currents and produces large oscillatory flows that dominate instantaneous velocities throughout much of the water column. Observational and modelling studies demonstrate that tidal currents overwhelmingly exceed mean background flows, such that the instantaneous circulation reverses direction over the tidal cycle (Walters *et al.*, 2010; Stevens, 2014).

Despite the dominance of oscillatory motion, the Cook Strait exhibits a persistent **subtidal** residual circulation when averaged over complete tidal cycles. This residual flow arises from nonlinear tidal rectification, interaction between tidal currents and bathymetric slope, and spatial asymmetry in channel geometry. Detailed current meter observations and hydrodynamic modelling indicate that this residual circulation is spatially heterogeneous, varying laterally across the strait and vertically through the water column, rather than forming a simple, uniform throughflow (Stevens, 2014; Hadfield and Stevens, 2021).

Residual circulation patterns typically involve weak net transport between the Tasman Sea and the Pacific Ocean, with locally enhanced jets and return flows concentrated near bathymetric features such as headlands, banks, and canyon heads. These features impose strong constraints on the direction and structure of flow, creating regions of flow convergence, divergence, and enhanced shear that are stable over climatically relevant timescales even though instantaneous currents fluctuate rapidly (Stevens, 2018).

Vertical structure within the circulation reflects the weakly stratified nature of the water column for much of the year. During periods of reduced stratification, momentum penetrates efficiently from surface to depth, allowing near-bed flows to respond rapidly to surface forcing. Conversely, episodic stratification can transiently decouple surface and bottom layers, modifying vertical shear and redistributing energy into internal motions and turbulent mixing rather than coherent mean flow (Stevens, 2018).

The interaction between strong tidal currents and steep bathymetry also promotes vigorous horizontal and vertical mixing, which acts to homogenise water properties over large areas of the strait. Consequently, the Cook Strait does not function as a classic advective boundary current system, but instead as a dynamically energetic mixing zone characterised by rapid exchange, short residence times, and limited long-term retention of water parcels (Hadfield and Stevens, 2021).

From a regional perspective, this circulation regime has important implications for redistribution of heat, nutrients, suspended sediments, and biological organisms. Dominance of oscillatory flow, coupled with relatively weak residual transport, favours repeated reworking of material over the shelf and slope rather than sustained unidirectional export. This dynamical setting contributes to strong physical-biological coupling and helps to explain the high productivity and

ecological complexity observed in adjacent regions such as Kaikōura and the greater Cook Strait system.

From an acoustic perspective (**Section 5.1.7**), circulation influences the transport and redistribution of water masses with differing temperature and salinity characteristics, thereby modifying sound-speed structure over temporo-spatial scales. Strong oscillatory currents and spatially variable residual flows introduce dynamic sound speed gradients and Doppler effects, influencing acoustic propagation pathways and the stability of acoustic conditions over tidal cycles.

In summary, overall, ocean circulation in the operational area is best characterised as tidally dominated, spatially heterogeneous, and strongly constrained by bathymetry, with weak but persistent residual pathways superimposed on energetic oscillatory flow. These characteristics underpin not only the physical environment, but also the distribution of prey, movement of higher trophic levels, and the propagation of underwater sound/noise within the region.

5.1.3. Density structure & seasonal stratification

This section covers temperature–salinity structure, seasonal variability, implications for vertical coupling and internal motions.

Despite the presence of strong tidal currents, seasonal stratification develops periodically in the operational area, particularly during austral spring and summer, when surface heating and episodic freshwater inputs reduce vertical density gradients sufficiently to permit partial decoupling of surface and deeper layers (Chiswell *et al.*, 2015b; Jhugroo *et al.*, 2020).

Stratification is spatially heterogeneous, reflecting variability in bathymetry, wind exposure, proximity to freshwater sources, and local circulation pathways (Bowman *et al.*, 1983). Even relatively weak density gradients can be significant dynamically, influencing vertical shear, modifying residual circulation, and enhancing the generation of internal motions (Stevens, 2014).

Freshwater-influenced processes play an important episodic role, with river discharge and high-rainfall events generating low-salinity surface layers and sub-mesoscale density fronts that enhance near-surface stratification, particularly in coastal and shelf-adjacent regions (Jhugroo *et al.*, 2020; Jhugroo *et al.*, 2025). These features can strengthen stratification in the upper tens of metres and introduce pronounced horizontal and vertical density gradients that interact with the background tidal flow.

Even relatively weak density gradients are significant dynamically in Cook Strait because they introduce [baroclinicity](#) into an otherwise strongly barotropic system, influencing vertical shear, modifying residual circulation, and enhancing the generation and propagation of internal motions (Stevens, 2014; Stevens *et al.*, 2021a). Consequently, the water column alternates on seasonal and event-driven temporo-spatial scales between well-mixed and partially stratified states, rather than exhibiting persistent or strongly layered stratification. This intermittent stratification has important implications for vertical coupling, acoustic propagation, and the interpretation of circulation and mixing processes within the operational area.

From an acoustic perspective (**Section 5.1.7**), density structure is a first-order control on [sound speed profiles](#) and therefore on acoustic propagation pathways. The presence or absence of stratification governs refractive structure within the water column, influencing the formation of [sound channels](#), shadow zones, and vertical acoustic coupling. Temporal variability in stratification consequently introduces variability in transmission loss and detectability.

In summary, within the operational area, density structure and seasonal stratification introduce temporo-spatial variability in vertical water column structure, arising from the interplay between surface heating, episodic freshwater input, and strong tidal forcing. Stratification develops intermittently under favourable conditions but remains spatially heterogeneous and frequently transient due to energetic mixing. Consequently, the water column alternates between well-mixed and partially stratified states, with density gradients modulating vertical shear, internal motion generation, and vertical coupling. These processes provide a key control on the redistribution of momentum and tracers and govern variability in circulation, mixing, and water column structure within the operational area.

5.1.4. Ocean-atmosphere interactions

This section describes the role of ocean–atmosphere coupling as an external forcing mechanism, focusing on wind stress, air–sea heat exchange, and atmospheric pressure variability, and their influence on circulation, stratification, wave climate, and short-term variability within the operational area.

Ocean–atmosphere interactions represent the dominant external forcing acting on the surface ocean, superimposed on internal dynamics governed by bathymetry, tides, and density structure (**Section 5.1.3**). In the Cook Strait region, atmospheric forcing exerts a first-order control on near-surface circulation, vertical mixing, stratification, and wave generation, and contributes substantially to short-timescale variability in both physical conditions and the acoustic environment (Walters *et al.*, 2010; Stevens *et al.*, 2021a).

Wind stress is the primary mechanism through which momentum is transferred from the atmosphere to the ocean. Over the GCS, prevailing westerly to south-westerly winds are intensified frequently by topographic channelling between the North and South Islands, producing strong and spatially heterogeneous wind fields at the sea surface (Chiswell and Roemmich, 1998; Salinger and Mullan, 1999). These winds drive episodic surface currents, enhance shear in the upper water column, and modulate the strength and structure of residual circulation when averaged over tidal cycles. During periods of sustained wind forcing, surface currents may align or oppose tidal flow, either reinforcing or partially cancelling near-surface velocities depending on wind direction relative to the tidal phase (Walters *et al.*, 2010).

Air–sea heat exchange provides a key pathway for modifying surface buoyancy and regulating seasonal and event-scale stratification. Net surface heat flux, governed by Incoming Short-Wave Solar Radiation (ISWSR), Outgoing Long-Wave Thermal Radiation (OLWTR), latent heat loss, and sensible heat exchange, controls the rate at which surface waters warm or cool relative to underlying layers (Fairall *et al.*, 1996). In austral spring and summer, positive heat fluxes promote surface warming and favour development of transient stratification, particularly during periods of reduced wind stress (**Section 5.1.5**). Conversely, in autumn and winter, enhanced heat loss and frequent storm activity promote convective mixing and contribute to

the breakdown of stratification, reinforcing the typically well-mixed character of the water column (Chiswell *et al.*, 2015a).

Atmospheric pressure variability also influences sea level and circulation through the inverted barometer effect, whereby changes in surface pressure induce corresponding adjustments in sea level height (Ponte, 2006b).

In a narrow, dynamically energetic strait such as the Cook Strait, pressure-driven sea level gradients can contribute to short-term modulation of **barotropic flow**, particularly when acting in concert with wind stress and tidal forcing. Although secondary to tides in determining absolute current magnitudes, these pressure gradients can influence residual transport pathways and enhance variability in surface elevation and current structure during synoptic weather events. Ocean–atmosphere coupling also exerts strong control over the regional wave climate. Wind-generated waves dominate surface conditions in the operational area, with wave height, period, and direction responding rapidly to changes in wind strength and fetch.

The Cook Strait is exposed to Southern Ocean swell entering from both the Tasman Sea and the southwest Pacific, as well as locally generated wind seas, producing a complex and highly variable wave field (Gorman *et al.*, 2003). Wave breaking and **wave–current interactions** enhance near-surface turbulence and mixing (**Section 5.1.6**), particularly during storm events, and can contribute to elevated background noise levels through surface agitation, bubble formation, and wave impact processes.

From an acoustic perspective (**Section 5.1.7**), ocean–atmosphere interactions influence both the generation and propagation of sound through modulation of surface conditions and near-surface turbulence. Wind stress and wave breaking increase ambient noise levels through bubble formation and surface agitation, while simultaneously modifying upper-ocean sound speed structure and boundary conditions, thereby affecting acoustic transmission near the surface.

In summary, within the operational area, the cumulative effect of wind stress, heat flux, pressure variability, and wave forcing is to introduce pronounced short-term and seasonally modulated variability into the physical environment. These processes act most strongly at the sea surface but propagate downward through the water column *via* turbulence, shear, and internal motions, interacting with density structure and tidal dynamics. Consequently, ocean–atmosphere interactions provide a key mechanism linking atmospheric variability to changes in circulation, stratification, mixing, and surface forcing relevant to both ecological processes and sound propagation within the operational area.

5.1.5. Waves, tides & extreme forcing

This section covers barotropic tides, **internal tides**, wave climate, and interaction with bathymetry. Hydrodynamics in Cook Strait reflect interaction between energetic barotropic tides, a variable wave climate, and episodic atmospheric extremes, with responses expressed across temporo-spatial scales from basin scale tidal propagation to localised shear and turbulence.

Ocean tides around New Zealand exhibit coherent spatial structure, with semidiurnal constituents propagating around the islands and showing reduced spring–neap variability on the east coast relative to other regions, which is

attributed to amphidromic structure and topographic modulation (Walters *et al.*, 2001). Within Cook Strait, tidal dynamics are intensified by constricted geometry and strong phase gradients across the Narrows, which generate large barotropic currents (Walters *et al.*, 2001; Walters *et al.*, 2010). Observations across the Narrows indicate that spring-tide currents can exceed 3 ms^{-1} , which makes separation of residual transport from tidal flow non-trivial and implies high bed stress during peak phases (Stevens, 2014).

Subtidal exchange provides a net component of along-strait transport superimposed on tidal oscillation (Stevens, 2014). Current observations resolve along-strait residual flows of order $0.05\text{--}0.1 \text{ ms}^{-1}$ and estimate net residual transport of -0.25 Sv (negative sign indicating southward transport from Tasman Sea to Pacific), with cross-strait structure and seasonal variability (Stevens, 2014). Tide-resolving hindcasts further support non-zero mean transport through Cook Strait and quantify a large M2 tidal volume flux amplitude, while indicating that subtidal variability is strongly wind-linked at regional scale (Hadfield and Stevens, 2021).

The Cook Strait is commonly weakly stratified; however, observational evidence shows that late summer–autumn stratification can persist, and associated vertical shear can influence estimates of residual exchange structure (Stevens, 2014). Where vertical density gradients exist, tidal flow over steep bathymetry can generate internal tides and internal wave fields that dissipate and enhance mixing (Sharples *et al.*, 2001). On the northeast New Zealand shelf edge, internal-tide dissipation and microstructure observations have been used to infer elevated vertical diffusivities and associated vertical nitrate flux, demonstrating a mechanistic link between internal-tide energetics and diapycnal exchange in New Zealand shelf systems (Sharples *et al.*, 2001). In Cook Strait and adjacent waters, wind and tidally driven circulation and mixing have been described as tightly coupled to bathymetric variability, with stratification and mixing fronts sensitive to forcing changes (Bowman *et al.*, 1983).

Wave conditions around New Zealand have historically been poorly sampled for long duration directional records; therefore, hindcast approaches have been used to generate regional wave climatologies (Gorman *et al.*, 2003). Extreme wave climatology for New Zealand waters based on multi-decadal hindcast data provides spatial and seasonal characterisation of extreme events and return-period estimates for significant wave height (Godoi *et al.*, 2017).

In Cook Strait, energetic tidal currents coincide with a wave field comprising both remotely generated swell and locally generated wind waves, so wave–current interaction is expected to modulate wavelength, phase speed, and steepness over tidal phases (Gorman *et al.*, 2003; Walters *et al.*, 2010) - (**Section 5.1.5**). In opposing current conditions, physical wave–current dynamics imply wave steepening and increased breaking propensity, particularly where currents accelerate through constrictions; consequently, short-lived hazardous sea states can develop in specific temporo-spatial windows tied to tidal phase (Walters *et al.*, 2010).

Severe wind and wave events affecting New Zealand coasts have been examined through numerical reconstruction of historical storms, demonstrating that intense atmospheric systems can produce hazardous sea state and rapid changes in forcing conditions. Atmospheric pressure variability contributes to sea-level variability through the inverted barometer response, and its seasonal to interannual signals

can be non-negligible in many regions (Ponte, 2006a). When strong winds and low pressure coincide with energetic tidal states in a constrained strait, compound extremes may arise through contemporaneous elevation of sea state, current shear, and water-level variability, with implications for mixing intensity and operational conditions (Revell and Gorman, 2003; Ponte, 2006a; Stevens, 2014).

High-energy tidal flow implies repeated mobilisation of seabed sediment in exposed corridors, while wave orbital motion and storm-driven forcing can further enhance resuspension during extreme events (Stevens, 2014; Godoi *et al.*, 2017). Regional geological context indicates that sedimentation and sediment transfer pathways on the Hikurangi margin have been shaped by interaction between tectonics and sediment transport processes, providing a framework for understanding sediment redistribution in energetic New Zealand margin settings (Lewis, 1980). In the greater Cook Strait region, circulation and mixing patterns have been linked to variable winds, strong tides, and abrupt bathymetric gradients, consistent with a system in which short-duration changes in forcing can reorganise stratification and mixing structure (Bowman *et al.*, 1983).

From an acoustic perspective (**Section 5.1.7**), waves and tides jointly influence both the acoustic-source environment and propagation conditions. Wave breaking contributes directly to ambient noise generation, while tidal currents and associated water column structure modify sound-speed gradients and propagation pathways. Wave-current interaction further introduces short-term variability in both noise levels and transmission characteristics, particularly during energetic or extreme forcing conditions.

In summary, within the operational area, waves, tides, and extreme forcing interact to produce a highly dynamic and intermittently energetic hydrodynamic regime characterised by strong oscillatory currents, variable sea states, and episodic forcing extremes. Barotropic tidal currents dominate instantaneous flow, while wave-current interactions and atmospheric forcing introduce short-term variability and modulate near-surface conditions. Consequently, periods of intensified forcing, particularly under coincident strong winds, low pressure systems, and peak tidal states, can generate compound effects that enhance shear, turbulence, and sediment resuspension. These processes govern variability in current structure, sea state, and vertical exchange, thereby exerting a primary control on hydrodynamic conditions and associated environmental processes within the operational area.

5.1.6. Mixing & turbulence

This section covers the characterisation of hydrodynamic processes associated with mixing and turbulence within the operational area. It outlines the dominant physical drivers, including tidal forcing, wave-current interaction, and bathymetric control, and describes their influence on water column structure and energy dissipation. The section draws on available region-specific observations and established principles from physical oceanography to define baseline conditions and to identify the key processes governing spatial and temporal variability in mixing intensity.

Mixing and turbulence within the Cook Strait system represent a critical intermediary process linking external forcing (**Section 5.1.5**) and internal hydrodynamic structure (**Sections 5.1.2 - 5.1.4**), governing redistribution of momentum, heat, salinity, suspended sediment, and biogeochemical tracers across a broad range of temporo-spatial scales. Within the operational area, turbulence is temporally intermittent and spatially heterogeneous, arising from the interaction of

energetic tidal currents, complex bathymetry, and variable density structure, rather than from uniform forcing (Bowman *et al.*, 1983; Stevens, 2014; Stevens *et al.*, 2021a). Turbulence generation is dominated primarily by shear associated with strong barotropic tidal flow, particularly where currents accelerate through constricted bathymetry or interact with steep gradients. In these regions, enhanced vertical shear promotes development of turbulent boundary layers and elevated dissipation rates, especially near the seabed, where frictional drag over rough topography maintains persistent turbulent production (Bowman *et al.*, 1983; Stevens, 2014). Flow-topography interaction further induces localised hydraulic control, flow separation, and turbulence hotspots associated with canyon heads, shelf breaks, and bathymetric sills, resulting in strong spatial variability in mixing intensity across relatively short horizontal scales.

Where stratification is present (**Section 5.1.3**), tidal flow over irregular bathymetry generates both internal tide and wave fields, which propagate and subsequently dissipate through breaking processes. This mechanism represents a primary pathway for [diapycnal mixing](#) within the system and facilitates vertical exchange of heat and nutrients between deeper and surface layers (Sharples *et al.*, 2001; Stevens *et al.*, 2021a). Episodic stratification therefore acts to redistribute, rather than suppress, turbulence by concentrating mixing at density interfaces, where shear instabilities are enhanced.

Surface forcing further contributes to turbulence generation, particularly during periods of strong wind stress and elevated sea state. Wind-driven shear within the upper water column, combined with wave breaking and wave-turbulence interaction, increases near-surface turbulent kinetic energy and promotes deepening of the mixed layer (Huang and Qiao, 2010). These processes act over short temporal scales; however, they can substantially modify vertical coupling within the water column during energetic atmospheric events. Freshwater-driven density gradients and sub-mesoscale frontal features may similarly enhance turbulence locally by intensifying shear at density interfaces, particularly following high rainfall events (Jhugroo *et al.*, 2020; Jhugroo *et al.*, 2025). The resulting turbulence regime exhibits strong vertical and horizontal structure. Under peak tidal forcing and weak stratification, turbulent mixing extends frequently through the full water column, producing well-mixed conditions and efficient vertical coupling (Stevens, 2014). Conversely, during periods of partial stratification, turbulence becomes vertically structured, with dissipation rates maximised within bottom boundary layers and near [pycnoclines](#), where internal wave breaking and shear instability facilitate diapycnal exchange (Sharples *et al.*, 2001). Horizontally, turbulence remains concentrated in regions of strong bathymetric control and flow acceleration, while reduced in broader, low-gradient shelf areas where current velocities and shear diminish (Bowman *et al.*, 1983; Stevens *et al.*, 2021a).

Mixing processes within the operational area exert a first-order control on transport pathways and biogeochemical exchange. Enhanced turbulent mixing facilitates episodic vertical flux of nutrients into the [euphotic zone](#), contributing to localised productivity in adjacent shelf and canyon systems (Sharples *et al.*, 2001). At the same time, repeated reworking of water masses under oscillatory tidal flow, combined with spatially heterogeneous turbulence, promotes rapid exchange and short residence times, limiting persistent stratification and long-term retention. Near the seabed, elevated turbulent stresses inhibit fine sediment deposition within high-energy corridors and promote periodic resuspension, contributing to sediment transport between shelf and deep-ocean environments (Stevens, 2014).

From an acoustic perspective (**Section 5.1.7**), turbulence introduces fine-scale variability in temperature and salinity structure, thereby modifying local sound speed gradients and propagation pathways. Turbulence-driven microstructure produces small-scale inhomogeneities that can scatter and refract acoustic energy, influencing transmission loss and detectability. Accurate representation of mixing regimes is therefore essential for interpretation of temporo-spatial variability in the acoustic environment and for parameterisation of sound propagation within the operational area.

Overall, mixing and turbulence in the Cook Strait system are best characterised as energetic, spatially heterogeneous, and strongly modulated by the interaction of tidal forcing, bathymetry, and transient stratification. These processes operate across a continuum of temporo-spatial scales, linking external forcing to internal ocean structure and underpinning both the physical and ecological dynamics of the operational area.

5.1.7. Ambient noise & soundscape characterisation

This section characterises ambient underwater noise and the wider soundscape within the operational area, describing the principal geophysical, biological, and anthropogenic sound sources, their temporo-spatial variability, and the role of oceanographic forcing in shaping the acoustic environment. The section draws upon available empirical measurements from Cook Strait and the wider central New Zealand region, supplemented where necessary by established understanding from comparable high-energy marine environments, to define baseline acoustic conditions and the assessment of potential project-related effects key controls on ambient noise.

The ocean soundscape comprises sound from geological processes, marine life (biophony), and anthropogenic activities, which together generate a spatially and temporally dynamic acoustic environment (Hildebrand, 2009; Putland *et al.*, 2017). Sound constitutes the primary sensory modality through which many marine species perceive, navigate, and interpret their environment, and consequently plays a central role in ecological interactions, predator-prey dynamics, communication, and habitat use. Anthropogenic underwater noise has increased substantially since the Industrial Revolution, and understanding its effects on marine mammals and other acoustically sensitive taxa remains an active area of research (Bayrakci and Klingelhofer, 2023).

Within the operational area, the underwater acoustic environment is governed by interacting geophysical, biological, and anthropogenic sound sources, the relative contribution of which varies across time and space according to environmental conditions and human activity. Although these soundscape components occur globally, their relative influence is strongly modulated by local oceanographic processes. In highly energetic environments such as Cook Strait, physical forcing is expected to exert a major influence on both ambient noise generation and acoustic propagation conditions.

Data from central New Zealand demonstrate that marine soundscapes comprise overlapping geophysical, biological, and anthropogenic sound sources occurring concurrently across time and frequency, reflecting the combined influence of environmental forcing and human activity (Warren *et al.*, 2021a). Baseline passive acoustic monitoring undertaken in the wider Cook Strait region indicates that ambient noise is primarily driven by geophysical processes including wind, wave

action, and seismic activity, together with anthropogenic contributions, principally vessel traffic and seismic surveys (NIWA, 2016–2017; Goetz and Hupman, 2017). These measurements demonstrate marked temporo-spatial variability in the regional acoustic environment, including differences in vessel noise propagation between deep and shallow water settings and variability associated with weather conditions and marine traffic intensity. These observations are consistent with the broader spectral partitioning of ocean noise, whereby low-frequency energy is dominated commonly by vessel traffic and impulsive industrial sources, while mid-to high-frequency sound is largely associated with sea-surface agitation driven by wind, wave action, and precipitation (Hildebrand, 2009). In addition, low-frequency baleen whale vocalisations recorded within Cook Strait demonstrate that acoustic signals may propagate over substantial spatial scales under regional environmental conditions, with seasonal detections of fin whale vocalisations confirmed through passive acoustic monitoring (Constaratas *et al.*, 2021).

The Cook Strait's strong tidal currents (**Section 5.1.5**), complex bathymetry (**Section 5.1.1**), and energetic mixing processes (**Section 5.1.6**) are expected to influence the acoustic environment through both sound generation and propagation mechanisms. In comparable high-energy shelf and strait environments, [hydrodynamic forcing](#) has been shown to contribute to variability in low-frequency ambient noise, including effects associated with current velocity, turbulence, and flow-related interactions with fixed recording systems (Basan *et al.*, 2024). In the wider central New Zealand region, including the South Taranaki Bight, ambient noise measurements similarly demonstrate that wind, rain, tidal forcing, and wave activity elevate sound levels across a broad frequency range, frequently overlapping with shipping, seismic surveys, and biological acoustic signals (Warren *et al.*, 2021a). These findings collectively indicate that physical forcing exerts a strong control on short-term ambient noise variability within the region and may influence sound transmission characteristics, signal detectability, and acoustic masking processes relevant to marine fauna. Within the New Zealand context, however, the evidence base for underwater ambient noise remains comparatively limited, with national assessments identifying gaps in long-term and spatially extensive empirical datasets (Clement, 2024). Consequently, characterisation of the baseline acoustic environment for the operational area requires integration of available empirical evidence, regional ecological and oceanographic understanding, and predictive acoustic modelling to provide an appropriate basis for assessing potential project-related effects.

5.2. Biological oceanography

Biological oceanography is the study of how marine organisms interact with their environment and how these interactions affect the ocean's physical, chemical, and geological properties. This field focuses on understanding the distribution, abundance, and productivity of marine species, as well as the processes that govern their spread and development. The topic includes various aspects of marine life, including plankton diversity, their productivity, and their role in the global carbon cycle and how marine organisms behave and develop in relation to their environment. Biological oceanography differs to marine biology, which often takes a top-down perspective, whereas biological oceanography typically adopts a bottom-up approach, focusing on the ecosystem (as a whole).

According to the New Zealand Marine Environmental Classification (NZMEC) system, the operational area comprises mainly Class 47, 63, 58 and 60 habitat (**Figure 5**), (Snelder *et al.*, 2005). Class 47 habitats occur in deep waters with a

mean depth of 2998 m over a latitudinal range between 37 – 47 °S; concentrations of chlorophyll a (Chl-*a*) are moderately low with a winter Sea Surface Temperature (SST) of 11.6 °C. The Class 63 habitats are extensive on the continental shelf and have a mean depth of 754 m, with moderate annual ISWSR, average Chl-*a* concentrations, and winter SST of 12.1 °C. Class 58 has a restricted occurrence with mean depths of 117 m and occurring within the Cook Strait area, the dominant feature of this habitat is strong tidal currents, SST in winter is 13.0 °C. More extensive than Class 58 is Class 60 habitats occurring in shallow waters with a mean depth of 112 m, with moderate ISWSR, moderately high Chl-*a* concentrations and a winter SST of 13.2 °C (Snelder *et al.*, 2005). There are also habitat classes within the Cook Strait that occupy a smaller proportion of the area such as Class 55, 64, 124, 130, 169 and 170. Class 55 habitats have moderately shallow waters with mean depths of 224 m, this habitat class has a high ISWSR and high wintertime SST of 15.1°C, concentrations of Chl-*a* are moderate. Class 64 habitats occur in shallow waters with a mean depth of 38 m, both orbital velocities and annual amplitude of SST are high with low seabed slopes, Chl-*a* concentrations on average are at its highest in this class. Around the entire New Zealand coastline occupying shallow waters with mean depth of 8 m are Class 124 habitats with very high orbital velocities and a winter SST of 12.7°C. Occurring only in the Marlborough Sounds are class 130 habitats, this class occupies sites with a distinctive set of environmental conditions typified by shallow water with a mean depth of 10 m, minimal slope, tidal currents, moderate orbital velocities and high gradients of SST. Class 169 habitats are southeast of the South Island in shallow waters with a mean depth of 66 m with low to moderate orbital velocities, moderate tidal currents, moderately low annual solar radiation and a wintertime SST of 9.9°C. On average Chl-*a* concentration in Class 169 habitats is high. Finally, Class 170 which has moderately shallow waters with a mean depth of 129 m, winter SST is low at 9.3 °C, tidal currents are moderate with moderate concentrations of Chl-*a* (Snelder *et al.*, 2005).

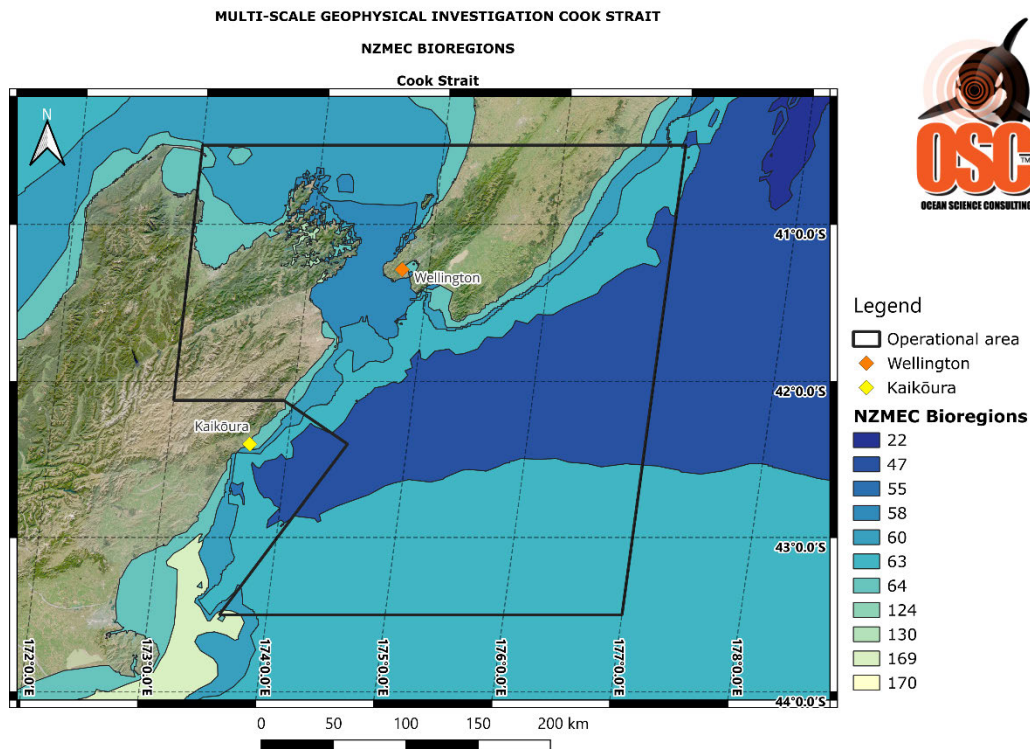


Figure 5: Bioregions as defined by the NZMEC system. Coordinate reference system: WGS 84/Equal Earth Asia-Pacific (EPSG:8859). *Source:* OSC (2026), modified from Snelder *et al.* (2005).

5.2.1. Plankton

This section covers the characterisation of plankton communities within the operational area. It describes the structure and function of phyto- and zooplankton assemblages, their temporo-spatial variability, and the physical and biogeochemical processes that regulate productivity. The section draws on available data from Cook Strait and the wider central New Zealand region, supplemented by established understanding from comparable shelf and strait environments, to define baseline conditions and identify key controls on plankton dynamics.

Plankton comprise a diverse assemblage of organisms suspended within the water column. Wassilieff (2009) listed common plankton groups in New Zealand, including primary producers (phytoplankton) and secondary consumers (zooplankton), which together underpin marine food webs and biogeochemical cycling (Grigoratou *et al.*, 2025). Marine phytoplankton contribute approximately half of global primary production and play a fundamental role in regulating the global carbon cycle through photosynthetic carbon fixation and the transfer of organic carbon through marine food webs and export pathways (Falkowski *et al.*, 1998; Behrenfeld *et al.*, 2006). Phytoplankton, including diatoms and dinoflagellates, mediate primary production through photosynthesis, while zooplankton, including copepods, euphausiids, and other taxa, transfer energy to higher trophic levels (Chandel *et al.*, 2024). Zooplankton additionally contribute to carbon export and the biological pump through the production of faecal pellets, respiration, excretion, moults, carcasses, and diel vertical migration, thereby linking surface productivity with deep-ocean biogeochemical processes (Steinberg

and Landry, 2017). In addition, some planktonic protists are **mixotrophic**, combining **phototrophic** and heterotrophic nutrition, which can influence nutrient cycling and carbon transfer through microbial food webs (Stoecker *et al.*, 2017). Collectively, these groups regulate energy flow and nutrient cycling within marine ecosystems.

Within Cook Strait and the wider central New Zealand region, plankton distributions are influenced strongly by hydrodynamic variability, including tidal mixing, advection, and the interaction of distinct water masses of subtropical and subantarctic origin (Garner, 1956; Bary, 1959; Ratnarajah *et al.*, 2023). Plankton communities within the Strait are therefore temporally variable and spatially heterogeneous, reflecting the mixing of water masses and the continual exchange of oceanographic conditions (Eddy *et al.*, 2025). Where multiple water masses interact, plankton assemblages are in a state of flux, with species composition and abundance reflecting the relative contribution and mixing history of those water masses.

Empirical studies conducted in Cook Strait indicate that phytoplankton biomass is influenced by advection, tidal mixing and zooplankton grazing, with biomass accumulation most likely where nutrient-rich waters become sufficiently stable to allow phytoplankton growth (Bradford *et al.*, 1986; Eddy *et al.*, 2025). During summer, nutrient-depleted, stratified waters derived from the Tasman Sea may dominate surface layers (Karabashev, 2023); however, localised upwelling, frontal processes, and tidal mixing act to supply dissolved inorganic nutrients to the euphotic zone, thereby sustaining primary production (Valcarcel *et al.*, 2025). In the GCS, Bradford *et al.* (1986) identified several region-specific controls on phytoplankton production, including tidal mixing off Marlborough Sounds, riverine inputs from the Manawatu River, eastern Cook Strait hydrographic conditions, and nutrient-rich upwelling in the Kahurangi Point-Cape Farewell region, the latter of which was associated with elevated chlorophyll concentrations and primary production relative to surrounding waters.

Zooplankton communities reflect similar physical controls, with composition, abundance, and distribution linked closely to water mass structure and transport processes (Lh  riau-Nice *et al.*, 2025). In the GCS, zooplankton assemblages have been shown to vary in response to the formation and advection of upwelling plumes, with distinct community structures associated with different stages of plume development (Bradford-Grieve *et al.*, 1993). This plume system is also associated with high zooplankton biomass and active nutrient recycling, including ammonia excretion, which may further influence phytoplankton dynamics within the plume (James and Wilkinson, 1988). These observations demonstrate the importance of advective processes and nutrient supply in structuring zooplankton populations, including changes in reproductive capacity and species composition linked to plume dynamics.

In high-energy shelf and strait environments, turbulence and mixing regulate plankton dynamics through their influence on nutrient flux and light availability (Aaron *et al.*, 2025). Increased mixing may enhance nutrient delivery to surface waters, thereby supporting phytoplankton growth; however, where mixing is sufficiently intense, it may reduce growth by limiting light exposure within the euphotic zone (Comesa  a *et al.*, 2021). Conversely, reduced mixing can promote phytoplankton accumulation where nutrient availability is sufficient (Sharoni *et al.*, 2026). The balance between stratification and mixing therefore governs the timing,

magnitude, and spatial distribution of plankton productivity, and represents a key control on ecosystem function.

Within the operational area, plankton communities are therefore expected to exhibit pronounced temporo-spatial variability driven by the interaction of hydrodynamic forcing, nutrient supply, and biological processes. This variability is characteristic of Cook Strait and adjacent systems and reflects the strong coupling between physical oceanography and lower trophic levels. Consequently, plankton dynamics provide a key mechanistic link between physical processes described in **Section 5.1** and higher trophic levels considered in subsequent sections.

5.2.2. Invertebrates

Benthic invertebrate communities within the operational area are structured primarily by bathymetric complexity, substrate type, and the highly energetic hydrodynamic regime that characterises the GCS (**Section 5.1**). Strong tidal currents, combined with steep bathymetric gradients and episodic sediment-transport processes, create spatially heterogeneous habitats that support diverse assemblages of benthic invertebrate taxa (McIlroy *et al.*, 2024). In general, in high-energy environments, such as constricted channels and canyon heads, coarse substrates and exposed bedrock dominate, favouring sessile and encrusting taxa, whereas lower-energy shelf and basin areas allow accumulation of finer sediments (Walters *et al.*, 2010; Galka, 2025), likely supporting infaunal communities. This pattern is consistent with observations from other high-energy shelf environments, where gradients in water depth, tidal-current strength, hydrography and sediment mobility are associated with corresponding changes in seabed morphology and sediment grain size (Butman, 1981).

Benthic communities in the GCS region comprise a mixture of soft-sediment and hard-substrate assemblages, including molluscs, annelids, echinoderms, and crustaceans (Michie, 2023). Representative taxa include bivalves, gastropods, polychaete worms, amphipods, decapod crustaceans, holothurians, echinoids, and ophiuroids, with local abundance and composition varying according to sediment grain size, hydrodynamic stress, and organic matter availability (Snelgrove and Butman, 1994; Thrush *et al.*, 1998; Thrush *et al.*, 2003; Snelder *et al.*, 2005). In areas where bedrock or stable hard substrata are present, epifaunal organisms such as sponges, bryozoans, and cold-water corals can contribute to structural complexity. In particular, habitat-forming cold-water corals can form three-dimensional biogenic structures, including reef-, mound-, or thicket-like formations, which may support other invertebrates and fish on slope margins, ridges and seamounts (Tracey *et al.*, 2011).

In general, bathymetric features such as canyon systems and shelf-slope transitions further enhance biodiversity by promoting localised retention and upwelling of nutrient-rich waters (**Section 5.1.1**) (Connolly and Hickey, 2014; Saeedi, 2026), which indirectly support benthic productivity through the vertical coupling of pelagic and benthic systems. These physically driven processes supply organic matter to the seabed, sustaining deposit-feeding and suspension-feeding communities (Kalybekova, 2025). Episodic sediment transport and resuspension events, associated with strong tidal flows and storm forcing (**Section 5.1.5**), contribute to disturbance regimes that structure community composition and limit competitive exclusion, thereby maintaining diversity across multiple spatial scales (Gallop *et al.*, 2015).

As in similar environments, invertebrate communities in the operational area will exhibit adaptations to high levels of physical disturbance, including morphological traits that enhance attachment, burrowing ability, or mechanical resilience (Hudson *et al.*, 2022). Sessile organisms, such as sponges and corals, are typically restricted to stable substrates where flow conditions, although energetic, do not exceed attachment thresholds (Manni *et al.*, 2025). Motile taxa exhibit behavioural and ecological flexibility, allowing rapid recolonisation following disturbance (Solé *et al.*, 2023). Consequently, benthic assemblages are characterised by dynamic equilibrium conditions rather than stable climax communities, reflecting the dominance of physical forcing over biological interactions.

From a functional perspective, benthic invertebrates play a critical role in ecosystem processes, including bioturbation, nutrient recycling, and secondary production (Covich *et al.*, 1999; Bolam *et al.*, 2002; Schenone *et al.*, 2023). Deposit – and suspension – feeding taxa contribute to cycling of organic matter and redistribution of sediments, influencing sediment structure and biogeochemical processes at the seabed. These processes are intrinsically linked to the physical environment, particularly mixing and turbulence (**Section 5.1.6**), which regulate delivery of particulate material to benthic habitats (Rhoads and Young, 1970; Khan and Rountos, 2025).

5.2.3. Fish

Fish communities in the wider Cook Strait region comprise a mixture of demersal, pelagic and reef associated taxa, reflecting the strong environmental gradients that characterise New Zealand's shelf and slope systems, including marked depth-related changes in demersal fish composition and diversity (Zintzen *et al.*, 2012).

Demersal assemblages vary predictably with distinct inner shelf, outer shelf, and slope communities identified along environmental gradients (Beentjes *et al.*, 2002; Francis *et al.*, 2002). This broad depth-related structuring is consistent with wider patterns described for New Zealand fish communities, where demersal fish composition and diversity change markedly along shelf and slope depth gradients (Zintzen *et al.*, 2012; Zintzen *et al.*, 2017). Within these demersal assemblages, a range of commercially and ecologically important species occur across shelf and slope habitats, including hoki (*Macruronus novaezelandiae*), red cod (*Pseudophycis bachus*), and gurnard species (e.g. *Chelidonichthys kumu*). As with other ecosystems, fish communities in the operational area are likely to exhibit behavioural flexibility, habitat selectivity, and mobility in response to local environmental conditions. Demersal species will generally associate with substrata or sediment regimes that provide suitable feeding and refuge conditions, whereas pelagic species tend to exploit the dynamic water column environment and associated prey fields. These communities are therefore likely characterised by temporo-spatially variable distributions, particularly in reef-associated habitats where fish assemblages have been shown to vary across transect, site and regional scales (Anderson and Millar, 2004).

Reef and near-reefal assemblages in New Zealand waters are distinct from demersal soft sediment communities and are characterised by taxa associated with rocky habitats, including wrasse such as *Notolabrus* spp., moki (*Nemadactylus macropterus*) and related reef-associated taxa and triplefins such as *Forsterygion* spp. (Anderson and Millar, 2004; Williams *et al.*, 2008). In New Zealand reef systems, fish assemblages have been shown to vary among habitat types, including kelp forest, algal turf, sand, sponge flats, barrens and macroalgal reef habitats (Choat and Ayling, 1987; Anderson and Millar, 2004; Williams *et al.*, 2008; Cole *et*

al., 2012). Demersal fish species contribute to benthic–pelagic coupling through predation on invertebrates and subsequent redistribution of biomass, while pelagic species link primary production to higher trophic levels. These processes are linked intrinsically to the physical environment, particularly mixing and turbulence (**Section 5.1.6**), which regulate productivity and prey availability.

Fish assemblages within the operational area are structured by the same physio-environmental drivers influencing benthic communities, including bathymetric complexity, substratum type, topographic complexity, the highly energetic hydrodynamic regime characteristic of Cook Strait and macroalgal canopy (Cole *et al.*, 2012). Strong tidal currents, steep bathymetric gradients, and persistent mixing of water masses generate spatially heterogeneous habitats that support a range of demersal and pelagic fish assemblages (**Section 5.1.1**, **Section 5.1.3**, and **Section 5.1.7**). In western Cook Strait specifically, reef fish abundance has been linked to depth, topographic complexity, substratum characteristics and macroalgal canopy cover, with different species showing different habitat associations (Cole *et al.*, 2012).

Overall, depth and associated environmental gradients represent primary controls on fish community composition in New Zealand shelf and slope systems, with secondary influences from latitude, sediment composition, habitat complexity and bottom temperature (Beentjes *et al.*, 2002; Zintzen *et al.*, 2012; Zintzen *et al.*, 2017). The New Zealand Marine Environment Classification was developed using environmental variables including depth, slope, wave-induced seabed orbital velocity, tidal current velocity (see **Section 5.1**), and sea-surface temperature metrics. Tuned against demersal fish distributions, it provides a useful broad-scale framework for interpreting fish assemblage variation across shelf and slope environments (Snelder *et al.*, 2005).

In rocky and structurally complex habitats, including areas of exposed bedrock and reefy outcrops, fish abundance and species richness are strongly influenced by topographic complexity and [biogenic habitat](#), such as macroalgal canopies (Cole *et al.*, 2012), while reef fish diversity and assemblage composition may differ significantly among nearshore habitat types (Williams *et al.*, 2008). Areas of increased structural complexity can support higher local diversity and abundance, reflecting the role of habitat heterogeneity in providing refuge, foraging opportunities, and habitats for different life stages. At larger spatial scales, fish assemblages within the New Zealand region are influenced by depth and latitude, with assemblages becoming increasingly similar with depth across broad spatial gradients (Zintzen *et al.*, 2017). These patterns reflect the combined influences of hydrodynamic processes, habitat availability, and dispersal connectivity.

Hydrodynamic processes exert both direct and indirect influences on fish community structure. Strong tidal currents and associated mixing processes can influence the distribution of planktonic prey and the transport of early life stages, while also affecting habitat suitability for demersal species through sediment transport and bedform dynamics (**Section 5.1.4** and **Section 5.1.6**). In dynamic systems such as the Cook Strait, these processes likely contribute to spatial variability in fish abundance and distribution, particularly where bathymetric complexity reef structure, sediment type and macroalgal habitats interact to create heterogeneous habitat conditions.

Fish detect and respond to underwater sound through a combination of particle motion which represents the oscillatory displacement, velocity, or acceleration of

water particles within a sound field, and, in some taxa, sound pressure detection; these modalities underpin a range of behavioural, physiological, and ecological responses to anthropogenic noise. All fish species are sensitive to particle motion, and it is recognised widely as the primary acoustic stimulus for fishes, including elasmobranchs and species lacking specialised hearing structures (Popper and Hawkins, 2019b). Sensitivity varies substantially among taxa, primarily as a function of auditory anatomy, particularly the presence or absence of a gas-filled swim bladder and associated accessory hearing structures. Consequently, responses to noise exposure are species-specific and context-dependent, with effects ranging from behavioural disturbance to physiological injury.

Species lacking swim bladders or accessory auditory structures, including most elasmobranchs and many demersal teleosts, are regarded typically as particle-motion-sensitive, detecting sound primarily through inertial mechanisms acting on the [otolith](#) organs. The fish inner ear, comprising otolith organs coupled to sensory hair cells, responds directly to particle acceleration arising from the differential movement between the fish body and dense otoliths (Popper and Fay, 2011; Popper and Hawkins, 2019b; Popper and Hawkins, 2020). In contrast, species possessing a swim bladder in close proximity to the ear or connected via accessory such as Weberian ossicles, can transduce sound pressure into local particle motion, thereby enhancing sensitivity and extending hearing bandwidth (Ladich and Schulz-Mirbach, 2016; Schulz-Mirbach *et al.*, 2020; Wiernicki *et al.*, 2020). However, this traditional distinction should be applied cautiously, as this terminology has been criticised as overly simplistic and unable to capture the diversity of auditory morphologies and hearing pathways across fishes (Popper and Fay, 2011; Alves *et al.*, 2025).

Empirical and methodological studies indicate that differences in auditory sensitivity are strongly influenced by the ability of some taxa to detect the pressure component of the sound field, rather than by particle motion detection alone. The ancestral and most common mode of fish hearing is generally considered to involve direct particle-motion detection through otolith organs, with pressure sensitivity representing an additional pathway that has evolved in some taxa through gas-filled structures and otophysic³ connections (Popper and Fay, 2011); however, comparisons among audiograms should be treated cautiously because experimental methods, acoustic tank conditions, threshold determination criteria and whether thresholds are expressed in sound pressure or particle motion can strongly affect measured sensitivity (Radford *et al.*, 2012; Wiernicki *et al.*, 2020; Alves *et al.*, 2025). Accordingly, particle motion remains a common component of fish hearing, while pressure detection constitutes an additional mechanism in taxa with suitable anatomical adaptations.

Recent advances have emphasised the need to quantify particle acceleration and substrate motion when assessing acoustic impacts on fish, as conventional metrics based solely on sound pressure are often inadequate. Particle motion is a vector quantity that conveys both magnitude and directional information, enabling fishes to detect the direction of sound sources and orient behaviourally (Popper and Fay, 2011; Jones *et al.*, 2025). Field measurements also indicate that particle acceleration and sound pressure may have different spatial ranges above ambient conditions. Rogers *et al.* (2021) reported that signals from an experimental seismic

³An otophysic connection is a physical connection between the swim bladder and the inner ear that enhances hearing sensitivity.

survey exceeded ambient particle acceleration up to 10 km from the source, while sound pressure exceeded ambient conditions up to 31 km.

Increasingly, experimental approaches employ accelerometers, shaker tables, controlled acoustic systems and standing-wave tube designs to isolate or better characterise particle motion and sound pressure effects (Schulz-Mirbach *et al.*, 2020; Guan *et al.*, 2025; Maiditsch *et al.*, 2025). X-ray and tomographic approaches have been used to visualise sound-induced motion of auditory structures, including swim bladder walls, Weberian ossicles and otoliths, under conditions designed to maximise either sound pressure or particle motion (Schulz-Mirbach *et al.*, 2020; Maiditsch *et al.*, 2025). However, separating pressure and particle motion in mediating these effects is recognised increasingly as critical (Popper and Hawkins, 2018; Popper and Hawkins, 2019b). Many existing exposure criteria and impact assessments have been developed using sound pressure metrics derived from marine mammal research or from fish studies in which particle motion was not adequately measured; these may not adequately reflect the acoustic stimuli most relevant to fish, particularly species that primarily detect particle motion (Popper and Hawkins, 2019b; Popper *et al.*, 2019).

Overall, fish assemblages within the operational area are best characterised as spatially heterogeneous, temporally variable, and strongly structured by the interaction of bathymetry, habitat complexity, and hydrodynamic forcing. These processes operate across a continuum of temporo-spatial scales, linking physico-environmental drivers to ecological structure, and underpinning trophic connectivity between benthic and pelagic systems. In this context, behavioural responses to underwater noise represent the primary mechanism of interaction with anthropogenic activity; however, the inherent dynamism and connectivity of the system are expected to mediate short term, localised effects, the implications of which are evaluated in **Section 6.2.3.6**.

5.2.4. Marine reptiles

All seven sea turtle species are threatened globally by global warming, climate change, sea-level rise, and fisheries-related mortality, particularly by-catch (Poloczanska *et al.*, 2009; Silva *et al.*, 2025). New Zealand does not support nesting populations; however, five species of marine turtle have been recorded within its waters (Gill, 1997). The principal species include the leatherback (*Dermochelys coriacea*), green (*Chelonia mydas*), and loggerhead (*Caretta caretta*), all of which occur as migratory or vagrant individuals rather than resident populations. Records are concentrated primarily in warmer northern waters, particularly within the Bay of Plenty, where individuals are observed foraging or transiting during seasonal movements (Godoy *et al.*, 2016; Edwards, 2023; Siders *et al.*, 2024). Occurrence within the operational area and wider Cook Strait region is considered rare and sporadic, reflecting its position at the southern extent of suitable thermal habitat and the influence of energetic, mixed, and comparatively coldwater masses.

5.2.5. Seabirds

The Cook Strait region represents a convergence zone between subtropical and subantarctic water masses, supporting a mixed assemblage of seabirds with differing biogeographic affinities (Garner, 1959). Seabird composition varies seasonally, with migratory pelagic taxa dominating offshore assemblages and coastal species associated with nearshore habitats (Fleming, 1957).

Forty or more seabird species are known to visit the Cook Strait. Of these, twelve species establish their breeding colonies there and in the surrounding areas such as Kaikōura and Wellington. These include: little penguin (*Eudyptula minor*), flesh-footed shearwater (*Ardenna carneipes*), Hutton's shearwater (*Puffinus huttoni*), and New Zealand king shag, *Leucocarbo carunculatus* (New Zealand Birds Online, 2026).

Important Bird Areas (IBAs) in New Zealand have been identified based on foraging and migratory habits of endemic seabirds, concentrated around major colonies, see **Figure 6**. **Table 4** details seabirds that might be encountered foraging in the area.

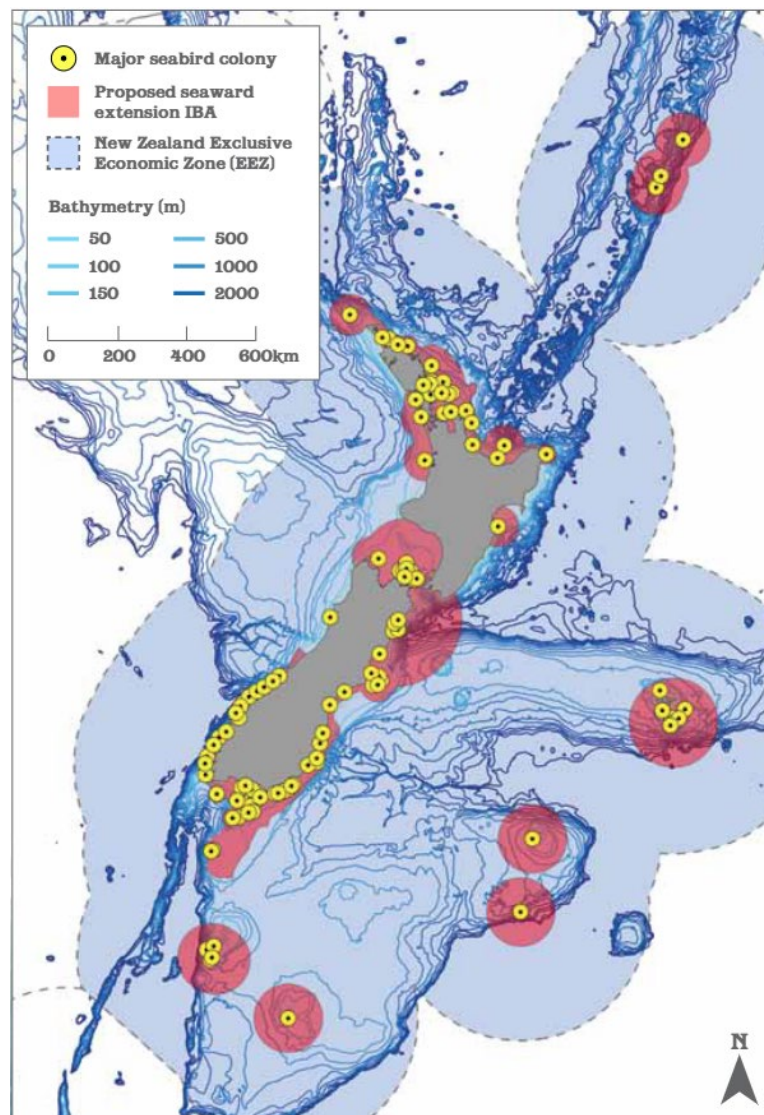


Figure 6: Major seabird colonies in New Zealand. *Source:* Abraham *et al.* (2014).



Species	Conservation status (IUCN and NZTCS)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Black Fronted Tern (<i>Chlidonias albobriatus</i>)	Endemic Nationally Endangered												
Black-browed mollymawk (<i>Thalassarche melanophris</i>)	Native Coloniser												
Campbell black-browed mollymawk (<i>Thalassarche impavida</i>)	Endemic Naturally Uncommon												
Cape Petrel (<i>Daption capense</i>)	Native Naturally Uncommon												
Common diving petrel (<i>Pelecanoides urinatrix</i>)	Native Relict												
Fairy prion (<i>Pachyptila turtur</i>)	Native Relict												
Flesh-footed shearwater (<i>Puffinus carneipes</i>)	At-risk Relict												
Fluttering shearwater (<i>Puffinus gavia</i>)	At-risk Relict												
Hutton's shearwater (<i>Puffinus huttoni</i>)	Threatened Nationally vulnerable												
Little penguin (<i>Eudyptula minor</i>)	Native Declining												
New Zealand king shag (<i>Leucocarbo carunculatus</i>)	Endemic Nationally Endangered												
Salvin's mollymawk (<i>Thalassarche salvini</i>)	Endemic Nationally Critical												
Spotted shag (<i>Phalacrocorax punctatus</i>)	Endemic Nationally Vulnerable												
Westland petrel (<i>Procellaria westlandica</i>)	Endemic Naturally Uncommon												
White-capped mollymawk (<i>Thalassarche cauta</i>)	Native Declining												

Table 4: Seabird conservation and breeding status/season according to both International Union for Conservation of Nature (IUCN) and New Zealand (NZ), including those that might be encountered foraging in the Cook Strait operational area. *Source:* Robertson *et al.* (2003); Robertson *et al.* (2021); New Zealand Birds Online (2026).

5.2.6. Marine mammals

Marine mammals likely to be found in the operational area of the Cook Strait and Kaikōura region and the neighbouring Marlborough Sounds are detailed, in alphabetical (not taxonomical) order here.

Baleen whales have a widespread distribution and are primarily oceanic marine mammals, which limits population data on these species. Abundance data tends to be confined to certain geographic and regional areas (Berkenbusch *et al.*, 2013).

Odontocetes (toothed whales and dolphins) are distributed widely across marine and some freshwater ecosystems, ranging from polar to tropical waters. Their distribution is influenced by factors such as prey availability, water temperature, oceanographic features (e.g. upwellings, thermoclines), and anthropogenic factors. Some species, such as the sperm whale (*Physeter macrocephalus*), have broad oceanic distributions, while others, like the Māui's dolphin (*Cephalorhynchus hectori maui*) are coastal and highly localised. Coastal species often inhabit continental shelf regions, whereas deep-diving species occur in offshore pelagic zones.

Oceanic odontocete species are generally less well understood in terms of abundance and distribution compared to their coastal counterparts due to the logistical challenges of conducting research in offshore environments. These species often inhabit vast, deep-water regions where survey efforts are constrained by financial, technological, and temporal limitations. Unlike coastal species, which can be studied through land-based observations or relatively short vessel surveys, oceanic odontocetes require extensive ship-based surveys, passive acoustic monitoring, or satellite telemetry. Additionally, their often elusive and deep-diving behaviours (e.g. beaked whales and sperm whales) further complicate direct observations and population assessments. As a result, many oceanic odontocetes are classified as *Data Deficient* by the International Union for Conservation of Nature (IUCN), with significant knowledge gaps regarding their population structure, migratory patterns, and habitat preferences. Threats assessed as having a serious impact on individuals included whaling, military sonar, entanglement, predation, vessel strikes, plastics, and oil spills (Feyrer *et al.*, 2024).

Pinnipeds present in New Zealand include the leopard seal (*Hydrurga leptonyx*), southern elephant seal (*Mirounga leonina*), and the endemic New Zealand sea lion (*Phocarctos hookeri*); however, the only species likely to be found in the operational area is the New Zealand fur seal (*Arctocephalus forsteri*) (Pavanato *et al.*, 2023). Threats to pinnipeds include entanglement, noise pollution, injuries from vessel collision, and loss of breeding grounds due to climate change and land development (Schoeman *et al.*, 2020; Roberts and Hendriks, 2022; Pavanato *et al.*, 2023).

Marine mammal illustrations presented in this publication have been created for illustrative and educational purposes using Artificial Intelligence (Microsoft Copilot for Business). Development of each image is a highly iterative process involving substantial expert review and refinement. Reference material supplied to the AI includes photographs of stranded animals, underwater photographs, published artists' impressions, anatomical drawings, and photographs from Ocean Science Consulting Ltd's own image archive. These materials are used to generate an initial illustration, which is then reviewed and revised repeatedly by experienced MMOs and marine mammal specialists within the company.

The objective is to produce an image that represents the species as accurately as possible; however, many marine mammal species are rarely observed, poorly photographed, or exhibit considerable variation between individuals. Differences associated with sex, age, geographic population, posture, lighting conditions, and natural markings can further influence appearance. Consequently, the illustrations should be regarded as informed approximations rather than exact depictions of any individual animal.

While every effort has been made to ensure anatomical accuracy and faithful representation of diagnostic characteristics, it is not currently possible to generate an image that is 100% identical to the appearance of a living animal. AI can, of course, generate spurious results (**APPENDIX D – INACCURATE IMAGE GENERATED BY AI**). Readers are therefore encouraged to consult official identification guides, field manuals, and photographic reference sources when undertaking species identification or verification. The illustrations provided here are intended to complement, rather than replace, established identification resources.

Species occurrence within the wider operational area was assessed using multiple lines of evidence, including published sighting and stranding records, acoustic detections, fisheries-observer records and modelled species distributions. Modelled species distributions were used to indicate areas of predicted occurrence or environmental suitability rather than relative abundance (Stephenson *et al.*, 2020). These model outputs are considered alongside empirical records when evaluating the likelihood of species occurrence within and around the operational area. The number of sightings or stranding records is not interpreted as a direct estimate of abundance because observation effort, detectability and reporting are spatially and temporally variable.

5.2.6.1. Antarctic & dwarf minke whale (*B. bonaerensis* & *B. acutorostrata* ssp.)

Figure 7 shows both Antarctic and dwarf minke whale. Seasonal distribution and migration of nearly all populations and species of minke whale are poorly understood (Risch *et al.*, 2019). The lack of data on minke whale species could be attributed to their small size, inconspicuous behaviour and seasonal distribution within remote pelagic and sea ice habitats.

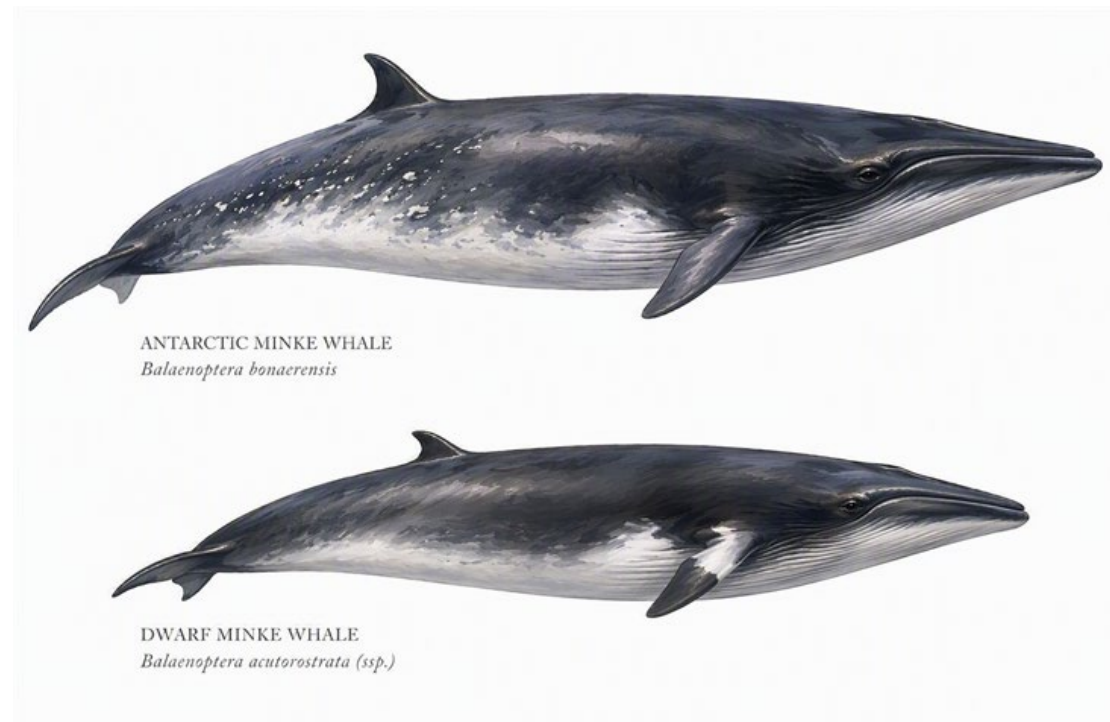


Figure 7: Antarctic and dwarf minke whale Source: OSC (2026).

The Antarctic minke whale is present within the Southern Hemisphere, typically between 60°S and the ice edge (Williams *et al.*, 2014); however, Antarctic minke whales have been acoustically detected within the Cook Strait between mid-July and mid-September and in Kaikōura in July and August (Goetz and Hupman, 2017; Warren *et al.*, 2021a). It is unknown how representative these acoustic detections are of the actual temporo-spatial presence of Antarctic minke whales within the area of operations. Antarctic minke whales have also been acoustically detected in Australia during winter and spring therefore it is not a surprise that they are occasionally present within New Zealand waters (Risch *et al.*, 2014).

The NZTCS status of the Antarctic Minke whale was changed from Data Deficient to Non-resident Native – Migrant. There is no evidence that this species breeds in New Zealand although it does visit New Zealand waters (Lundquist *et al.*, 2025).

Dwarf minke whales appear to be distributed within the lower latitudes of the Southern Hemisphere. Most sightings of dwarf minke whales are between December and March to the South of Australia and New Zealand (Authority, 2011). The range of the dwarf minke whale is sympatric with the Antarctic minke whale; it is difficult to distinguish between these minke whale species visually, making some of the sightings-based information potentially inaccurate (Acevedo *et al.*, 2011). Acoustic presence of the Antarctic minke whale and a known overlap in the range of this species means that we cannot rule out the dwarf minke whale being

present within the area of operations. The dwarf minke whale NZTCS status changed from Not Threatened to Data Deficient in 2019 due to a potentially resident population in New Zealand's subantarctic waters, but there are insufficient data on population abundance (Baker *et al.*, 2019). In 2025 the dwarf minke whale NZTCS status remains Data Deficient as there is still a lack of recent distribution and abundance data of this species in New Zealand waters (Lundquist *et al.*, 2025).

Although these records demonstrate that minke whales may occur in New Zealand waters, they appear to be recorded infrequently. Government fisheries-observer data compiled by Richard and Berkenbusch (2024) contained nine minke whale sightings comprising 33 animals across New Zealand waters, suggesting that they may occur in the wider region, but are encountered relatively infrequently.

5.2.6.2. Antarctic blue whale & pygmy blue whale (*Balaenoptera musculus intermedia* & *B. m. brevicauda*)

Figure 8 shows the Antarctic blue and pygmy blue whale. The blue whale is a cosmopolitan species, found in all oceans. They feed almost exclusively on euphausiids (krill).

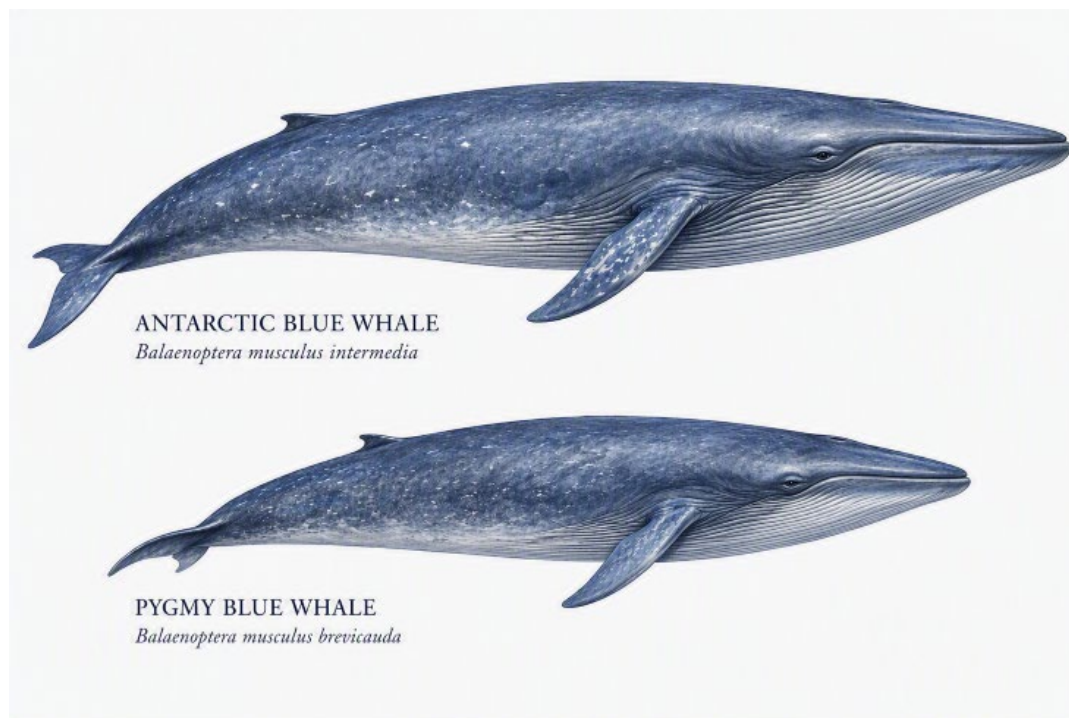


Figure 8: Antarctic blue and pygmy blue whale Source: OSC (2026).

Their migration patterns are not well understood, but appear to be diverse, with some individuals residing year-round in productive habitats, while others undertake long migrations from tropical waters to high latitude feeding grounds. The International Union for Conservation of Nature (IUCN) has classified blue whales as Endangered due to the historic population reduction of 89–97%, attributed to commercial whaling (Cooke, 2018d). The global population is estimated at 5,000 to 15,000 individuals and recovering (Cooke, 2018d). Blue whales observed around New Zealand appear to be pygmy blue whales, based on genetics and morphology, but they are difficult to distinguish from blue whales in the field; however, acoustic monitoring demonstrates that Antarctic blue whales use waters around southern

New Zealand regularly, travelling through the Cook Strait (Branch *et al.*, 2007a; Branch *et al.*, 2007b; Cooke, 2018d; Warren *et al.*, 2021b). The NZTCS status of the blue whale was changed from Data Deficient to Non-Resident Native – Migrant due to the limited data on this species in New Zealand (Lundquist *et al.*, 2025).

Pygmy blue whales can be found in New Zealand throughout the year; this native population has been shown to be genetically distinct (Barlow *et al.*, 2018; Barlow *et al.*, 2023). Acoustic detections of pygmy blue whales in the Cook Strait and Kaikōura indicate that they are present within the area of operations. Pygmy blue whale acoustic detections in Kaikōura peaked during the austral autumn and spring. However, pygmy blue whale vocalisations declined within the Cook Strait during September and October (Warren *et al.*, 2021b). The pygmy blue whale NZTCS status was changed from Data Deficient to Threatened – Nationally Vulnerable as this population was subject to whaling and is assumed to have not fully recovered to pre-whaling numbers (Lundquist *et al.*, 2025).

5.2.6.3. Fin whale (*B. physalus*)

The fin whale (**Figure 9**) is present throughout most of the world's oceans with some populations of fin being resident year-round while others make seasonal migrations to higher latitudes for feeding opportunities (Edwards *et al.*, 2015; Geijer *et al.*, 2016).



Figure 9: Fin whale. Source: OSC (2026).

Fin whales are generalist feeders, with a diet primarily of krill, but also eat fish. Females reach sexual maturity after about a decade. The IUCN has classified fin whales as Vulnerable, due to the historic population reduction of 70% attributed to commercial whaling, but subsequent recovery to 30% of the level three generation ago.

Fin whales can be found in the east coast of New Zealand, with some wintering individuals possibly being part of a broader 'acoustic population' whose range extends to southern Australia and Antarctica (Constaratas *et al.*, 2021). During the austral winter, fin whale calls were detected on the eastern side of Cook Strait and offshore Gisborne (Constaratas *et al.*, 2021). Lack of acoustic detections on the west side of the Cook Strait may be due to habitat preference, but more research is required. Its classification under the NZTCS changed Data Deficient to Non-Resident Native – Migrant in 2025 due to evidence of temporal trends in sightings

and acoustic detections and no evidence of breeding in New Zealand (Constaratas *et al.*, 2021; Lundquist *et al.*, 2025).

5.2.6.4. Humpback whale (*Megaptera novaeangliae*)

The humpback whale (**Figure 10**) is a wide-ranging species found in all ocean basins. All subpopulations, other than one in the Arabian Sea, migrate between mating grounds in tropical waters and feeding areas in high latitude productive waters (Cooke, 2018b).

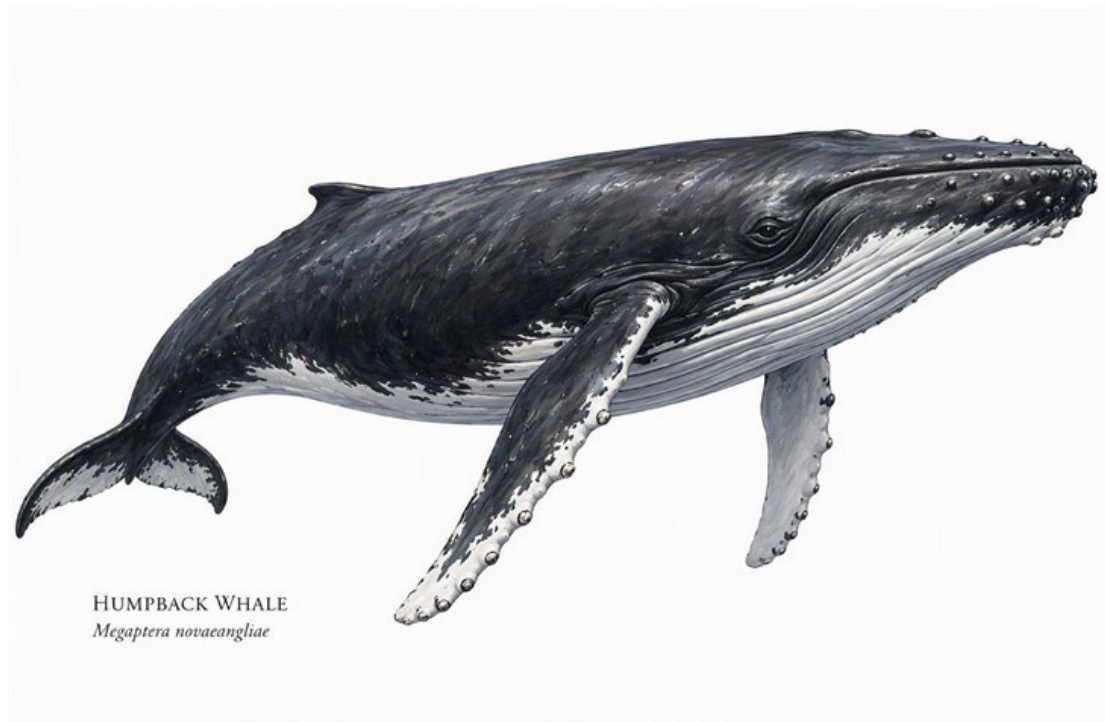


Figure 10: Humpback whale. Source: OSC (2026).

The global population of humpback whales is estimated at 135,000, which is higher than the level three generations ago, so is listed as Least Concern (Cooke, 2018b).

Humpback whales can be seen passing along the coast of New Zealand as they migrate between summer feeding grounds in Antarctic waters and winter breeding grounds in the tropical waters of the South Pacific. Many reported sightings are from the east coast of New Zealand, with almost half from Kaikōura and the Cook Strait (Constantine *et al.*, 2007). Individuals and groups with site-fidelity to the New Caledonia, Tonga and East Australia breeding grounds are likely to pass mainland New Zealand during both north- and south-bound migrations, these migration paths are supported by genetic evidence (Franklin *et al.*, 2014; Duffy *et al.*, 2015; Steel *et al.*, 2018). The migration periods are typically June to August when they migrate north and September to November when the migrate south (Constantine *et al.*, 2016; Warren *et al.*, 2020). Over a 12-year study period there was a small but significant increase in the number of humpback whales migrating through the Cook Strait, suggesting a slow population recovery (Steel *et al.*, 2025). Although humpback whales use the Cook Strait as part of their migration to give birth, some individuals have been recorded giving birth in the waters surrounding New Zealand (McPhee-Frew *et al.*, 2025).

Humpback whales are listed as Least Concern by the IUCN due to a consistently increasing trend in their global population; however, the regional Oceania subpopulation, which migrates through the operational area, is recognised as demographically isolated, and is listed as endangered due to slower population recovery (Childerhouse *et al.*, 2008). The NZTCS classifies the species as Non-Resident Native – Migrant as there is no endemic population but do visit New Zealand (Lundquist *et al.*, 2025).

5.2.6.5. Pygmy right whale (*Caperea marginata*)

The pygmy right whale (**Figure 11**) is sighted rarely and there is no estimate on global population size.



Figure 11: Pygmy right whale. Source: OSC (2026).

Pygmy right whales are thought to feed on copepods, as suggested by limited stomach content records from fresh strandings. They are difficult to identify at sea, so they might not be as uncommon as records would suggest. They are classified as Least Concern, primarily due to low exposure to anthropogenic threat (Cooke, 2018a).

Pygmy right whales are known to inhabit Australian mid-latitude waters year-round (Dedden *et al.*, 2023; Nguyen Hong Duc *et al.*, 2026). The only sightings of live pygmy right whales in New Zealand have been made in the Cook Strait and offshore waters in the southeast of the country (Matsuoka *et al.*, 2005; Kemper *et al.*, 2013). It is classified as Data Deficient under the NZTCS (Lundquist *et al.*, 2025).

5.2.6.6. Sei whale (*Balaenoptera borealis*)

The sei whale (**Figure 12**) is a cosmopolitan species, with a mainly offshore distribution. They primarily feed on krill and copepods but have also been reported preying on fish.

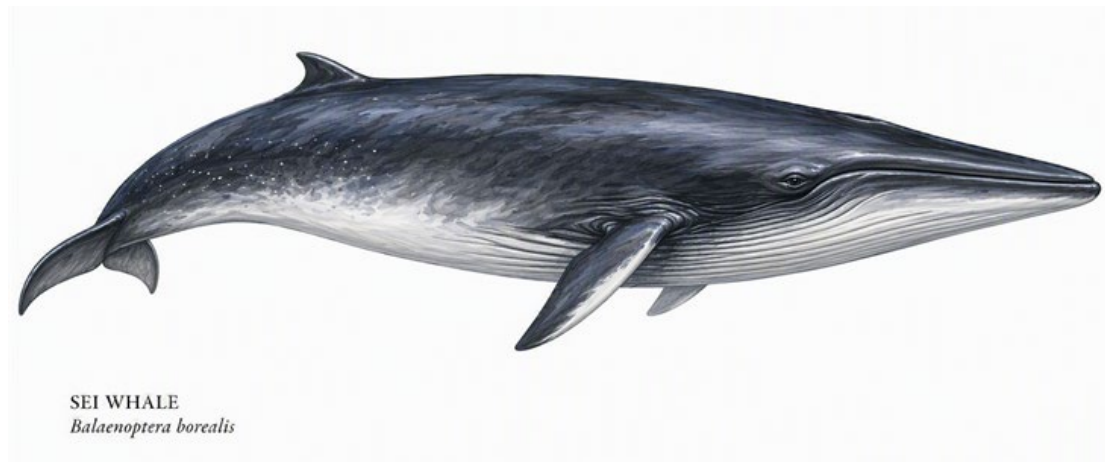


Figure 12: Sei whale. Source: OSC (2026).

Sei whales can be difficult to differentiate from Bryde's whales (*Balaenoptera brydei*), which is unlikely to be encountered, as they are associated primarily with the warm-temperate waters of the upper North Island, particularly the Hauraki Gulf, where they form a resident population and are recorded regularly. The IUCN has classified sei whales as Endangered, due to the historic population reduction attributed to commercial whaling and limited evidence of recovery. The global population size is thought to be recovering, but status has precautionarily not been decreased to Vulnerable (Cooke, 2018c).

The Southern Hemisphere lacks reliable abundance information for sei whale populations (Berkenbusch *et al.*, 2013; Austin, 2021); however, there has been an acoustic detection of a sei whale within the Cook Strait region within the month of July (Goetz and Hupman, 2017). Sei whales may transit through the operational area. Their NZTCS changed from Data Deficient to Non-Resident Native – Migrant. Although data on this species is limited, there is no evidence that it breeds in New Zealand (Lundquist *et al.*, 2025). Government fisheries-observer data included only five sei whale sightings events, comprising 10 animals, across New Zealand waters (Richard and Berkenbusch, 2024). This is consistent with the limited local evidence available for the species and suggests that sei whales may occur in the operational area only occasionally, most likely while migrating.

5.2.6.7. Southern right whale (*Eubalaena australis*)

Southern right whale (**Figure 13**) has a circumpolar distribution within the Southern Hemisphere.



Figure 13: Southern right whale. Source: OSC (2026).

Southern right whales were once found extensively throughout New Zealand waters but, due to unconstrained whaling they were hunted to near extinction (Jackson *et al.*, 2016). Southern right whales migrate seasonally between winter calving grounds and summer feeding grounds where they feed on krill and copepods (Valenzuela *et al.*, 2018).

Southern right whales in New Zealand are distributed primarily around the Auckland Islands during winter, which represent the principal calving and socialising habitat for the population (Rayment *et al.*, 2012). Smaller numbers of southern right whales have been recorded around Campbell Island and mainland New Zealand during winter (Carroll *et al.*, 2014; Torres *et al.*, 2017). Recent satellite tracking and stable isotope studies have substantially improved knowledge of the offshore distribution of New Zealand southern right whales outside the wintering season. Whales from the New Zealand population migrate to offshore feeding grounds across the Southern Ocean, with the Subtropical Front south of Australia identified as the primary foraging region, together with more limited use of the Subantarctic Front and higher-latitude waters (Derville *et al.*, 2023; Riekkola *et al.*, 2025). Riekkola *et al.* (2025) found that 71% of area-restricted search locations for New Zealand southern right whales were associated with the subtropical Front, with a smaller proportion associated with the Subantarctic Front and Antarctic waters.

Between 2003 and 2010 southern right whales were sighted within the Cook Strait area, with this species being acoustically detected in 2016 (Carroll *et al.*, 2014; Goetz and Hupman, 2017). These records indicate possible recolonisation of southern right whales within the Cook Strait region and their potential presence within the area of operations for the project (**Figure 14**). Their NZTCS status is listed as Threatened – Nationally Increasing due to this small population

experiencing previous decline but numbers are predicted to increase (Lundquist et al., 2025).

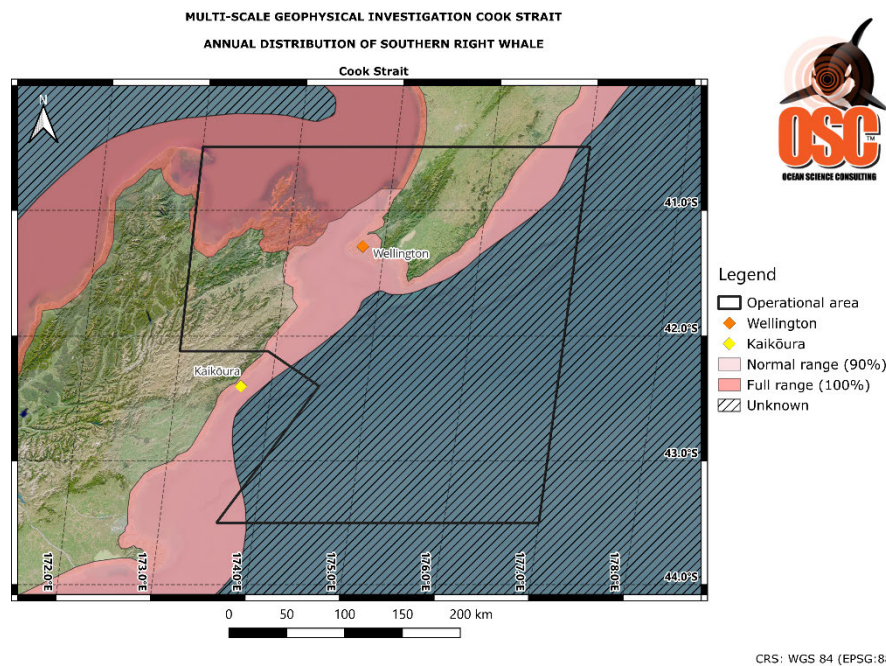


Figure 14: Southern right whale annual distribution in operational area. WGS 84/Equal Earth Asia-Pacific (EPSG 8859). Source: OSC (2026), modified from MPI (2026).

5.2.6.8. Arnoux's beaked whale (*Berardius arnuxii*)

The Arnoux's beaked whale (**Figure 15**) is found in a circumpolar pattern in the southern hemisphere and considered uncommon throughout its distribution. It is thought to inhabit deep waters and feed on fish and cephalopods.



Figure 15: Arnoux's beaked whale. Source: OSC (2026).

The IUCN classifies Arnoux's beaked whale as Least Concern despite few data, due to its wide distribution and relatively frequent sightings (Brownell Jr. and Taylor, 2021).

The operational area is within the northernmost distribution limit of the Arnoux's beaked whale, but sighting and stranding records within the Cook Strait suggest possible presence in the area (Thompson *et al.*, 2013; Feij *et al.*, 2024). The NZTCS status of the Arnoux's beaked whales is classed as Data Deficient (Lundquist *et al.*, 2025).

5.2.6.9. Bottlenose dolphin (*Tursiops truncatus*)

The bottlenose dolphin (**Figure 16**) is among the most common cetacean species worldwide. Global abundance has been estimated at 750,000 individuals but is likely much higher.

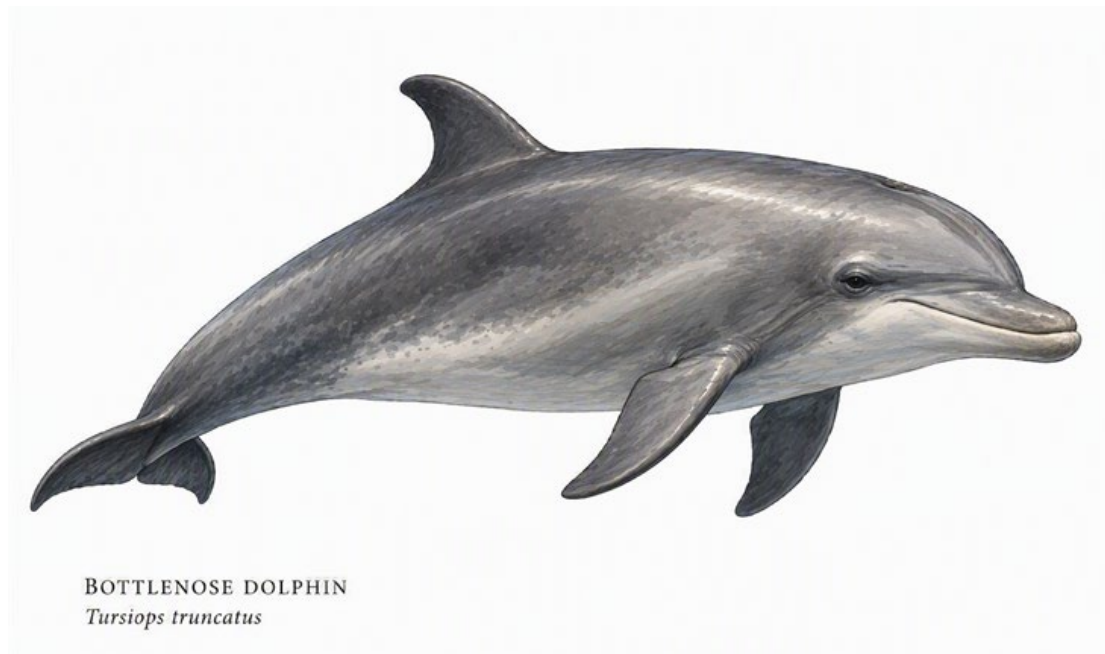


Figure 16: Bottlenose dolphin. Source: OSC (2026).

Bottlenose dolphins exhibit complex social behaviours partly facilitated by the variety of vocalisations they can produce (Lusseau, 2007; Patiño-Pérez *et al.*, 2024). They can be found in inshore, coastal, shelf, and oceanic waters, with coastal populations being the most vulnerable to anthropogenic disturbance (Wells *et al.*, 2019). The documented occurrence of bottlenose dolphins in the wider region is also consistent with fisheries-observer data, which include numerous bottlenose dolphin records across New Zealand waters (Richard and Berkenbusch, 2024). Coastal and pelagic populations exploit different enough niches to be split into two ecotypes (Zaeschar *et al.*, 2020). They generally feed on a variety of species, with a notable difference in the diets of coastal and pelagic ecotypes (Hartel, 2010; Mormede, 2023). The diet of coastal dolphins in southern New Zealand has been shown to mainly consist of fishes found in rocky reefs and benthic habitat (Lusseau, 2003). The global population is classified by the IUCN as Least Concern. There are certain coastal populations classified as Critically Endangered, one of them being the Fiordland population in south New Zealand (Wells *et al.*, 2019).

Bottlenose dolphins are known to be present within the Marlborough Sounds, which is a series of rias adjacent to the Cook Strait (Merriman *et al.*, 2009; Goetz and Hupman, 2017). The Marlborough Sounds is only a section of a much larger home range; this population of bottlenose dolphins is known to travel at least 80 km out

of the area (Merriman *et al.*, 2009), **Figure 17**). In 2025 the NZTCS status for bottlenose dolphins was changed from Threatened – Nationally Endangered to Threatened – Nationally Vulnerable, the change due to the oceanic bottlenose dolphin population being greater than 1,000 individuals; however the coastal populations face a number of anthropogenic threats and rely on conservation management measures (Lundquist *et al.*, 2025).

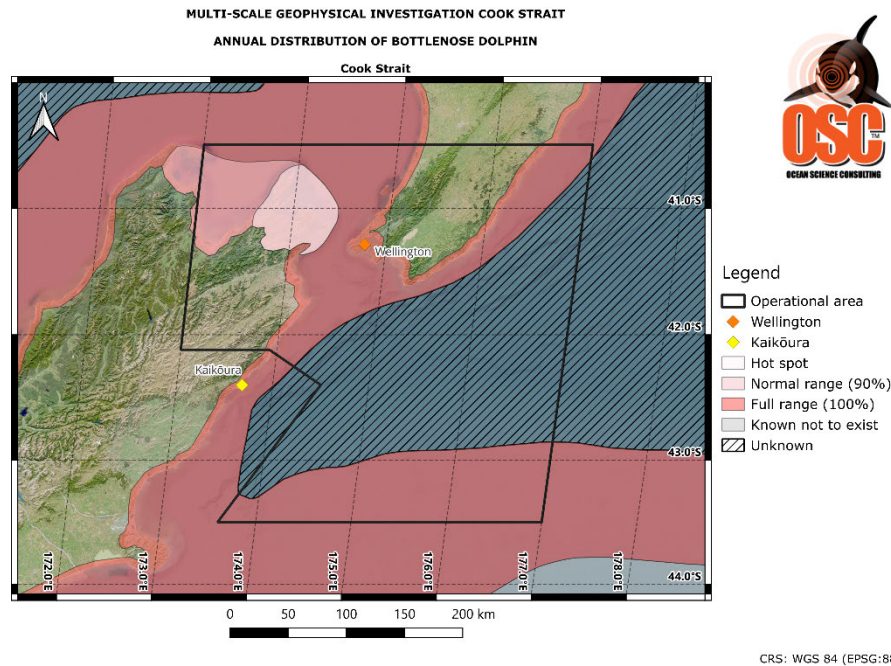


Figure 17: Bottlenose dolphin annual distribution in operational area. WGS 84/Equal Earth Asia-Pacific (EPSG 8859). *Source:* OSC (2026), modified from MPI (2026).

5.2.6.10. Common dolphin (*Delphinus delphis*)

Common dolphins (**Figure 18**) are distributed widely in all oceans, from coastal to offshore waters.



Figure 18: Common dolphin. *Source:* OSC (2026).

Estimates put the global population at around six million, but it is probably higher. They are very social animals that live in large groups. Stomach content analysis shows that common dolphins are generalist predators feeding on a variety of small pelagic schooling fish and cephalopods (Marçalo *et al.*, 2018; Brand *et al.*, 2021). The IUCN classifies them as being of Least Concern (Braulik *et al.*, 2021).

New Zealand is the southernmost distribution limit for common dolphins in the Pacific Ocean (Natoli *et al.*, 2006; Amaral *et al.*, 2012), and the species is widely distributed across New Zealand waters (Stockin *et al.*, 2008). Multiple strandings of common dolphins have been recorded within the Cook Strait region (Stockin *et al.*, 2009; Palmer *et al.*, 2022; Peters *et al.*, 2022; Palmer *et al.*, 2023), while live sightings have been recorded in the neighbouring Marlborough Sounds (Goetz and Hupman, 2017), and off Kaikōura (therefore within the operational area), including alongside dusky dolphins (*Lagenorhynchus obscurus*) (Piwetz *et al.*, 2025).

This local evidence is consistent with wider fisheries-observer records, in which common dolphin was one of the most frequently recorded cetaceans with 1,523 sighting events comprising 38,635 animals across New Zealand waters (Richard and Berkenbusch, 2024). Although these records do not constitute an abundance estimate for the operational area, they provide substantial empirical evidence of occurrence and should be considered alongside the modelled distribution shown in **Figure 19**. Common dolphins are classified as Not Threatened under the NZTCS (Lundquist *et al.*, 2025).

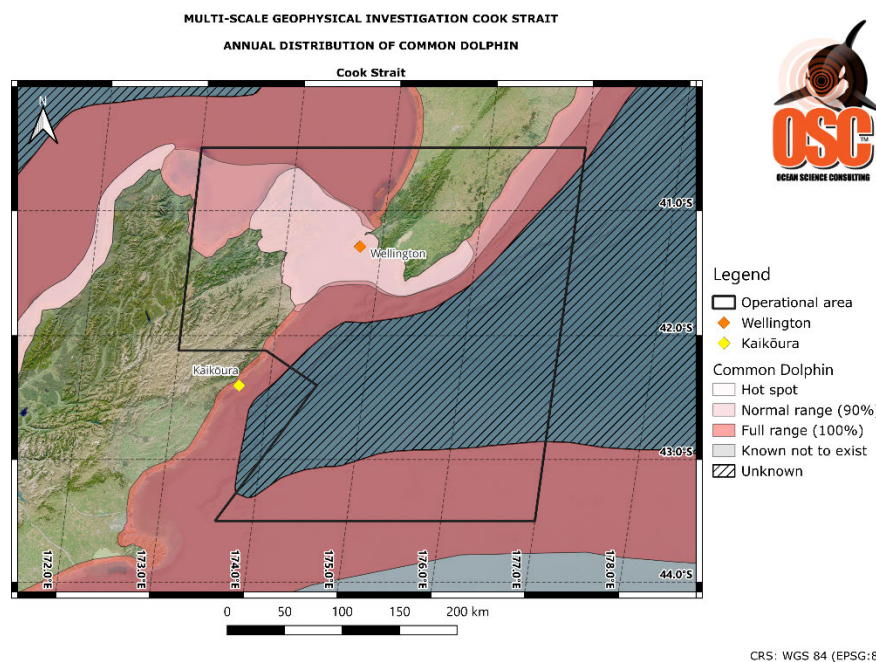


Figure 19: Common dolphin annual distribution in operational area. WGS 84/Equal Earth Asia-Pacific (EPSG 8859). *Source:* OSC (2026), modified from MPI (2026).

5.2.6.11. Dusky dolphin (*Lagenorhynchus obscurus*)

Dusky dolphins (**Figure 20**) are a coastal and mesopelagic species that has a wide but discontinuous distribution within the southern hemisphere (Orbach *et al.*, 2018).

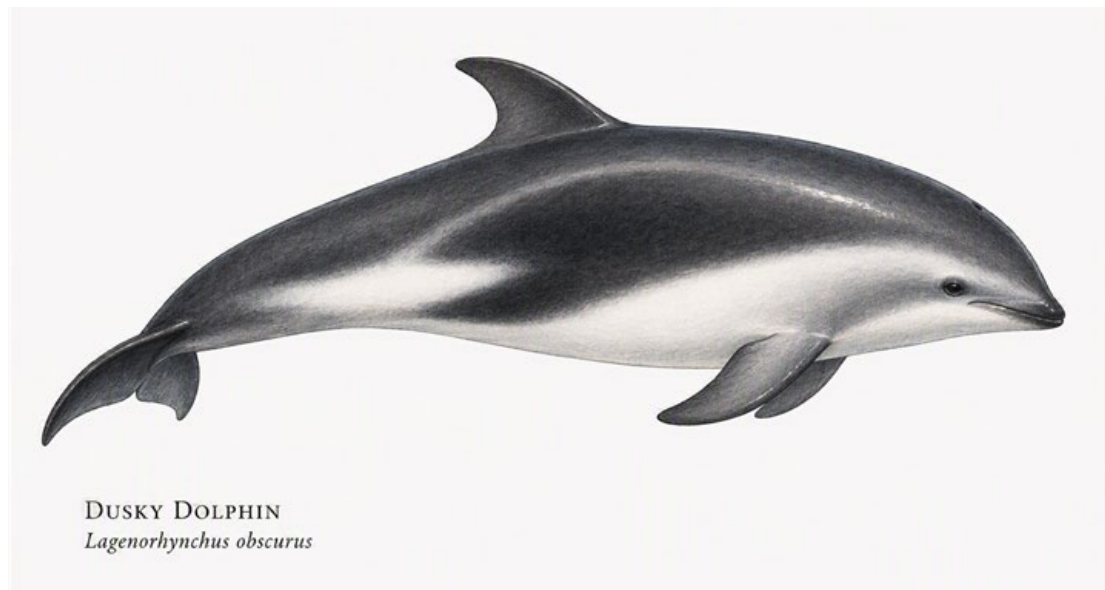


Figure 20: Dusky dolphin. Source: OSC (2026).

The diet of dusky dolphins consists of small pelagic fish and squid (Caputo *et al.*, 2021). The IUCN lists classifies this species as Least Concern, however in most parts of the world there is little information on this species' population structure and abundance (Alafaro-Shiguieto *et al.*, 2019; Degradi *et al.*, 2020).

Dusky dolphins are present in the nearby area of Kaikōura and are known to migrate between Kaikōura and the Marlborough Sounds and neighbouring Admiralty Bay, passing through the Cook Strait (Markowitz *et al.*, 2004), **Figure 21**. Admiralty Bay is an important feeding ground for dusky dolphins during the austral winter (Markowitz *et al.*, 2010). Recently, there have been reports of a decline in the individual resighting rates of dusky dolphins in Admiralty Bay (Pearson *et al.*, 2012; Piwetz *et al.*, 2025). There is no clear underlying cause for this but could be a combination of prey characteristics, human activity and inter-species competition (Piwetz *et al.*, 2025).

The known regional occurrence of dusky dolphins is further supported by government fisheries-observer data. Richard and Berkenbusch (2024) recorded 424 dolphin sightings events comprising 19,769 animals across New Zealand waters, with sightings distributed around the South Island. Although these records are not a direct estimate of abundance within the operational area, they provide substantial independent evidence of occurrence and support consideration of the species alongside its modelled spatial distribution.

Dusky dolphins off Kaikōura appear to belong to an open population of individuals with a substantial number of individuals both entering and leaving the area (Orbach *et al.*, 2018). The social structure of the dusky dolphins in the area could be driven by the Kaikōura Canyon which provides a unique ecological habitat as it is one of the most productive canyons worldwide (Orbach *et al.*, 2018). The NZTCS classifies dusky dolphins as Not Threatened (Lundquist *et al.*, 2025).

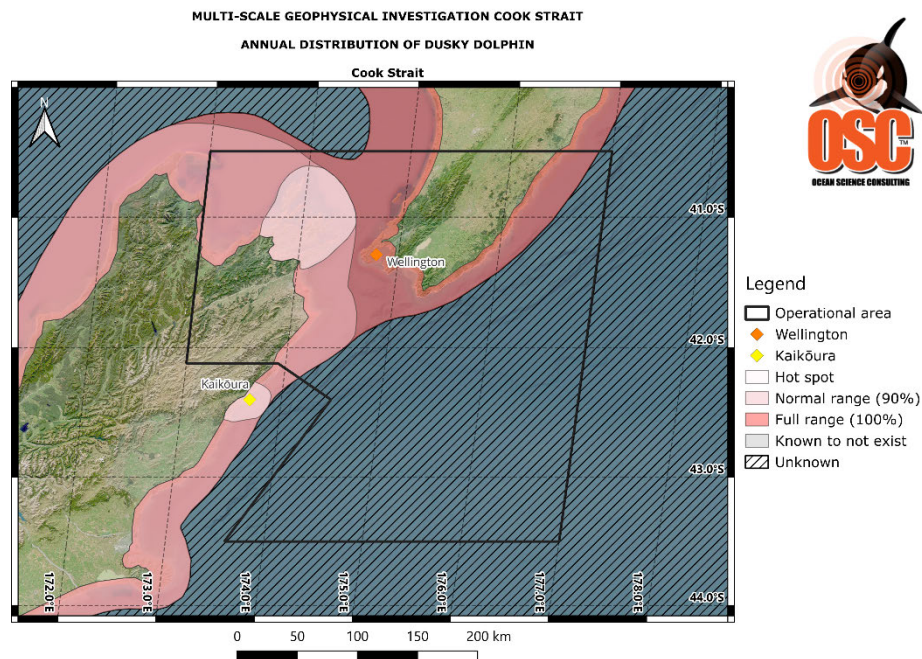


Figure 21: Dusky dolphin annual distribution in operational area. WGS 84/Equal Earth Asia-Pacific (EPSG 8859). Source: OSC (2026), modified from MPI (2026).

5.2.6.12. Goose-beaked whale (*Ziphius cavirostris*)

Goose-beaked whales (**Figure 22**) have the most extensive range of any beaked whale species and are widely distributed in offshore waters of all oceans.



Figure 22: Goose-beaked whale. Source: OSC (2026)

Goose-beaked whales are primarily associated with deep offshore waters and complex bathymetric features, particularly steep continental slopes, escarpments and submarine canyons, which can provide important foraging habitat (Tepsich *et al.*, 2014). They primarily feed on cephalopods and fish. The IUCN classifies them as Least Concern; however, the Mediterranean population is classified as Vulnerable (Baird *et al.*, 2020).

Acoustic detections within the deeper waters of Cook Strait region and off the coast of Kaikōura indicates the presence of ziphiids in the wider area and support the potential occurrence of Cuvier's beaked whales within the survey area (Goetz and Hupman, 2017). In 2025 the NZTCS status for goose-beaked whales changed from Data Deficient to At Risk – Uncommon, there are no estimates of abundance or trends for this species in New Zealand waters as the majority of information comes from stranded individuals; however there is no known significant threat for this population so it is assumed to be stable (Lundquist *et al.*, 2025).

5.2.6.13. Gray's beaked whale (*M. grayi*)

Gray's beaked whales (**Figure 23**) have a circumpolar range in the southern hemisphere.

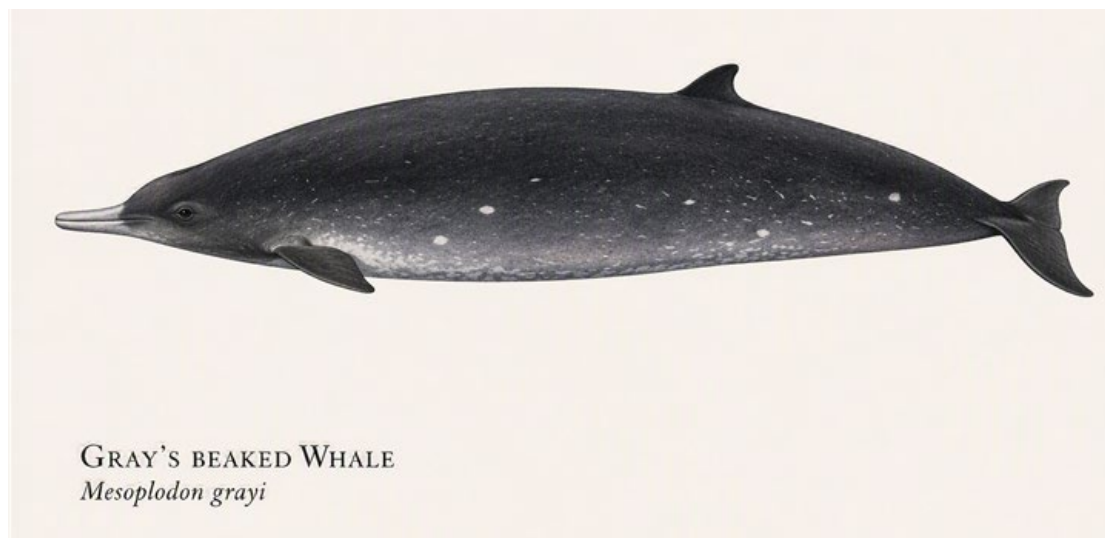


Figure 23: Gray's-beaked whale. Source: OSC (2026).

Gray's beaked whale are rarely sighted alive, and much of the available information on their distribution comes from stranding records, particularly in New Zealand (Thompson *et al.*, 2013). They are thought to inhabit deep waters and prey on fish and cephalopods (Pitman and Taylor, 2020). Genetic evidence suggests historically large population sizes, no known exploitation, few apparent behavioural barriers, and abundant habitat (Thompson *et al.*, 2016). The IUCN classifies the species as of Least Concern (Pitman and Taylor, 2020).

Stranding records provide evidence of Gray's beaked whale occurrence in the Cook Strait region (Thompson *et al.*, 2013), indicating that the species may occur within or near the survey area. The NZTCS classifies it as Not Threatened (Lundquist *et al.*, 2025).

5.2.6.14. Hector's dolphin (*Cephalorhynchus hectori*)

South Island Hector's dolphins (**Figure 24**) (*Cephalorhynchus hectori hectori*) are discontinuously distributed around the coast of the South Island, including the west, north, east and south coasts (Hamner *et al.*, 2012b; Ogilvy *et al.*, 2023).

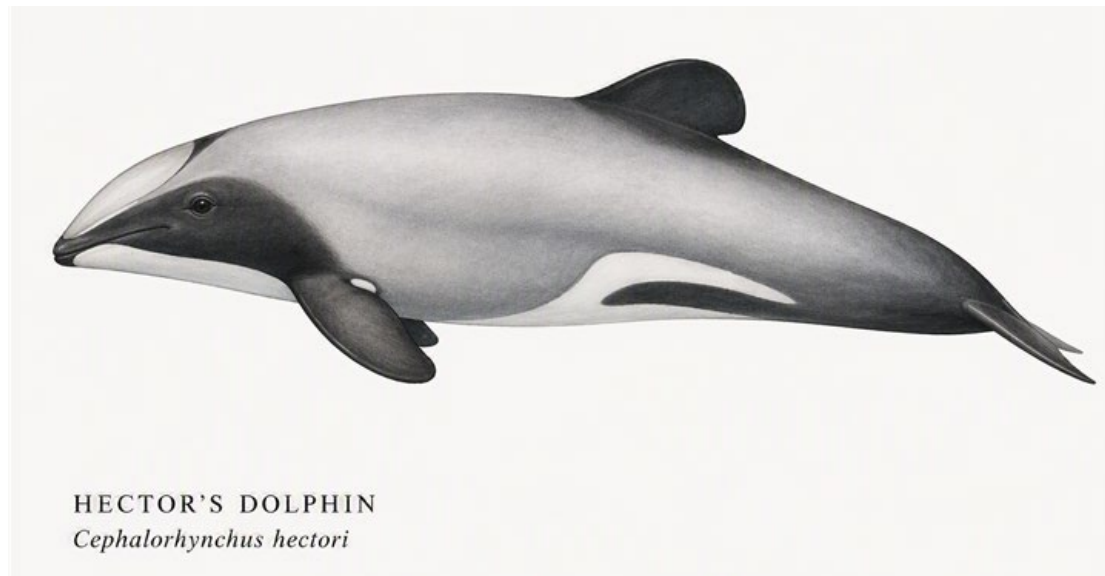


Figure 24: Hector's dolphin. Source: OSC (2026).

Hector's dolphins occur along the north coast of the South Island, including Golden Bay, Queen Charlotte Sound and Cloudy Bay (Ogilvy *et al.*, 2023). Queen Charlotte Sound supports year-round occurrence of the species, while Cloudy Bay also provides habitat immediately adjacent to Cook Strait (Ogilvy *et al.*, 2023). Although Hector's dolphin populations around the South Island show regional genetic differentiation, genetic evidence also demonstrates occasional long-distance dispersal, and individuals from different regional populations may occur outside their typical ranges (Hamner *et al.*, 2013).

Hector's dolphins exhibit seasonal distribution patterns, with smaller, more dispersed groups occurring farther offshore during winter than in summer. In Queen Charlotte Sound and Cloudy Bay, densities are greater during summer, while in winter dolphins show a greater preference for offshore waters (Ogilvy *et al.*, 2023). Their diet differs between the east and west coast of the South Island but includes benthic fish, demersal fish, mid-water fish and fish species found at the surface of the water (Slooten and Dawson, 2021). The NZTCS classifies Hector's dolphins as Threatened – Nationally Vulnerable (Lundquist *et al.*, 2025).

Given the occurrence along the north coast of the South Island, including Queen Charlotte Sound and Cloudy Bay, Hector's dolphins may occur within or near the Cook Strait survey area and should therefore be considered during operations.

5.2.6.15. Killer whale (*Orcinus orca*)

Killer whales (**Figure 25**) are widely distributed and abundant globally, in coastal and offshore areas, with only some regional populations showing decline.

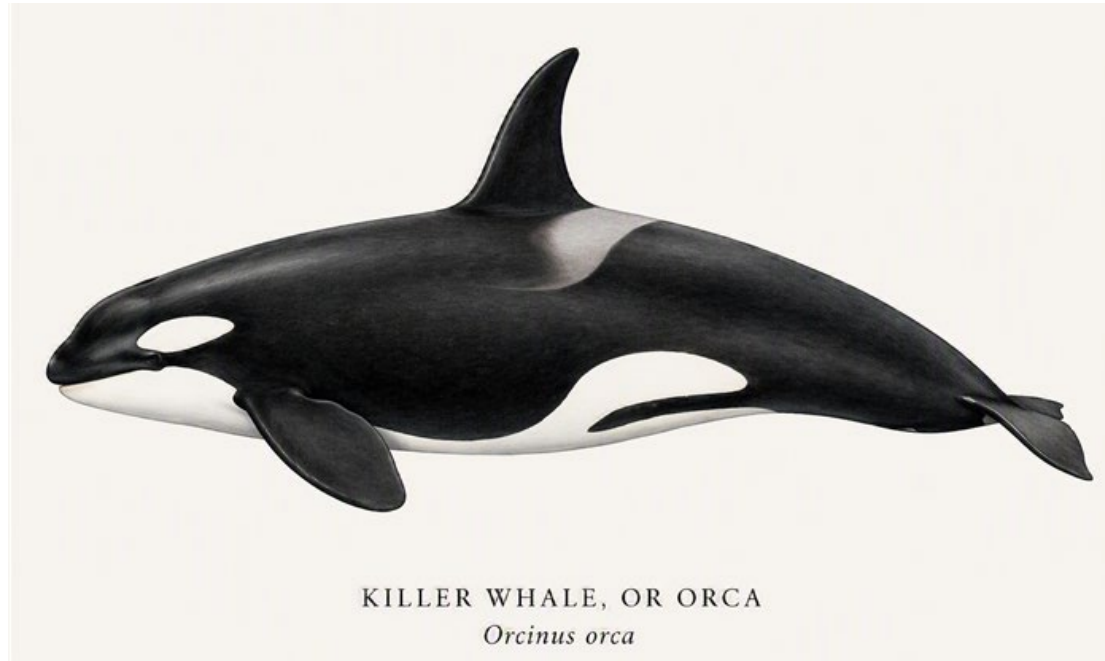


Figure 25: Killer whale. Source: OSC (2026).

Killer whales are generalist feeders, preying on marine mammals, fish, cephalopods, and birds. They use a variety of foraging tactics, with some populations specialising in specific prey and forming socially isolated ecotypes. There is evidence that the species is not well defined taxonomically, so the IUCN classifies it as Data Deficient (Reeves *et al.*, 2017).

The New Zealand coastal population of killer whales has been shown to be distinct genetically from Australian populations (Reeves *et al.*, 2022). Killer whales are present in the Cook Strait area (**Figure 26**) year-round with sightings peaking between November and February (Visser, 2007). Killer whales have been documented taking fish from longlines worldwide, including New Zealand fisheries (Visser, 2000; Tixier *et al.*, 2018). They have also been observed interacting and preying on other cetaceans but not necessarily exploiting them as a primary food source (Visser, 1999; Srinivasan, 2023).

Under the current NZTCS assessment, the resident New Zealand population is treated as a taxonomically unresolved entity, *Orcinus aff. orca*, and is classified as Threatened - Nationally Critical. Type C killer whales are classified as Non-Resident Native – Migrant while Types B and D are classified as Non-Resident Native – Vagrant (Lundquist *et al.*, 2025).

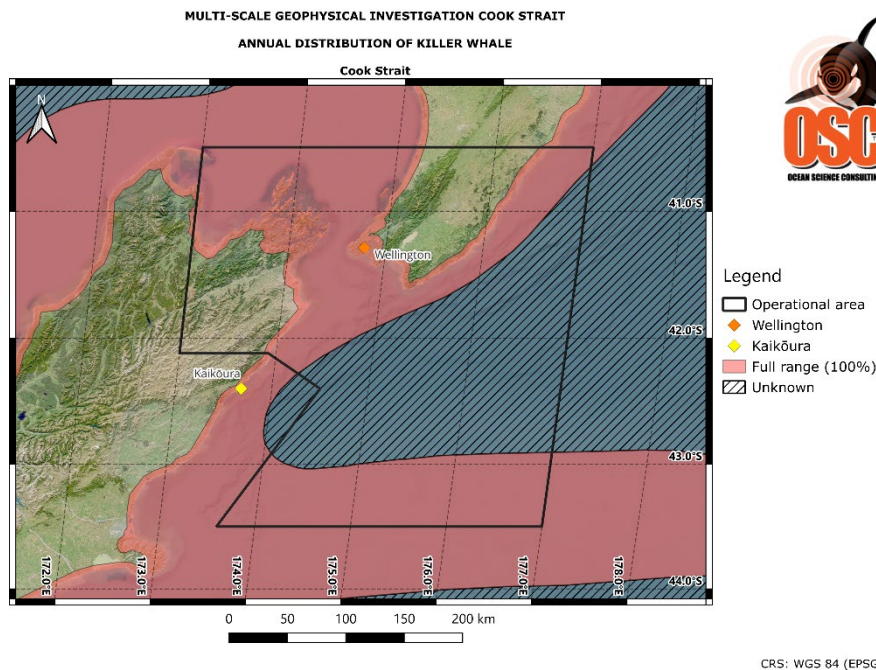


Figure 26: Killer whale annual distribution in operational area. WGS 84/Equal Earth Asia-Pacific (EPSG 8859). *Source:* OSC (2026), modified from MPI (2026).

5.2.6.16. Long-finned pilot whale (*Globicephala melas*)

Long-finned pilot whales (**Figure 27**) are widely distributed in temperate and subpolar waters, except for the north Pacific.

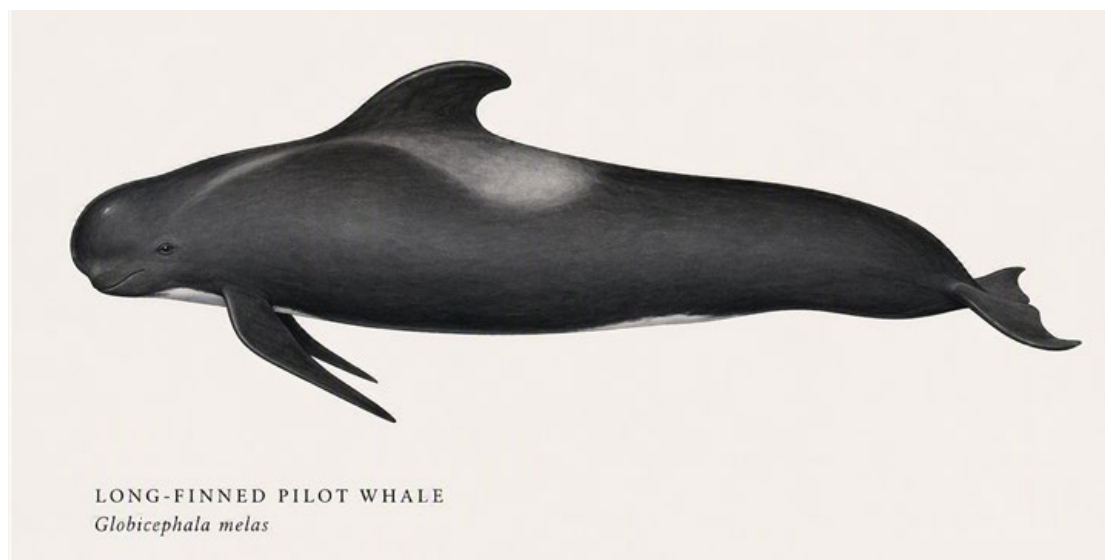


Figure 27: Long-finned pilot whale. *Source:* OSC (2026).

There are no population estimates for this species as it is hard to distinguish from short-finned pilot whales, *G. macrorhynchus* (NOAA Fisheries, 2024). They generally prefer waters along continental shelf edges and primarily prey on small and medium sized fish; however, long-finned pilot whales in New Zealand feed primarily on cephalopods, typically arrow squid (Meyer, 2020). Isotope values extracted from skin samples are typical of species with oceanic feeding behaviour,

indicating that long-finned pilot whales in New Zealand are primarily oceanic; however, their foraging strategy is unclear due to a lack of tagging, video, or distribution data (Hinton *et al.*, 2022). The IUCN classifies them as Least Concern due to no evidence of significant population decline (Minton *et al.*, 2018).

Live sightings are rare, with most data on the species coming from strandings (Betty *et al.*, 2023). Pilot whales are encountered most frequently in January. The seasonal and spatial patterns of both sightings and strandings may be a result of long-distance or in-shore migrations during warmer months, and/or a reflection of seasonal fluctuations in the distribution of prey (Hinton *et al.*, 2022). It is likely that offshore waters also represent important habitat for the species, but with the low mark-rate and re-sights of individuals, there are no accurate abundance estimates (Meyer, 2020). Between 2003 to 2019 pilot whale groups have been sighted off the coast of Kaikōura and have been spotted alongside oceanic bottlenose dolphins (Meyer *et al.*, 2025). The NZTCS classifies them as Not Threatened (Lundquist *et al.*, 2025).

Government fisheries-observer data also provide evidence of offshore occurrence, with 122 sighting events comprising 1,492 animals recorded across New Zealand waters (Richard and Berkenbusch, 2024).

5.2.6.17. *Māui Dolphin (Cephalorhynchus hectori maui)*

Māui dolphin are only found on the west coast of the North Island (Hamner *et al.*, 2012a; Parsons, 2024), and is visually impossible to distinguish from the Hector's dolphin; however, their location can be determined by examining stomach contents which reveals a distinct divide separated into regions of GCS (Miller, 2015; Lucke *et al.*, 2019).

With falling population sizes due to becoming bycatch in set gill nets or trawling fishing gear as well as predation from killer whales and sharks, including gill sharks (*Hexanchidae spp.*) and white sharks (*Carcharodon carcharias*), they have been classified as a Critically Endangered species (Miller, 2015; Lucke *et al.*, 2019; Constantine, 2023). Stomach-content examinations indicate that their diet includes a range of epipelagic fish species including sprat (*Sprattus muelleri*), pilchards (*Sardina pilchardus*), and anchovy (*Engraulis australis*) (Miller, 2015; Lucke *et al.*, 2019).

Māui dolphins are highly unlikely to occur within the GCS due to their very small population size and highly restricted distribution, which is concentrated along the northwest coast of the North Island, considerably farther north of the survey area (Oremus *et al.*, 2012; Parsons, 2024; Alvarez-Costes *et al.*, 2025).

Māui dolphins are classified as Threatened – Nationally Critical under the NZTCS (Lundquist *et al.*, 2025).

5.2.6.18. Pygmy sperm whale (*Kogia breviceps*)

Figure 28 shows a pygmy sperm whale. There is very limited information on the distribution, abundance, behaviour, or population structure of pygmy sperm whales globally (Plön *et al.*, 2023).

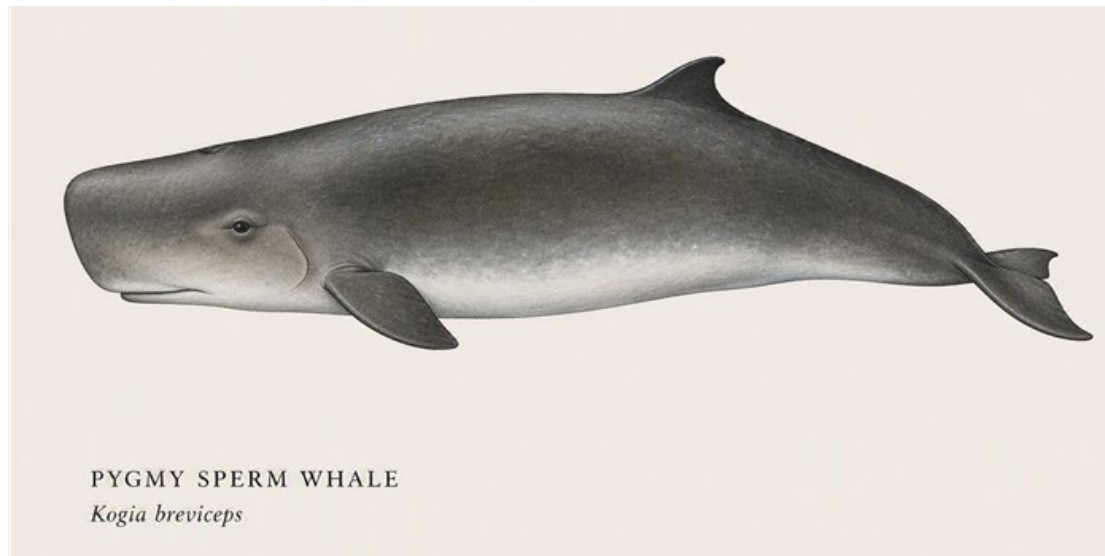


Figure 28: Pygmy sperm whale. Source: OSC (2026).

This is largely due to short surfacing interval, cryptic surface behaviour, and long, deep dives which make these whales extremely challenging to observe at sea; however, high detection rates during acoustic surveys indicate that this species is not as uncommon as visual surveys would suggest (Kiszka and Braulik, 2020; Steidl, 2024). Their diet consists primarily of cephalopods (Dinets, 2021). They do not seem to experience significant impacts from exposure to anthropogenic noise, and they also do not appear to be bycaught frequently in fishing gear (Kiszka and Braulik, 2020).

Evidence of their presence within the Cook Strait comes from stranding records between 2010 and 2021 (Peters *et al.*, 2022). They are generally thought to be found in deep waters, so they might be encountered in the operational area. In the latest NZTCS assessment, the pygmy sperm whale was reclassified from Data Deficient to At Risk – Uncommon (Lundquist *et al.*, 2025). There are no population estimates of this species in New Zealand waters, but it was considered unlikely that more than 20,000 individuals are present in New Zealand waters, resulting in this classification (Lundquist *et al.*, 2025).

5.2.6.19. Shepherd's beaked whale (*Tasmacetus shepherdi*)

Shepherd's beaked whales (**Figure 29**) have a circumpolar distribution in the Southern Hemisphere (Towers and Tixier, 2022).

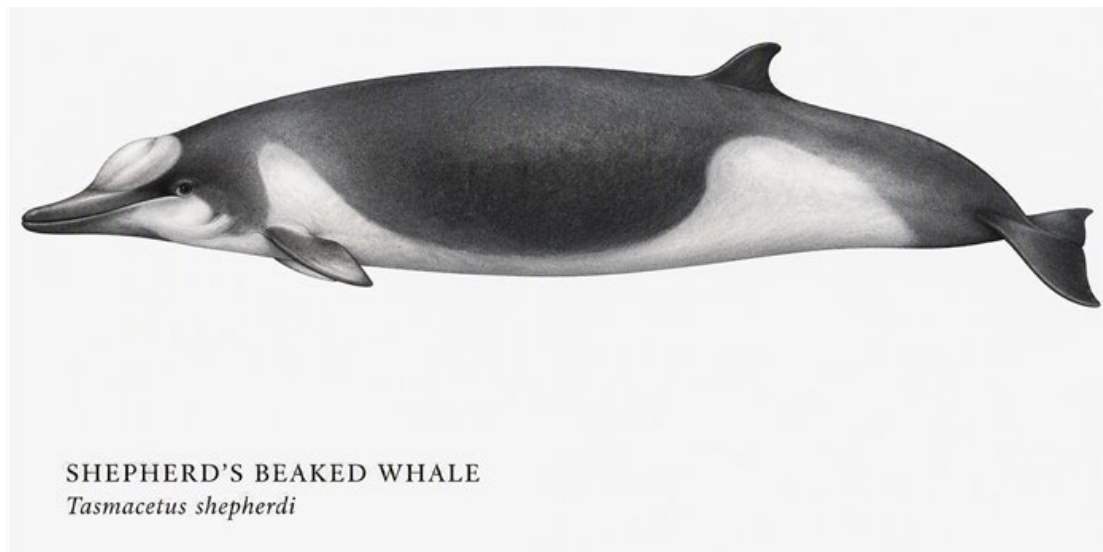


Figure 29: Shepherd's beaked whale. Source: OSC (2026).

Most information on the species comes from stranding records (Pitman *et al.*, 2006; Braulik, 2018b). It is thought to inhabit deep waters and prey on cephalopods and fish, depending on the time of day and access to seamount or continental slope areas (Best *et al.*, 2014).

Shepherd's beaked whales have been recorded in New Zealand waters primarily through stranding records, although confirmed live sightings remain rare. The species is generally associated with deep, cold offshore waters, and its occasional presence within the wider survey region cannot be excluded (Pitman *et al.*, 2006). The NZTCS classifies this species as Data Deficient (Lundquist *et al.*, 2025).

5.2.6.20. Southern right whale dolphin (*Lissodelphis peronii*)

Southern right whale dolphins (**Figure 30**) have a circumpolar distribution in the Southern Hemisphere, usually found in offshore waters, feeding on a diet of fish and cephalopods (Arrial *et al.*, 2024).

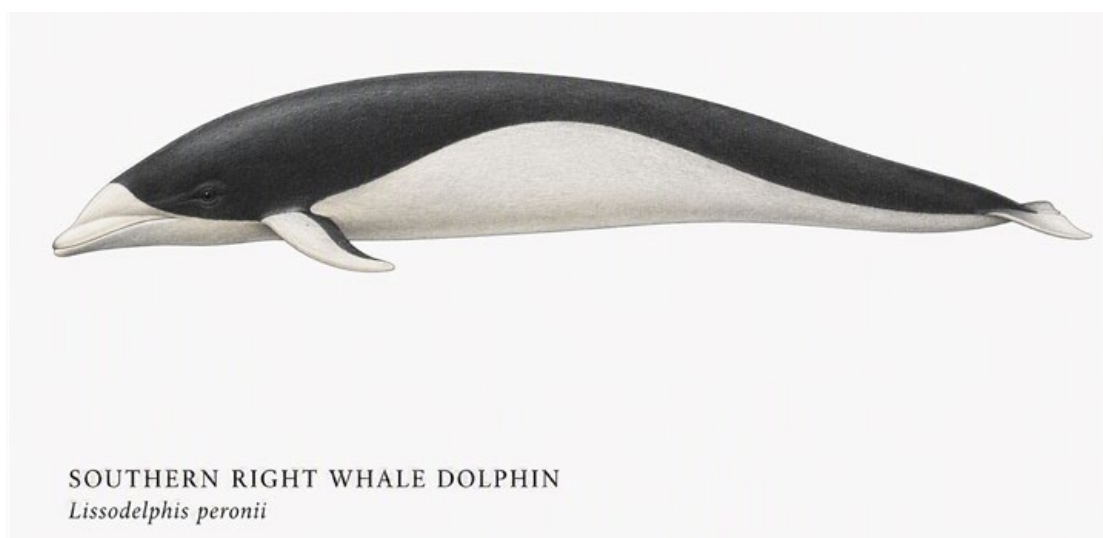


Figure 30: Southern right whale dolphin. Source: OSC (2026).

In New Zealand, southern right whale dolphins have been recorded east of Kaikōura (Visser *et al.*, 2004) and more recent live sightings alongside long-finned pilot whales have also been reported off the coast of Kaikōura (Meyer *et al.*, 2025). These sighting and stranding records suggest that the species could occur within the operational area. Under the latest NZTCS assessment, southern right whale dolphins were reclassified from Data Deficient to At Risk – Uncommon. Large pods comprising hundreds of animals have historically been sighted offshore, but no abundance or population trend estimates are available for New Zealand waters, and anecdotal reports suggest decreased sightings off Kaikōura. (Lundquist *et al.*, 2025). The IUCN classifies the species as Least Concern, despite limited data, due to its wide distribution and lack of identified major threats (Braulik, 2018a).

5.2.6.21. Sperm whale (*Physeter macrocephalus*)

The largest of the odontocetes is the sperm whale (**Figure 31**), which can be found in oceans worldwide. They spend most of their time diving to forage and their diet is primarily made of cephalopods (Fernandes, 2016).



Figure 31: Sperm whale. Source: OSC (2026).

The IUCN classified them as Vulnerable, due to historical population declines attributed to commercial whaling and uncertain population abundance trends (Taylor *et al.*, 2019).

In the Kaikōura region, repeated use of the area by male sperm whales has been documented, including through acoustic and long-term monitoring studies (Giorli and Goetz, 2020). They are known to pass through both the Kaikōura and Cook Strait regions year-round, with the Strait providing productive feeding habitat (Warren, 2020; Stephenson *et al.*, 2021). More recent work has also identified Cook Strait as a feeding habitat for subadult male sperm whales moving between regions of New Zealand (Steidl *et al.*, 2026). Long-term photo identification data from Kaikōura indicate a significant decline in the number of male sperm whales using the area, particularly during summer, while no significant decline was detected during winter (Somerford *et al.*, 2022). Their status under the NZTCS changed from Data Deficient to At Risk – Declining, based on the long-term decline observed off Kaikōura and evidence of reduced recruitment to the population using

the area (Lundquist *et al.*, 2025). The sperm whale is likely to be present within the Cook Strait when operations commence.

5.2.6.22. Strap-toothed whale (*Mesoplodon layardii*)

Strap-toothed whales (**Figure 32**) are an understudied, data deficient species who spend most of their time in deep water feeding on squid (Australian Museum, 2024).

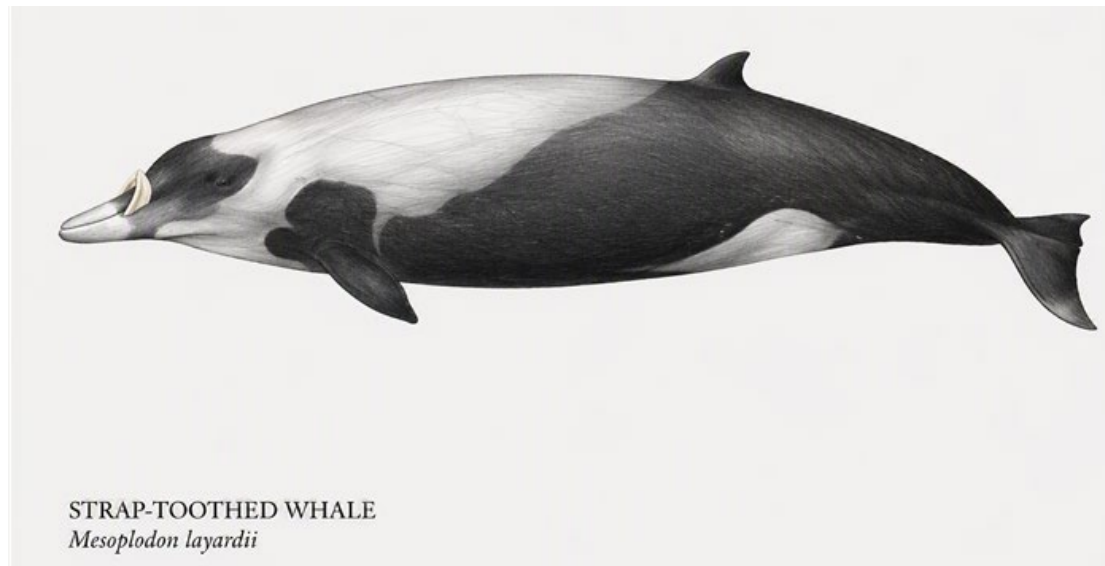


Figure 32: Strap-toothed whale. Source: OSC (2026).

They predominantly travel in small groups of up to 3 adults and are believed to move inland from deeper water to calve, resulting in strandings on the coast of Australia and New Zealand (Thompson *et al.*, 2013; Pitman *et al.*, 2019; Australian Museum, 2024). Stranding records from the wider Cook Strait region indicate that strap-toothed whales may occur in or transit through the area. The species remains classified as Data Deficient under the NZTCS (Lundquist *et al.*, 2025).

5.2.6.23. Striped dolphin (*Stenella coeruleoalba*)

The striped dolphin (**Figure 33**) is a widely distributed species, found in tropical to warm-temperate waters (Archer II, 2018).

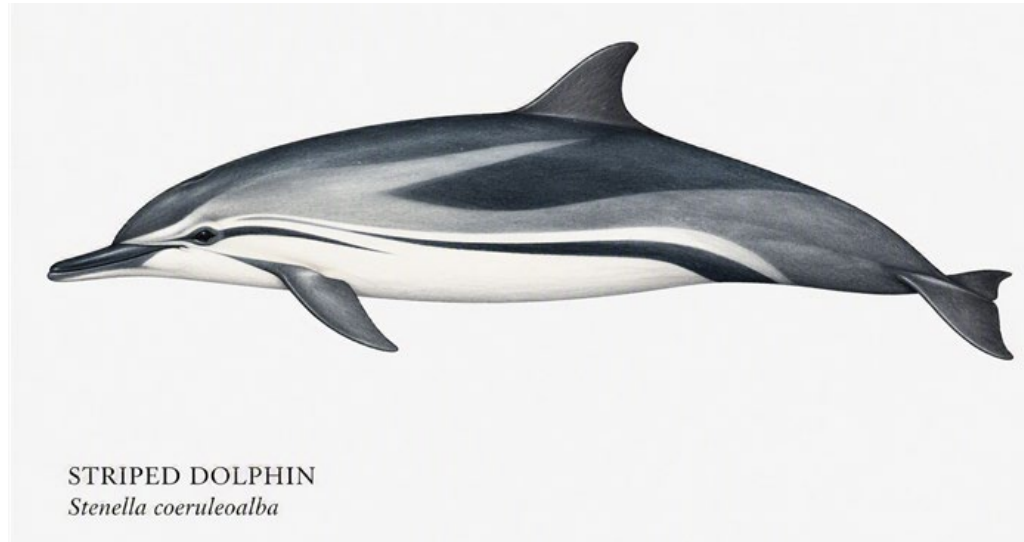


Figure 33: Striped dolphin. Source: OSC (2026).

The global population is estimated to be over two million. They inhabit deep waters, with studies mainly focused in the Mediterranean and Mexican coasts (Aguilar, 2000; Azzolin *et al.*, 2020). They prey on a variety of species, including cod and squid (Saavedra *et al.*, 2022). The IUCN classifies the global population as Least Concern; however, the Mediterranean subpopulation is classified as Vulnerable due to population decline (Braulik, 2019).

Stranding records potentially place striped dolphins within the Cook Strait region (Peters *et al.*, 2022). The species remains classified as Data Deficient under the NZTCS (Lundquist *et al.*, 2025).

5.2.6.24. New Zealand fur seal (*Arctocephalus forsteri*)

New Zealand fur seals (NZFS) (**Figure 34**) are active during both day and night and possess acute vision and good hearing under water (Nowak, 2003).



Figure 34: New Zealand fur seal. *Source:* OSC (2026).

They are sexually dimorphic, with males being much larger than females. They are polygynous, with males competing over territory in colonies before females arrive. Those territories include 5–8 females for every male. Pups are born from mid-November to January, and the number of seals ashore declines rapidly a couple of days after as they depart on foraging trips (Chilvers and Goldsworthy, 2015). They are generalist feeders, with females choosing to forage in continental shelf waters, while males prefer deeper continental shelf breaks or pelagic waters (Page *et al.*, 2005). Foraging trips have been recorded to last up to 20 days. Populations are currently increasing in both Australia and New Zealand, and their breeding range is expanding, so they are classified as Least Concern by the IUCN (King, 2024; Hall *et al.*, 2025a). While populations are increasing, there are concerns that effects from global warming are causing population increases to slow or halt altogether (Hall *et al.*, 2025b).

NZFS have been recorded to have at least two breeding colonies, and six non-breeding haul-out locations within the Cook Strait as of 2023 (**Figure 35**) (Pavanato *et al.*, 2023). This indicates that their presence is highly likely both within and around the Cook Strait at the time of operations. They are also present in the Kaikōura region with a significant colony at Ōhau Point (**Figure 36**). This species remains classified as Not Threatened under the NZTCS, with an increasing population qualifier (Lundquist *et al.*, 2025).

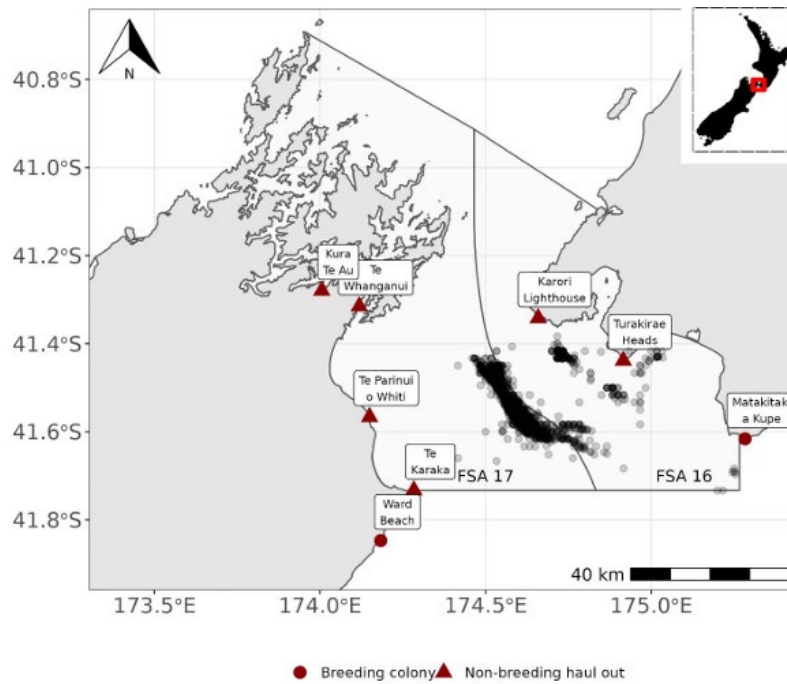


Figure 35: New Zealand fur seal colonies in operational area. *Source:* Pavanato *et al.* (2023).

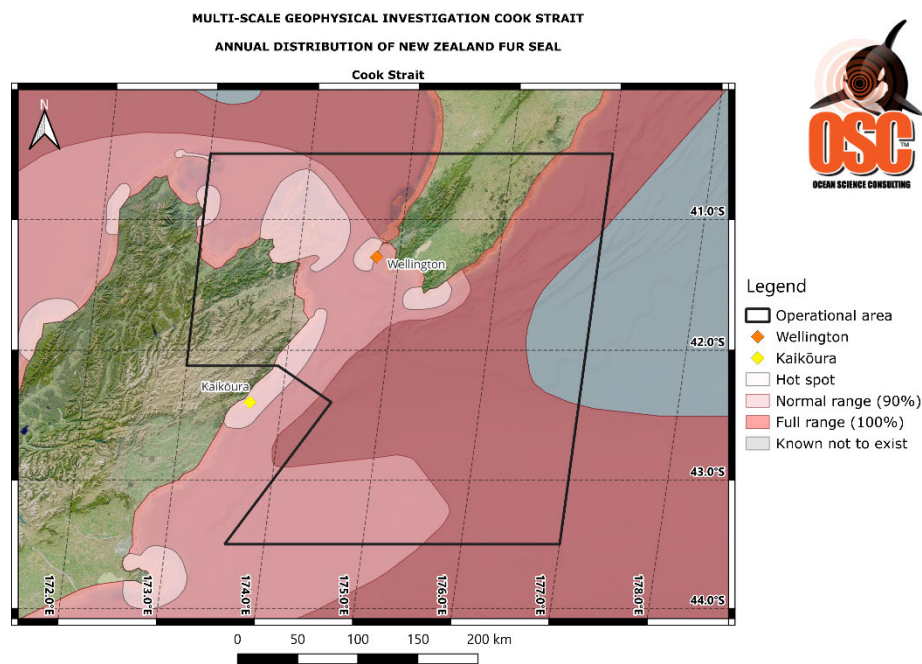


Figure 36: New Zealand fur seal annual distribution in operational area. WGS 84/Equal Earth Asia-Pacific (EPSG 8859). *Source:* OSC (2026), modified from MPI (2026).

5.3. Coastal environment & marine conservation

The Cook Strait is situated between the North and South Islands of New Zealand. Multibranched deep canyon systems dominate the eastern part of the Cook Strait. The depth throughout the Cook Strait ranges from 50 m at the northern part of the shelf to 2,700 m in the Hikurangi trough (Lamarche *et al.*, 2012). Strong wind-driven and tidal currents are found within the Cook Strait, with especially strong accelerations at the narrowest point within the strait (Walters *et al.*, 2010; Stevens, 2014). The continental shelf in wider Cook Strait has a varied seafloor morphology with rock outcrops of marine siltstone and mudstone, as well as sediment grain size ranging from coarse gravel to mud (Neil *et al.*, 2016).

The Cape Palliser is one of largest NZFS colonies on the North Island and is close to the busy Cook Strait fishing and shipping channel (Hall *et al.*, 2025a). New Zealand fur seals are susceptible to bycatch especially from hoki (*Macruronus novaezelandiae*) trawl vessels especially within the Cook Strait area due to these nearby colonies (Abraham and Berkenbusch, 2017).

The Kaikōura region is made up of rocky reefs with large canopy-forming seaweeds such as kelp and algal beds. In 2016 an earthquake causes extensive coastal uplift along 130 km of coastline (Clark *et al.*, 2017). The earthquake resulted in a devastating impact on the highly productive nearshore ecosystems affecting the intertidal primary and secondary habitat-forming seaweeds and the invertebrates that are dependent on these biogenic habitats (Thomsen *et al.*, 2020). The disturbance affected habitat-forming and culturally important species such as pāua (*Haliotis iris*) and bull kelp (*Durvillaea spp.*) prompting an emergency ban on shellfish and seaweed harvesting in the area (Alestra *et al.*, 2021). Before the earthquake the intertidal reefs supported diverse algal communities (Schiel, 2004). The latest reports show that the intertidal community is still impacted by the earthquake, as large portions are devoid of algal cover and now unsuitable for colonisation of large algae (Alestra *et al.*, 2021).

The likely reason there is a lack of algal recovery in this area is high temperatures and erosion rates (Schiel *et al.*, 2019). Low intertidal zones now host the most abundant algal communities with large brown algae dominating; however, the assemblages of large brown algae are no longer dominated by bull kelp but with other species of fucoids (primarily *Carpophyllum maschalocarpum*) with no site showing any sign of bull kelp recovery (Alestra *et al.*, 2021). The physical habitats themselves have changed with the boulder fields and intertidal reefs comprising of soft sedimentary rock which continue to erode, contributing to the poor recovery of the benthic communities within the area (Alestra *et al.*, 2021).

Close to shore Kaikōura has an underwater canyon system which is 60 km long and 1,200 m deep and is home to several marine mammal species including sperm whales, dusky dolphins and Hector's dolphins (Markowitz *et al.*, 2011; Lundquist *et al.*, 2012; Hamner *et al.*, 2016). Kaikōura is one of two places in the world where sperm whales are the primary focus of a year-round whale watching industry (Markowitz *et al.*, 2011). The Kaikōura canyon has been described as one of the most productive deep-sea habitats (De Leo *et al.*, 2010). Kaikōura is also an important area for seals with Ōhau Point having the most significant New Zealand fur seal breeding colony along the eastern coast of the South Island. The overall population of New Zealand fur seals in Kaikōura has continued to grow and spread out since the 2016 earthquake (Hall *et al.*, 2024).

5.3.1. Protected areas

In 1992, New Zealand became a Party to the Convention on Biological Diversity, requiring the country to have a National Biodiversity Strategy and Action Plan (NBSAP). The New Zealand Biodiversity Strategy (NZBS) includes objectives specific to the conservation of the sea through implementation of a network of Marine Protected Areas (MPAs), aiming to reverse the loss of biodiversity. New Zealand has designated 3 types of MPAs (Rovellini and Shaffer, 2020).

Type 1 MPAs are no-take areas that include marine reserves established under the Marine Reserves Act 1971, with the purpose of reserving marine life for scientific study. Marine reserves provide the highest level of marine protection with designated areas from sea surface to seafloor, including the foreshore being completely protected. New Zealand's territorial sea includes 44 such reserves, two of which are situated in coastal areas near the operational area (**Figure 37**).

There are six marine reserves that fall within the operational area. Hikurangi marine reserve is approximately 104 km², extending offshore for 23.4 km and 1,400 m deep, encompassing part of the Kaikōura canyon and including 1.95 km of shoreline near Goose Bay. This makes Hikurangi marine reserve the largest and deepest in New Zealand (Gerrity *et al.*, 2025). Taputeranga marine reserve is located on Wellington's south coast and was established in 2008 covering 9 km². Kāpiti marine Reserve is located 50 km north of Wellington, established in 1992 and covers 22 km². Within the Marlborough Sounds there is the Long Island - Kokomohua marine reserve which was 1993 and covers a 6 km². Horoirangi marine reserve lies north of Nelson city along the eastern side of Tasman Bay/Te Tai-o-Aorere, established in 2005 covering 9 km². Along the coast of the Abel Tasman National Park is the Tonga Island marine reserve which was established in 1993 and covers an area of 18 km².

Type 2 MPAs are established outside the Marine Reserves Act 1971 and include Fisheries Act 1996 statutory tools to establish prohibitions. At a minimum they must provide for prohibition of trawling, Danish seine netting and dredging. Type 2 MPAs provide enough protection from the adverse effects of fishing to meet the MPA Protection Standard. Both Cable Protection Zones (CPZ) and Pipeline Protection Zones (PPZ) are included within type 2 MPAs and prevent marine-based activities that may threaten undersea cables or pipelines. All anchoring and fishing operations of any type are illegal within the CPZ. Currently there are a total of 19 Type 2 MPAs around New Zealand, covering 2.6% of the territorial sea (DOC, 2019).

Within the Cook Strait, there is legislation protecting areas which are critical to preserving electrical and communication systems connecting the two islands. The Cook Strait CPZ forbids anchorage or fishing within a certain area across the strait. This is to protect submerged pipelines from damage from trawling and the use of set nets (Transpower, 2022). The CPZ is reinforced by Submarine Cables and Pipelines Protection Order 2009 which was built upon the Submarine Cables and Pipelines Protection Act 1996 issued to protect submerged pipelines (**Figure 37**) (New Zealand Ministry of Transport, 1996; New Zealand Ministry of Transport, 2009).

The third type of MPA includes all other areas that afford some level of protection, but do not satisfy the minimum requirements of protection to qualify as MPAs. This includes Benthic Protected Areas (BPAs), customary management areas, seamount area closures and marine mammal sanctuaries. There are no BPAs within the operational area, but the Mid Chatham Rise BPA is ca. 50 km from the southeast corner of the operational area.

The Marine Mammals Protection Act 1978 allows for the establishment of marine mammal sanctuaries to protect marine mammals and important areas used for biologically significant behaviours, including feeding and breeding (Fisheries New Zealand, 2025). Activities within these sanctuaries may be subject to specific restrictions, and seismic survey is generally prohibited except where limited exemptions apply. Where an exemption permits seismic surveying, operations must comply with the applicable sanctuary requirements and the 2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations. New Zealand has seven marine mammal sanctuaries established under the Marine Mammals Protection Act 1978, in addition to two sanctuaries established under special legislation in the Kaikōura region (DOC, 2026). Two marine mammal sanctuaries occur within the survey operational area, with a further three located within the broader region. Relevant sanctuaries include the Clifford and Cloudy Bay Marine Mammal Sanctuary, the West Coast North Island Marine Mammal Sanctuary and the Banks Peninsula Marine Mammal Sanctuary. Only The Clifford and Cloudy Bay Marine Mammal Sanctuary and The West Coast North Island Marine Mammal Sanctuary fall within the operational area. The Clifford and Cloudy Bay Marine Mammal Sanctuary was established in 2008 and encompasses important habitat for Hector's dolphins (DOC, 2026). The West Coast North Island Marine Mammal Sanctuary was established in 2008 and extended in 2020 (DOC, 2026). The Banks Peninsula Marine Mammal Sanctuary based outside the operational zone was first established in 1988 for the protection of Hector's dolphins and was subsequently extended in 2008 and 2020 (**Figure 37**) (DOC, 2026).

The Kaikōura ([Te Tai o Marokura](#)) marine management area includes three [mātaitai](#) reserves, two [taiāpure](#) and two marine mammal sanctuaries: Te Rohe o Te [Whānau Puha](#) and Ōhau Point New Zealand Fur Seal Sanctuary. Enforcement of [mātaitai](#) and [taiāpure](#) customary management areas rests with the Minister of Fisheries and fisheries officers, whereas the marine reserves and marine mammal sanctuaries are enforced by the Department of Conservation. [Mātaitai](#) reserves provide for customary fishing use and management practices. The local [iwi/hapū](#) develop and manage the [mātaitai](#) reserves, applying customary management and food gathering practices.

Though biodiversity protection is not the primary function of these reserves, should the [tangata whenua](#) so wish then the [mātaitai](#) reserves can be implemented in such a way that meets the criteria for a type 2 MPA. [Taiāpure](#) are recognised as traditional [Māori](#) fishing grounds but include areas of special spiritual or cultural significance. Te Rohe o Te Whānau Puha Whale Sanctuary covers approximately 4,700 km² of the coastal and offshore environment around Kaikōura. The sanctuary extends from the northern boundary of the Kaikōura marine management area at Clarence Point to the south near Gore Bay and 56 km offshore. The inner zone of Te Rohe o Te Whānau Puha has tighter restrictions on seismic survey activities than the outer zone. Ōhau New Zealand Fur Seal Sanctuary encompasses the 800 m length of the shoreline and intertidal area around Ōhau point which is north of

Kaikōura. This area is a significant breeding colony for New Zealand fur seals (**Figure 38**).

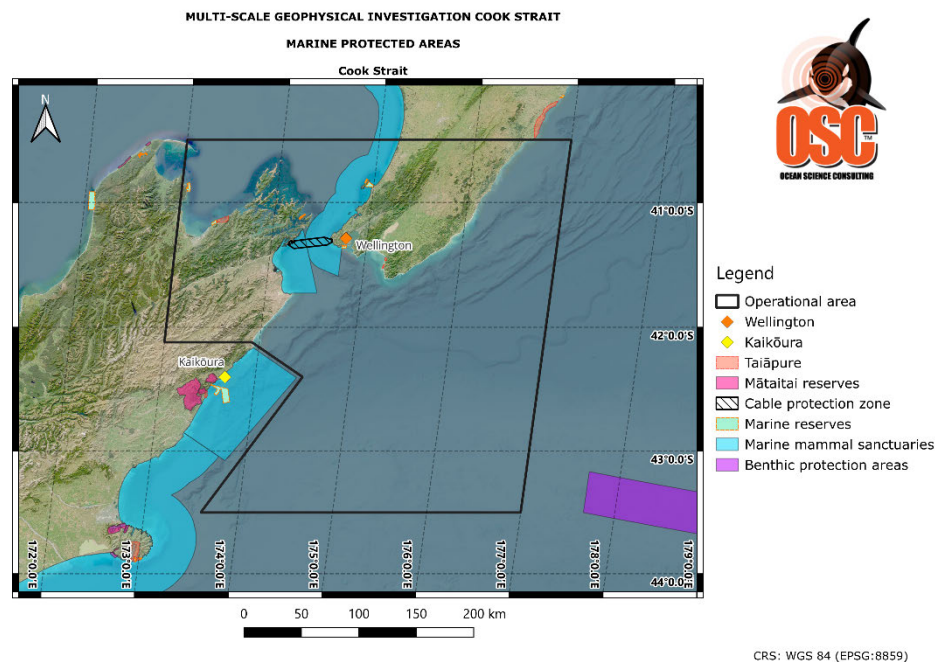


Figure 37: Current marine protected areas near operational area. WGS 84/EPG:4326. Source: OSC (2026).

5.4. Cultural environment

Māori legend tells of Kupe the navigator who discovered the strait, subsequently named [Raukawa Moana](#), by following a giant octopus across the Strait (Stevens *et al.*, 2021b). This strait was used by the *iwi* for trade, fishing and inhabitation of the North and South Islands (Anderson, 2025). It was then discovered by Dutch explorer Abel Tasman in 1642 who believed that it was a bight rather than a strait; James Cook in 1769 confirmed it was a strait by climbing Kaitapeha hill on South Island (Moon, 2019).

Māori have a strong connection with marine mammals, deeming them spiritual guides and beings (Elmahdy *et al.*, 2025). Researchers have collaborated with the *iwi* to determine marine mammal populations and diversity when conducting studies due to their connection and dependence on them (Brough *et al.*, 2025).

New Zealand's marine and coastal area has the status of 'common marine and coastal area' and is 'incapable of ownership' by the Crown, Māori, or anyone else under the Marine and Coastal Area ([Takutai Moana](#)) Act 2011 (New Zealand Parliamentary Counsel Office, 2011). The purpose of the act is to "establish a durable scheme to ensure the protection of the legitimate interests of all New Zealanders" in the marine and coastal area.

The customary rights of Māori are primarily recognised through the ability of Māori groups to achieve recognition of two new rights under the Act; customary marine title and Protected Customary Rights (New Zealand Parliamentary Counsel Office, 2011). Rather than providing for property rights of ownership or title to the [takutai moana](#), the new rights are primarily focused on enhancing the participation of Māori in the management of the [takutai moana](#) and allowing them to carry out certain customary rights (Downs, 2020). Areas under Protected Customary Rights allow

access to marine environment for seafood and cultural/spiritual activities. Areas can be granted Customary Marine Titles for greater control of management (Reid *et al.*, 2019). To date, 20 Customary Marine Titles have been granted with a further 201 active applications still to be processed by the High Court (Courts of New Zealand, 2026; Land Information New Zealand, 2026). There are Protected Customary Rights and Customary Marine Title applications which overlap with the operational area (**Figure 38**).

The fishing rights of Māori are protected through special reserves with additional rules regarding fishing (**Figure 39**). Mātaitai reserves are areas closed to commercial fishing, that may have bylaws affecting recreational and customary fishing. A *taiāpure* is an estuarine or littoral coastal area which is traditionally important to *hapū* or *iwi*. A *taiāpure*, once established, can protect these local areas and allows *hapū* and *iwi* to manage their own fisheries (Day, 2004).

The Takutai Moana Act 2011 requires the Crown to engage with *iwi*, *hapū*, and *whānau* in the management of marine and coastal areas (New Zealand Parliamentary Counsel Office, 2011). Their views should be taken into account to help identify local impacts not normally able to be considered without knowledge of the local environment and traditions (Hale *et al.*, 2024).

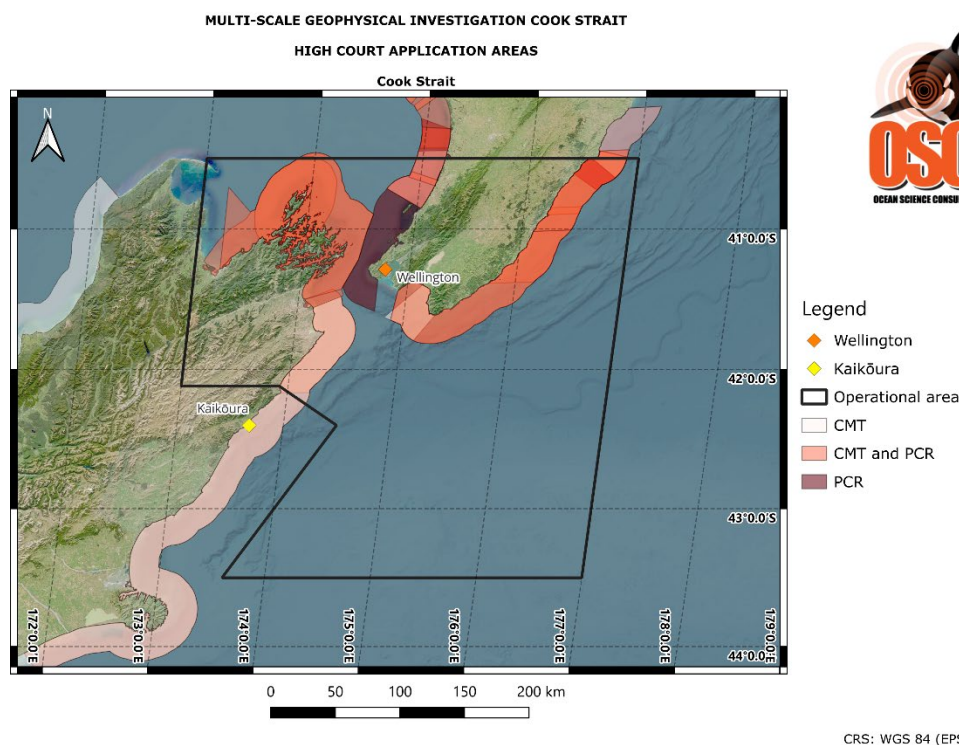


Figure 38: Customary Marine Title and Protected Customary Rights application areas under the *Takutai Moana* Act 2011. CMT- Customary Marine Title, PCR – Protected Customary Rights. *Source:* OSC (2026) modified from Kōrero Takutai (2026). **Figure 39:** Taiāpure and Mātaitai reserves. *Source:* OSC (2026)

5.5. Socio-economic environment

The Cook Strait plays a less significant role in commercial fishing compared to other areas in New Zealand due to its restrictions for submarine cable protection and marine conservation. The main species are hoki caught via trawling and New

Zealand king salmon (*Oncorhynchus tshawytscha*) which have been introduced as small farms offshore from Cape Lambert (New Zealand Ministry of Primary Industries, 2023; New Zealand Ministry of Primary Industries, 2025).

5.5.1. Recreational fishing

The Cook Strait is a popular area for recreational fishing, largely due to the number of large population centres such as Wellington. The vast majority of catch is New Zealand blue cod (*Parapercis colias*), terakihi (*Nemadactylus macropterus*), hapuku groper (*Polyprion oxygeneios*), snapper (*Chrysophrys auratus*), and yellowtail kingfish (*Seriola lalandi*) using fishing rods. Most recreational fishing activity takes place from trailer motorboats or larger boats, and off land (Heinemann and Gray, 2024).

5.5.2. Commercial shipping

CentrePort in Wellington is the only major port in the Cook Strait which generates significant shipping traffic, with 459 ship visits in 2025 (MOT, 2026). The Cook Strait is also an important ferry route that connects the North and South Island from Wellington to Picton. Interislander and Bluebridge are the two ferry operators in the area, these ferries perform around 6,300 one-way sailings a year (Ministry of Transport, 2023). The Cook Strait is a natural choke point for both vessels and marine mammals due to how narrow the passage there is the risk of vessel collisions. The nearby Southern Taranaki Bight is a known feeding spot for blue whales; furthermore, both blue whales and humpbacks have been recording passing directly through the Cook Strait (Torres, 2013; Warren *et al.*, 2021b; Steel *et al.*, 2025). Areas with increased vessel traffic can result in more frequent vessel strike events with marine mammals, especially during whale migration periods (Mayaud *et al.*, 2022).

5.5.3. Recreational vessels

The Cook Strait is also a hotspot of recreational vessel activity. Frequent vessel activity has been shown to displace marine mammal species like Hector's dolphins (*Cephalorhynchus hectori*) from core habitat due to increased noise levels (Carome *et al.*, 2023). Recreational vessels have a cumulative effect on noise levels produced by anthropogenic activity resulting in behavioural changes (Hermannsen *et al.*, 2019; Pine *et al.*, 2021). Another major concern is the spread of Non-Indigenous Species (NIS) and biofouling, which has led to tight regulations around recreational vessel traffic in New Zealand (Dodgshun *et al.*, 2007; Georgiades and Kluza, 2017; Hilliam *et al.*, 2024).

5.5.4. Oil & Gas (O&G) activities

The Continental Shelf Act was passed in 1964, after which the New Zealand government began allocating offshore exploration licences (NZPM, 2021). The Māui gas field, which was discovered in 1969 and operational in 1979, made New Zealand self-sufficient in gas (NZPM, 2021). Currently, all offshore O&G activity in New Zealand take place in the Taranaki Basin area, in the west of the North Island.

5.5.5. Deep-sea mining

The South Taranaki Bight near the operational area was a potential target for deep sea mining due to iron sand deposits, this project has faced repeated legal and environmental pushback (Williamson, 2026). In 2026 the South Taranaki Bight seabed mining proposal was declined under the New Zealand Fast Track process. Outside the operational area in neighbouring Chatham Rise there was a Minerals Mining Permit issued in 2013 for phosphate nodule extraction from the seafloor (Kaikkonen *et al.*, 2025). A marine consent application to carry out mining of these phosphorite nodules was denied in 2015, part of the reason being the potential adverse effects on biological communities (NZ EPA, 2015). Deep-sea mining has been noted as a major threat to benthic ecosystems for multiple reasons. Three major impacts associated with deep-sea mining are: sediment plumes clogging respiratory and olfactory surfaces; changing light scattering properties in light limited ecosystems; and noise production (Drazen *et al.*, 2020; Boschen-Rose *et al.*, 2021). As the technology for large scale operations has not yet materialised, it is impossible to predict the exact magnitude and interactions of negative impacts produced by these activities in any ecosystem or organism (Christiansen *et al.*, 2020). At present there are no deep-sea mining operations in the proposed operational area.

6. POTENTIAL ENVIRONMENTAL EFFECTS & MITIGATION METHODS

Impacts potentially associated with both planned activities and unplanned events of the SUBTRANS seismic survey have been identified, described, and evaluated across marine mammal species and other ecological receptor groups. **Section 6.1** emphasises potential impacts from operations including scoping, mitigation and evaluating risk factors involved. **Section 6.2** discusses the results of these investigations and highlights the potential impact on environmental and biological considerations. **Section 6.3** summarises these findings.

The assessment methodology adheres to the principles outlined in the Guidelines for Ecological Impact Assessment in the UK and Ireland (CIEEM, 2018) to ensure a rigorous, transparent, and scientifically grounded evaluation. The approach combines a structured framework for assessing ecological effects with best practices for Environmental Impact Assessments (EIA), tailored to the requirements of the 2013 Code of Conduct (see **Section 1.2**).

6.1. Environmental Impact Assessment methodology

The Environmental Impact Assessment (EIA) methodology applied within this assessment was designed to provide a transparent and repeatable framework for evaluating potential impacts on marine mammal receptors, considering the effectiveness of mitigation measures, species occurrence, conservation status, and receptor sensitivity. The methodology comprised the following stages:

1. Scoping;
2. Identification of mitigation;
3. Evaluating residual risk across receptors:
 - i. Evaluating 'Likelihood' and severity of residual risk;
 - ii. Evaluating the population exposure;
 - iii. Valuation of receptors; and,
 - iv. Determining final residual risk score across receptors, and;
4. Interpretation and mitigation recommendations.

6.1.1. Scoping

The scoping phase is foundational in defining the scope of ecological receptors, impact pathways, and mitigation strategies for a seismic survey. This stage involves a structured approach to ensure that all potential environmental and ecological effects are systematically identified and appropriately addressed. The process begins by delineating the operational area which is established based on the spatial and temporal extent of potential impacts resulting from seismic activities. The operational area serves as a boundary to identify key ecological receptors, with a focus on marine mammals but also considering other receptors such as invertebrate, sea birds, and sea reptiles, with significant spatial and temporal overlap with the proposed survey. Although the broader assessment considers additional ecological receptors, the quantitative risk assessment framework described below was developed specifically for marine mammal receptors.

6.1.2. Mitigation

Mitigation protocols and procedures that are already prescribed by the 2013 Code of Conduct (see **Section 1.2**) and included in the survey protocols were identified

and described. These mitigation measures were incorporated into the assessment process, allowing residual risk to be evaluated following implementation of the prescribed controls.

6.1.3. Evaluating residual risks across receptors

The following sections describe the framework used to assess residual risk to marine mammal receptors at both the individual and population levels, taking account of species occurrence, exposure, and conservation status.

6.1.3.1. Likelihood and severity score

For each risk identified, the likelihood and severity of the impact is assessed across receptor groups. The likelihood score represented the chance of the impact occurring for each receptor at the individual level if it was present in the operational area during the survey period and is scored from 0 to 4, see **Table 5** for definitions. The severity score represented the level of impact to the receptor if it occurred and is scored from 0 to 4, see **Table 6** for definitions.

Score	Likelihood
4	Highly likely: The event is almost certain to occur
3	Likely: The event is expected to occur in most circumstances
2	Possible: The event could occur, though not expected
1	Unlikely: The event is not anticipated but could happen under rare circumstances
0	Impossible: The event will not occur under any scenario

Table 5: Likelihood score. Scores used to quantify risk to marine mammals from seismic and vessel activities. *Source:* OSC (2026).

Score	Severity
4	Severe: widespread or irreversible impacts. Includes significant long-term behavioural changes in marine mammals (e.g. abandonment of critical habitats, disruption of migration or breeding behaviours), physical injury (e.g. auditory damage), or ecosystem-wide disturbances
3	Significant: Notable impacts that may include temporary behavioural changes (e.g. displacement from foraging areas, avoidance of activity zones), minor physical disturbances (e.g. short-term stress or reduced health), or moderate habitat alteration
2	Moderate: Limited impacts, such as mild, short-term behavioural changes (e.g. temporary alertness or minor deviation from normal activity), reversible physical disturbance (e.g. momentary stress without lasting harm), or minimal habitat alteration
1	Minimal: Minor, localised impacts with no lasting behavioural changes or physical harm. May involve negligible disruption to habitat or activities (e.g. momentary alertness with immediate recovery)
0	None: No measurable impacts, either behavioural or physical. Complete absence of ecological or individual-level consequences

Table 6: Severity score. Scores used to quantify risk to marine mammals from seismic and vessel activities. *Source:* OSC (2026).

6.1.3.2. Population-exposure score

The population-exposure score for each marine mammal receptor accounts for variation in species occurrence and distribution, and therefore for differences in the potential for individuals of each species to overlap spatially and temporally with survey activities. Population exposure was assessed using multiple lines of evidence, including available published and publicly accessible information on marine mammal occurrence, spatial distribution models for New Zealand cetaceans (Stephenson *et al.*, 2020), and species-specific information on distribution and habitat use.

Stephenson *et al.* (2020) used a combination of opportunistic sightings and data from dedicated surveys to develop spatial models of cetacean distribution within New Zealand's Exclusive Economic Zone (EEZ). The dataset incorporated historical and contemporary observations from several sources, while environmental predictors including sea-surface temperature, chlorophyll-*a* concentration, water depth, and bathymetric complexity were used to characterise spatial patterns in species occurrence. The modelling approaches included Boosted Regression Trees (BRT) and Random Effects Smoothing (RES), with RES applied to species for which relatively few sightings were available.

The BRT and RES outputs provide useful information on the relative spatial distribution of individual species and were therefore used to identify areas where occurrence may be comparatively more likely for each species. However, model outputs are normalised independently for each species and consequently cannot be interpreted as estimates of relative abundance or as directly comparable probabilities of occurrence among species. Accordingly, BRT and RES values were not converted directly into population-exposure scores.

Instead, population-exposure scores were assigned using a weight-of-evidence approach that considered the frequency and spatial distribution of available DOC sightings and strandings records, the degree of spatial overlap indicated by the Stephenson *et al.* (2020) models, and other available evidence of species distribution and habitat use within the area of biological relevance. Sightings and strandings records were interpreted cautiously because these data may reflect spatial and temporal variation in observation effort and detectability and were therefore not treated as direct measures of abundance. Similarly, the spatial models were used to inform relative distribution within species rather than comparisons of occurrence among species.

Population exposure was classified on an ordinal scale from 0 (no credible exposure) to 10 (very high exposure), as defined in **Table 7**. Where evidence from different sources was inconsistent or limited, the score was assigned precautionarily, taking account of the quality and quantity of available information. This approach allows species for which spatial modelling was unavailable, including pinnipeds and some cetaceans, to be evaluated within the same framework without assigning exposure values solely on the basis of model availability.

Exposure score	Population exposure	Evidence supporting assignment
10	Very high	Regular and widespread occurrence within the area of biological relevance, supported by extensive records and strong spatial/distributional evidence of recurrent overlap with survey activities.
9	Very high	Regular occurrence and substantial spatial overlap, supported by numerous records and/or strong distributional evidence.
8	High	Frequent occurrence and substantial potential overlap, supported by multiple records and distributional evidence.
7	High	Regular occurrence is supported, although records or expected spatial overlap are less extensive.
6	Moderate	Confirmed and recurrent occurrence, with moderate potential for spatial and temporal overlap.
5	Moderate	Confirmed occurrence, but available evidence indicates intermittent and/or spatially restricted overlap.
4	Low	Occurrence is documented or well supported, but records are sparse and/or expected overlap is limited.
3	Low	Occurrence is considered plausible and supported by limited evidence but is expected to be infrequent.
2	Very low	Rare occurrence is documented or otherwise supported, with very limited expected overlap.
1	Very low	Occurrence is possible but considered exceptional within the area of biological relevance.
0	None	No credible evidence of spatial or temporal overlap with the assessed activity.

Table 7: Population exposure score. Ordinal scores used to characterise the potential for marine mammal populations to overlap spatially and temporally with survey activities. Scores are assigned using a weight-of-evidence assessment incorporating available evidence of species occurrence, species-specific spatial distribution information (including Stephenson *et al.* (2020), where available), and other relevant evidence of distribution and habitat use. Spatial-model outputs and opportunistic records are used as complementary lines of evidence and are not interpreted as directly comparable estimates of abundance or occurrence among species. *Source:* OSC (2026).

6.1.3.3. Valuation of receptors

Valuation of marine mammal receptors accounts for species conservation status when calculating residual risk across receptors. Conservation status was based primarily on the most recent assessment under the New Zealand Threat Classification System (NZTCS; (Lundquist *et al.*, 2025)), which supersedes the previous assessment by Baker *et al.* (2019). The NZTCS is considered the primary basis for receptor valuation because the assessment relates specifically to marine mammal populations occurring within Aotearoa New Zealand waters.

The NZTCS assessment incorporates information on population size, distribution and expected population trend when assigning conservation status. Population trend was therefore not scored separately in the present assessment, as doing so could result in the same component of conservation risk being represented more than once within the receptor valuation. Instead, each resident species was

assigned a valuation score directly from its current NZTCS conservation status, as shown in **Table 8**.

Species classified by the NZTCS as Non-Resident Native – Migrant or Non-resident Native – Vagrant require separate consideration because these categories primarily describe their residency status in New Zealand rather than their extinction risk. For these taxa, the IUCN Red List status reported by (Lundquist *et al.*, 2025) was used to inform the valuation score. Where the NZTCS assessment lists more than one IUCN classification, the classification applicable to the taxon or population most relevant to New Zealand waters was used where this could be determined. Data Deficient taxa were assigned an intermediate precautionary valuation because insufficient demographic information is available to determine their extinction risk reliably.

Valuation scores range from 0 to 10, with higher values representing receptors of greater conservation concern. Valuation modifies the residual-risk calculation at the population level and does not imply that an individual animal of a species with higher conservation status is intrinsically more susceptible to a particular impact.

Valuation score	NZTCS conservation status – resident native taxa	IUCN status – Non-resident Native taxa
10	Threatened – Nationally Critical	Critically Endangered
9	Threatened – Nationally Endangered	—
8	Threatened – Nationally Vulnerable	Endangered
7	Threatened – Nationally Increasing	—
6	At Risk – Declining	Vulnerable
5	Data Deficient	Data Deficient
4	At Risk – Uncommon	Near Threatened
3	—	—
2	Not Threatened	Least Concern
1	—	—
0	—	—

Table 8: Valuation of marine mammal receptors . Valuation scores for resident native taxa are based on conservation status under the New Zealand Threat Classification System (NZTCS; (Lundquist *et al.*, 2025)). For taxa classified by the NZTCS as Non-resident Native – Migrant or Non-resident Native – Vagrant, IUCN Red List status reported by (Lundquist *et al.*, 2025) is used to inform receptor valuation because Migrant and Vagrant describe residency rather than extinction risk. Higher scores represent greater conservation concern. Source: OSC (2026), based on (Lundquist *et al.*, 2025).

For each species the highest scoring conservation status and its population trend score were averaged to provide a single value for the risk matrix calculation. It is important to note that an increased residual-risk score from a high valuation does not mean that the actual risk to the species increases at the individual level but that a greater risk is assumed at the population level due to conservation status.

6.1.3.4. Residual risk matrix

The final residual-risk score for each receptor and impact pathway was calculated using the likelihood, severity, population-exposure and valuation scores described in **Sections 6.1.3.1–6.1.3.3**.

First, likelihood and severity scores were averaged to provide the initial impact-risk score:

$$\text{Initial impact – risk Score} = \frac{\text{Likelihood Score} + \text{Severity Score}}{2}$$

The initial impact-risk score was then scaled according to the population-exposure score:

$$\text{Exposure – adjusted Risk Score} = \frac{\text{Risk Score} \times \text{Population Exposure Score}}{10}$$

Population exposure is an ordinal score assigned using the weight-of-evidence approach described in **Section 6.1.3.2**. A score of 10 therefore leaves the initial impact-risk score unchanged, whereas progressively lower exposure scores reduce the residual-risk score in proportion to the assessed potential for the receptor to overlap spatially and temporally with survey activities.

Finally, the exposure-adjusted risk score was scaled according to receptor valuation:

$$\text{Residual – Risk Score} = \frac{\text{Scaled Risk Score} \times \text{Valuation Score}}{5}$$

A valuation score of 5 is neutral and leaves the exposure-adjusted risk score unchanged. If the species has a valuation score greater than 5, the residual-risk score is increased to reflect greater conservation concern; if the valuation score is below 5, the residual-risk score is reduced accordingly. Valuation therefore modifies the population-level significance assigned to the assessed impact rather than the likelihood or severity of an effect on an individual animal.

The resulting residual-risk scores were assigned to the risk categories presented in **Table 9**.

Residual risk score	Description
5.50–8.00	Severe: Extremely high residual risk that requires additional targeted mitigation solutions
3.50–5.49	High: Risk is elevated and requires further mitigation action or management is warranted
2.50–3.49	Moderate: Risk of residual effect is moderate. Additional mitigation consideration may be necessary or current mitigation management justified
1.50–2.49	Minor: Risk of residual effect is low and predicted to disappear rapidly. No further mitigation consideration is required.
0.50–1.49	Negligible: Risk of residual effect is extremely low and does not require further consideration
0.00–0.49	None: No effect

Table 9: Residual-risk matrix . Residual-risk categories assigned to the final scores calculated from likelihood, severity, population exposure and receptor valuation. *Source:* OSC (2026).

The framework provides a transparent and repeatable mechanism for comparing residual risks across marine mammal species while accounting for differences in species occurrence, conservation status, and sensitivity to survey-related activities. The resulting residual risk scores are intended to inform professional judgement and support the identification of proportionate mitigation measures rather than represent absolute measures of ecological consequence.

6.2. Results

Results of the impact assessment are presented in this section, evaluating the scope of potential risks identified and how they can be applied to marine mammals and other receptors.

6.2.1. Scoping

The principal potential impacts associated with the proposed offshore seismic survey arise from the generation of high-intensity impulsive underwater sound and the presence of survey vessels within the operational area. Among these, underwater noise represents the primary mechanism through which marine mammals may be affected and therefore forms the principal focus of the acoustic impact assessment presented in this section.

The nature and magnitude of these effects depend upon several interacting factors, including source characteristics, received sound levels, exposure duration, hearing sensitivity of the affected species, behavioural context and the environmental conditions governing sound propagation. Consequently, assessment of potential impacts cannot rely solely upon source output specifications but requires evaluation of the spatial distribution of received sound levels throughout the operational area.

To address this requirement, a site-specific underwater sound propagation assessment was undertaken using numerical transmission-loss modelling configured with representative environmental conditions for Cook Strait. The modelling incorporated regional bathymetry, water-column properties, seabed characteristics and representative source locations spanning the expected range of operational water depths. The resulting propagation predictions provide the quantitative basis for evaluating the potential for physical injury, auditory impairment, behavioural disturbance and acoustic masking considered in the

following sections. Full details of the modelling methodology and results are provided in **APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING**.

6.2.1.1. *Area of biological relevance*

The area of biological relevance considered in this assessment encompasses the proposed SUBTRANS seismic survey region within central Cook Strait and the southern Hikurangi Margin, together with the surrounding marine environment potentially influenced by survey-related activities. It includes environments ranging from the shallow continental shelf surrounding Cook Strait to deep offshore basins exceeding 2,000 m water depth and therefore encompasses the range of environmental conditions relevant to the assessment of potential effects on marine mammal receptors.

For the purposes of this MMIA, the area of biological relevance is distinguished from the *operational area* as defined by the 2013 Code. The operational area comprises the geographical area within which acoustic source activation may occur, including seismic data acquisition, acoustic source testing and soft-start initiation, subject to applicable restrictions on source activation. The area of biological relevance used in this assessment is broader and is intended to encompass the spatial extent over which marine mammal receptors and potential survey-related effects are considered, including effects associated with underwater sound propagation and vessel operations.

Given the pronounced bathymetric variability that characterises Cook Strait and the southern Hikurangi Margin, the spatial extent of underwater sound propagation cannot be represented by a simple radial distance from the acoustic source. Site-specific numerical transmission-loss modelling was therefore used to investigate propagation under representative shallow- and deep-water conditions, accounting for regional bathymetry, water-column properties and seabed characteristics (**APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING**). The modelling informs the assessment of potential acoustic exposure within the area of biological relevance.

6.2.1.2. *Marine mammal receptors*

Of the marine mammal taxa recognised as occurring in New Zealand waters by (Lundquist *et al.*, 2025), 26 were identified from the available evidence as potentially occurring within the area of biological relevance and were therefore scoped into the assessment (**Table 10**). The assessment drew on the spatial distribution models of Stephenson *et al.* (2020), together with species-specific published literature and other publicly available information on distribution and occurrence in New Zealand waters. Where spatial modelling was unavailable or insufficient to establish potential presence, published records and species-specific distribution information were used to determine whether occurrence within the area of biological relevance was plausible.

Species were scoped out only where the available evidence indicated that their known distribution did not overlap, or was not reasonably expected to overlap, with the area of biological relevance (**Table 11**). The scoping exercise was precautionary: where credible published evidence supported potential occurrence, the species was retained for assessment rather than excluded on the basis of limited information.



The assessment did not have access to the underlying DOC marine mammal sightings and strandings database. Consequently, the frequency of records within that database was not used as a quantitative criterion for inclusion or exclusion. Where additional occurrence information identified during review indicates that a species previously scoped out has documented records within the area of biological relevance, its inclusion has been reconsidered on a precautionary basis.



Taxonomic group	Common Name	Binomial Name	Species of Concern	Vessel risk
Baleen whales	Dwarf minke whale	<i>Balaenoptera acutorostrata subsp.</i>	Yes	Yes
	Sei whale	<i>Balaenoptera borealis</i>	Yes	Yes
	Antarctic Blue whale	<i>Balaenoptera musculus intermedia</i>	Yes	Yes
	Pygmy blue whale	<i>B. musculus brevicauda</i>	Yes	Yes
	Fin whale	<i>Balaenoptera physalus</i>	Yes	Yes
	Antarctic minke whale	<i>Balaenoptera bonaerensis</i>	Yes	Yes
	Pygmy right whale	<i>Caperea marginata</i>	Yes	Yes
	Southern right whale	<i>Eubalaena australis</i>	Yes	Yes
	Humpback whale	<i>Megaptera novaeangliae</i>	No	Yes
Toothed whales	Arnoux's beaked whale	<i>Berardius arnuxii</i>	Yes	Yes
	Hector's dolphin	<i>Cephalorhynchus hectori</i>	Yes	Increased
	Māui's dolphin	<i>Cephalorhynchus hectori maui</i>	Yes	Increased
	Common dolphin	<i>Delphinus delphis</i>	No	Increased
	Long-finned pilot whale	<i>Globicephala melas</i>	No	Yes
	Pygmy sperm whale	<i>Kogia breviceps</i>	Yes	Yes
	Dusky dolphin	<i>Lagenorhynchus obscurus</i>	No	Yes
	Southern right-whale dolphin	<i>Lissodelphis peronii</i>	Yes	Yes
	Gray's beaked whale	<i>Mesoplodon grayi</i>	No	Yes
	Strap-toothed whale	<i>Mesoplodon layardii</i>	Yes	Yes
	Killer whale	<i>Orcinus orca</i>	Yes	Increased
	Sperm whale	<i>Physeter macrocephalus</i>	Yes	Yes
	Striped dolphin.	<i>Stenella coeruleoalba</i>	Yes	Yes
	Shepherd's beaked whale	<i>Tasmacetus shepherdi</i>	Yes	Yes
	Bottlenose dolphin	<i>Tursiops truncatus</i>	Yes	Increased
	Goose-beaked whale	<i>Ziphius cavirostris</i>	Yes	Yes
Pinnipeds	New Zealand fur seal	<i>Arctocephalus forsteri</i>	No	Yes

Table 10: Marine mammal species considered potentially present within the area of biological relevance and scoped into the impact assessment for the Subduction to Strike Slip Transition (SUBTRANS) seismic survey Source: OSC (2026).

Taxonomic group	Common name	Binomial name
Baleen whales	Bryde's whale	<i>Balaenoptera edeni</i>
Toothed whales	Short-finned pilot whale	<i>Globicephala macrorhynchus</i>
	Risso's dolphin	<i>Grampus griseus</i>
	Southern bottlenose whale	<i>Hyperoodon planifrons</i>
	Dwarf sperm whale	<i>Kogia sima</i>
	Hector's beaked whale	<i>Mesoplodon hectori</i>
	Spade-toothed whale	<i>Mesoplodon traversii</i>
Pinnipeds	False killer whale	<i>Pseudorca crassidens</i>
	Southern elephant seal	<i>Mirounga leonina</i>
	New Zealand sea lion	<i>Phocarcos hookeri</i>

Table 11: Marine mammal species scoped out of the impact assessment based on the publicly available evidence of their distribution relative to the area of biological relevance. Source: OSC (2026).

6.2.1.3. Other receptors

Other receptors considered in the impact assessment were sea birds, elasmobranchs, marine reptiles, fish, invertebrates, and zooplankton, all of which may be affected by underwater noise generated by seismic surveys. Seismic airgun pulses have the potential to cause physiological injury, auditory impairment, behavioural changes, and ecosystem-level disruptions. The risk was considered broadly across these taxonomic groups (not to species level). At the scoping stage, risk across these receptors due to increased vessel presence was considered negligible and therefore scoped out.

6.2.1.4. Mitigation

The 2013 Code of Conduct incorporates built in mitigation measures designed to reduce both the physical and behavioural risks posed by seismic surveys. For the SUBTRANS seismic survey, these measures are implemented through rigorous protocols (see **APPENDIX A – MITIGATION PROTOCOL**) that are integrated throughout the planning, execution and post-survey phases.

For Level 1 seismic activities, a minimum of two qualified MMOs and two qualified PAMOs must always be on board. Pre-start observations will be undertaken, and no [acoustic source activation](#) is permitted during daylight unless at least one qualified MMO has conducted continuous visual monitoring (using both binoculars and the naked eye) for a minimum of 30 minutes and the PAM system has been operational for at least 30 minutes without detecting vocalisations. These requirements reduce the likelihood of operations commencing when marine mammals are detected within the relevant mitigation zones, thereby reducing the potential for close-range exposure to high-intensity sound.

An important aspect of the mitigation strategy is the 'soft start' or 'ramp-up' procedure, whereby the acoustic source's intensity is gradually increased over 20–40 minutes. This gradual increase allows marine mammals to detect the initial low-level sound and move away from the source before full operational levels are reached, helping to reduce the likelihood of both physical effects (such as auditory threshold shifts) and behavioural disturbances, including abrupt startle responses

from deep diving species. An exception is made when a brief pause (of less than 10 minutes) in full-power firing occurs and no marine mammals are detected in the [exclusion zone](#); in such cases, the source may be reactivated at full power, as the short duration minimises risk.

Furthermore, strict shutdown protocols are in place. If marine mammals are detected within predefined, species-specific mitigation zones the acoustic source must be immediately shut down. This rapid response minimises the duration of exposure to potentially harmful noise levels, thus reducing both the risk of physical injury (such as tissue trauma) and behavioural impacts (such as prolonged disruption of natural activities).

When arriving at a new location within the operational area for the first time, additional requirements apply to the initial acoustic source activation during night-time or poor sighting conditions. Initial activation may proceed where MMOs have undertaken observations within 20 nautical miles of the planned start-up position for at least the preceding two hours of good sighting conditions and no marine mammals have been detected. Where fewer than two hours of good sighting conditions have occurred, activation may only proceed where PAM monitoring and visual monitoring by two MMOs have both been conducted during the two hours immediately preceding the proposed operation. During this period, no Species of Concern may have been detected within the relevant mitigation zones; no New Zealand fur seals may have been sighted within the relevant mitigation zone during the 10 minutes immediately preceding activation; and no other marine mammals may have been sighted or acoustically detected within the relevant mitigation zones during the 30 minutes immediately preceding activation (DOC, 2013). Full requirements for pre-start observations and initial source activation are provided in **APPENDIX A – MITIGATION PROTOCOL**.

The Code also differentiates mitigation procedures based on the classification of marine mammals. Specific measures are tailored for:

- Species of concern with calves;
- Species of concern;
- Other marine mammals; and,
- New Zealand fur seals.

This categorisation ensures that the most vulnerable groups receive enhanced protection. For instance, stricter criteria for activation delays and larger exclusion zones are applied to species of concern and their calves to prevent any disruption that might affect reproduction or survival (see **APPENDIX C - SPECIES OF CONCERN** for full details).

Finally, the integration of both visual monitoring by trained MMOs and acoustic detection via PAM is critical. PAM enhances detection capabilities under poor visibility conditions and is effective in identifying deep-diving cetaceans that might not surface frequently. This dual-monitoring approach reduces uncertainty, ensuring that mitigation actions are taken promptly to minimise both physical harm and behavioural disruption.

In summary, the mitigation measures reduce the risk of physical injury and adverse behavioural responses in marine mammals during seismic survey operations. All these mitigation activities were considered when assessing the risk to marine

mammals, with the evaluation accounting for the residual risk – that is, the remaining risk after the mitigation measures have been implemented.

6.2.2. Impact assessment – marine mammals

In this section results of the impact assessment across marine mammal species are presented.

6.2.2.1. Increased vessel activity

Increased vessel activity in marine environments poses significant risk to marine mammals, primarily due to its effect on behaviour and habitat displacement, through the physical presence of the vessel or by associated increase in noise levels (Lusseau and Bejder, 2007; Anderwald *et al.*, 2013; Erbe *et al.*, 2019).

Furthermore, vessel movements increase risk of mortality due to vessel collisions, particularly in areas where vessel traffic intersects with the habitats of highly mobile or slow-moving marine species, such as baleen whales (Laist *et al.*, 2001; Schoeman *et al.*, 2020). The cumulative effects of these disturbances result in increased vessel presence being an important threat for consideration within the MMIA.

6.2.2.2. Collision risk

The impacts of collision risk range from stress to physical injury and mortality, with chronic exposure potentially leading to broader population-level consequences (Schoeman *et al.*, 2020). Large whale species that spend a large proportion of time in waters close to the surface are considered the most vulnerable marine mammals to vessel collision, especially in habitat that overlaps with busy shipping lanes (Frantzis *et al.*, 2019; Winkler *et al.*, 2020). Limiting vessel speed has been identified as an effective approach to reducing risk (Vanderlaan and Taggart, 2007; Conn and Silber, 2013).

Globally, vessel strikes are a cause of mortality for baleen whale species, including the critically endangered North Atlantic right whale (Mullen *et al.*, 2013). Injuries sustained during collisions can range from deep lacerations to blunt force trauma, frequently resulting in mortality. High incidence of non-lethal injuries within a population can have lasting population effects, including reduced reproductive success and increased vulnerability to predation and disease (Schoeman *et al.*, 2020).

In New Zealand, large baleen whales, including southern right whales (*Eubalaena australis*), are vulnerable to vessel collision, during their migratory and calving periods in areas like the Auckland Islands and the Cook Strait, where shipping lanes are heavily used (Torres *et al.*, 2013). Blue whales are vulnerable to ship strikes in areas where their distribution overlaps with shipping activity, particularly in South Taranaki (Barlow, 2022).

Vessel strikes have been documented in New Zealand waters across a range of cetacean species, including both large whales and smaller odontocetes (Martinez and Stockin, 2013). The IWC Ship Strike Database includes 38 vessel-strike records associated with New Zealand, of which 26 were classified as definite, nine as probable and three as possible (Winkler *et al.*, 2020). Vessel-strike mortality can

be locally significant, while recorded incidents are likely to underestimate true occurrence because collisions may go unnoticed or unreported and carcasses may not be recovered (Martinez and Stockin, 2013; Constantine *et al.*, 2015; Winkler *et al.*, 2020).

Constantine *et al.* (2015) described stakeholder engagement in the Hauraki Gulf to identify possible mitigation measures, with speed restrictions considered as the most feasible option. A voluntary speed reduction to 10 knots (18.5 kmh^{-1}) was implemented by the shipping industry in response.

Toothed whales also face distinct risks from vessel collision. Many species, including dolphins, exhibit attraction towards vessels, often interacting with vessels (*e.g.* bow riding) which can lead to close interactions and increased collision risks (Hawkins and Gartside, 2009) as seen with common dolphin in New Zealand waters (Martinez and Stockin, 2013). When collisions with vessels occur, they often result in severe injuries for toothed whales, including blunt trauma and propeller wounds (Van Waerebeek *et al.*, 2007). The risk is generally considered less than baleen whales due to their potential for evasive movement, but habituation may increase risk (Van Waerebeek *et al.*, 2007). Large deep-diving species such as sperm whales are also vulnerable, particularly in areas where shipping lanes intersect with key habitats (Di-Meglio *et al.*, 2018).

Pinnipeds are at risk of vessel collision in coastal regions where vessel traffic is concentrated (Schoeman *et al.*, 2020). These animals often use haul-out sites near heavily trafficked areas, making them susceptible to vessel strikes. Juvenile pinnipeds are especially vulnerable as they may lack experience needed to avoid fast-moving vessels during foraging excursions (Olson *et al.*, 2021). Similarly to toothed whale species, when a vessel collision occurs, it typically results in severe injuries or mortality for pinnipeds.

Following application of the revised population-exposure and receptor-valuation framework, residual collision risk varies among species according to both their expected occurrence within the area of biological relevance and their current conservation status (**Table 12**). Residual risk was assessed as High for Hector's dolphin and killer whale, Moderate for humpback whale and sperm whale, Minor for Antarctic blue whale, pygmy blue whale, southern right whale and bottlenose dolphin, and Negligible or None for the remaining receptors. These results reflect population-level prioritisation within the residual-risk framework and do not indicate that collision is likely to occur; the underlying likelihood of collision remains assessed as Unlikely or Possible, depending on the receptor.

Additional mitigation measures further reduce the likelihood of vessel collision. Dedicated Marine Mammal Observers (MMOs) will monitor the relevant mitigation zones during survey activities, while vessel operations will be conducted in accordance with applicable survey procedures and marine-mammal mitigation requirements. The combination of low operational survey speeds, dedicated observers and established mitigation procedures reduces the residual collision risk for marine mammal species considered within the assessment (**Table 12**).



Species		Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
Antarctic Blue whale		10	3	2	4	1.80	Minor
Antarctic minke whale		4	2	2	4	0.48	None
Arnoux's beaked whale		5	3	1	4	0.75	Negligible
Bottlenose dolphin		8	6	1	4	2.40	Minor
Common dolphin		2	8	1	4	0.80	Negligible
Dusky dolphin		2	7	1	4	0.70	Negligible
Dwarf minke whale		5	2	2	4	0.60	Negligible
Fin whale		6	4	2	4	1.44	Negligible
Goose-beaked whale		4	4	1	4	0.80	Negligible
Gray's beaked whale		2	4	1	4	0.40	None
Hector's dolphin		8	9	1	4	3.60	High
Humpback whale		8	6	2	4	2.88	Moderate
Killer whale		10	6	2	4	3.60	High
Long-finned pilot whale		2	5	1	4	0.50	Negligible



Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
Māui dolphin	10	1	1	4	0.50	Negligible
New Zealand fur seal	2	8	1	4	0.80	Negligible
Pygmy blue whale	8	4	2	4	1.92	Minor
Pygmy right whale	5	3	2	4	0.90	Negligible
Pygmy sperm whale	4	3	1	4	0.60	Negligible
Sei whale	8	3	2	4	1.44	Negligible
Shepherd's beaked whale	5	3	1	4	0.75	Negligible
Southern right whale	7	5	2	4	2.10	Minor
Southern right-whale dolphin	4	3	1	4	0.60	Negligible
Sperm whale	6	7	2	4	2.52	Moderate
Strap-toothed whale	5	3	1	4	0.75	Negligible
Striped dolphin	5	3	1	4	0.75	Negligible

Table 12: Residual risk of vessel collision. Residual-risk category is based on the final residual-risk score calculated from the likelihood, severity, population-exposure and valuation scores for each species. *Source:* OSC (2026).

6.2.2.3. Behavioural disturbance

Marine mammals exhibit complex behavioural responses to vessel presence, often altering their natural activities that can have significant ecological consequences (Bejder *et al.*, 2006; Williams *et al.*, 2006; Christiansen *et al.*, 2013). Disturbances are caused by a range of vessel types, sizes, and activities with most research focusing on the impact of ecotourism vessels (Parsons, 2012; Machernis *et al.*, 2018).

Documented responses for both baleen and toothed whales include short-term behavioural change and avoidance of key habitats (Lusseau, 2004). For example, bottlenose dolphins exhibit changes in surface behaviour, including increased swimming speeds and altered dive patterns (Nowacek *et al.*, 2001). In sperm whales, the presence of tourism vessels has been linked to disruptions in deep-diving foraging behaviour (Oliveira *et al.*, 2022). For humpback whales, ecotourism in Maui, Hawaii, USA, has been shown to significantly alter humpback whale swim speed, respiration rate, path directness and dive times, with these linked to greater energetic expenditure (Currie *et al.*, 2021). Fin whales and blue whales have been shown to be disturbed by vessel traffic, altering their swimming behaviour and exhibiting evasive behaviour (Szesciorka *et al.*, 2019; Santos-Carvalho *et al.*, 2021).

The impact of vessel activity on pinnipeds is primarily related to disturbances during haul-out or breeding activities. Vessel traffic near these areas often results in behavioural changes such as flushing into the water, which can increase energy expenditure and reduce time available for rest and thermoregulation (Jansen *et al.*, 2010). Pinniped responses and ecological effects in open water are less well understood.

For the proposed survey, the severity of behavioural disturbance associated with vessel presence (**Table 13**) was assessed as Minimal (score 1) for all marine mammal groups because any behavioural responses are expected to be localised, temporary and reversible following vessel passage. Survey operations will be conducted using a single seismic vessel operating at relatively low acquisition speeds (approximately 3.5 knots; 6.5 km h⁻¹) along predefined survey transects, thereby limiting both the spatial extent and duration of vessel-related disturbance. The likelihood of behavioural responses to vessel presence was considered Likely (score 3) for all marine mammal groups, reflecting the expectation that some individuals encountered within the area of biological relevance may temporarily modify their behaviour in response to the approaching vessel (**Table 13**). Such responses may include changes in swimming speed or direction, dive behaviour, surfacing patterns or short-term avoidance. However, these effects are expected to be temporary and reversible and are not anticipated to result in prolonged disruption of biologically important behaviours at the individual level.

Following application of the revised population-exposure and receptor-valuation framework, residual behavioural-disturbance risk varies among species according to their expected occurrence within the area of biological relevance and their conservation status. Species-specific residual-risk scores are presented in **Table 13**.



Species		Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
Antarctic Blue whale		10	3	3	1	1.20	Negligible
Antarctic Minke whale		4	2	3	1	0.32	None
Arnoux's beaked whale		5	3	3	1	0.60	Negligible
Bottlenose dolphin		8	6	3	1	1.92	Minor
Common dolphin		2	8	3	1	0.64	Negligible
Dusky dolphin		2	7	3	1	0.56	Negligible
Dwarf minke whale		5	2	3	1	0.40	None
Fin whale		6	4	3	1	0.96	Negligible
Goose-beaked whale		4	4	3	1	0.64	Negligible
Gray's beaked whale		2	4	3	1	0.32	None
Hector's dolphin		8	9	3	1	2.88	Moderate
Humpback whale		8	6	3	1	1.92	Minor
Killer whale		10	6	3	1	2.40	Minor
Long-finned pilot whale		2	5	3	1	0.40	None
Māui dolphin		10	1	3	1	0.40	None



Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
New Zealand fur seal	2	8	3	1	0.64	Negligible
Pygmy blue whale	8	4	3	1	1.28	Negligible
Pygmy right whale	5	3	3	1	0.32	Negligible
Pygmy sperm whale	4	3	3	1	0.48	None
Sei whale	8	3	3	1	0.96	Negligible
Shepherd's beaked whale	5	3	3	1	0.60	Negligible
Southern right whale	7	5	3	1	1.40	Negligible
Southern right-whale dolphin	4	3	3	1	0.48	None
Sperm whale	6	7	3	1	1.68	Minor
Strap-toothed whale	5	3	3	1	0.60	Negligible
Striped dolphin	5	3	3	1	0.60	Negligible

Table 13: Residual risk of behavioural disturbance from vessel presence. Residual-risk category is based on the final residual-risk score calculated from the likelihood, severity, population-exposure and valuation scores for each species. *Source:* OSC (2026).

6.2.2.4. Displacement from habitat due to vessel presence

Habitat displacement due to increased vessel presence and associated vessel noise is considered a significant impact for marine mammal species (Anderwald *et al.*, 2013). Baleen whales are vulnerable to displacement from vessel activity as they often inhabit coastal and offshore waters that overlap busy shipping lanes (Pirodda *et al.*, 2019). Increase in shipping can impact on baleen whale foraging (Blair *et al.*, 2016) and may also effect migratory routes and associated energy budgets (Braithwaite *et al.*, 2015; Johnston and Painter, 2024).

Displacement of toothed whales often occurs in regions of intensive vessel traffic, especially near ports or areas with concentrated fishing activity. For example, bottlenose dolphins in coastal zones have been observed to avoid areas with heavy boat traffic, leading to habitat fragmentation and reduced access to critical resources (Pirodda *et al.*, 2015). Vessel size has less of a direct influence compared to vessel behaviour; smaller vessels that rapidly change direction or operate erratically can cause immediate avoidance, even over shorter distances (Bejder *et al.*, 2006). For all cetacean species, displacement from critical habitats such as calving or feeding areas, even in the short-term, can lead to energetic stress and reduced reproductive success (Pirodda *et al.*, 2014).

Pinnipeds also experience displacement risks that vary with habitat use (Anderwald *et al.*, 2013). Such disturbances are most commonly associated with smaller vessels, such as those used for ecotourism or recreational purposes, which are more likely to enter nearshore habitats close to haul-out sites (Tadeo *et al.*, 2021).

For the proposed survey, the likelihood of displacement from habitat due to vessel presence was assessed as Possible (score 2) and the severity as Minimal (score 1) for all marine mammal receptors (**Table 14**). The survey will be undertaken by a single vessel operating at relatively low acquisition speeds (approximately 3.5 knots; 6.5 km h⁻¹) along predefined survey transects, thereby limiting the spatial extent and duration of vessel-related disturbance at any given location. Any displacement response associated specifically with vessel presence is therefore expected to be localised and temporary, with animals able to resume use of affected habitat following vessel passage. Following application of the revised population-exposure and receptor-valuation framework, residual displacement risk varies among species according to their expected occurrence within the area of biological relevance and their conservation status. Species-specific residual-risk scores are presented in **Table 14**.

Residual displacement risk was Minor for Hector's dolphin and killer whale, Negligible for eight receptors, and None for all remaining species. The higher residual-risk scores for Hector's dolphin and killer whale reflect their comparatively high receptor valuation and/or assessed population exposure rather than an expectation of prolonged habitat displacement.



Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk Category
Antarctic Blue whale	10	3	2	1	0.90	Negligible
Antarctic Minke whale	4	2	2	1	0.24	None
Arnoux's beaked whale	5	3	2	1	0.45	None
Bottlenose dolphin	8	6	2	1	1.44	Negligible
Common dolphin	2	8	2	1	0.48	None
Dusky dolphin	2	7	2	1	0.42	None
Dwarf minke whale	5	2	2	1	0.30	None
Fin whale	6	4	2	1	0.72	Negligible
Goose-beaked whale	4	4	2	1	0.48	None
Gray's beaked whale	2	4	2	1	0.24	None
Hector's dolphin	8	9	2	1	2.16	Minor
Humpback whale	8	6	2	1	1.44	Negligible
Killer whale	10	6	2	1	1.80	Minor
Long-finned pilot whale	2	5	2	1	0.30	None



Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk Category
Māui dolphin	10	1	2	1	0.30	None
New Zealand fur seal	2	8	2	1	0.48	None
Pygmy blue whale	8	4	2	1	0.96	Negligible
Pygmy right whale	5	3	2	1	0.45	None
Pygmy sperm whale	4	3	2	1	0.36	None
Sei whale	8	3	2	1	0.72	Negligible
Shepherd's beaked whale	5	3	2	1	0.45	None
Southern right whale	7	5	2	1	1.05	Negligible
Southern right-whale dolphin	4	3	2	1	0.36	None
Sperm whale	6	7	2	1	1.26	Negligible
Strap-toothed whale	5	3	2	1	0.45	None
Striped dolphin	5	3	2	1	0.45	None

Table 14: Residual risk of displacement from habitat due to vessel presence. Residual-risk category is based on the final residual-risk score calculated from the likelihood, severity, population-exposure and valuation scores for each species. *Source:* OSC (2026).

6.2.2.5. Masking from underwater radiated noise from vessel

Research suggests that the auditory masking caused by shipping noise may impair the detection of biologically relevant sounds, such as the calls of conspecifics or the acoustic cues of predators (Southall *et al.*, 2007; Erbe *et al.*, 2016). Baleen whales rely on low-frequency vocalisations for communication with some species vocalising within ranges that overlap significantly with noise produced by vessels (Hildebrand, 2009). Masking, where biologically relevant sounds are obscured by anthropogenic noise, is a critical concern for baleen whales. This phenomenon is especially problematic in areas of high shipping density, such as major shipping lanes and port vicinities.

Studies indicate that vessel noise can interfere with the long-distance communication of species like the blue whale and fin whale, potentially disrupting reproductive behaviours that depend on low-frequency calls (Clark *et al.*, 2009). Chronic exposure to such noise has been associated with behavioural changes, including habitat displacement and altered calling rates (McKenna *et al.*, 2012; Erbe *et al.*, 2016). In the Hauraki Gulf, Putland *et al.* (2018) reported vessel noise significantly reduces the communication space of the Bryde's whale with losses of up to 87.4% during routine passages and up to 99% during close approaches.

Toothed whales utilise higher-frequency echolocation clicks and whistles for navigation, foraging, and social interaction. Although these frequencies are typically higher than the dominant frequencies of vessel noise, the broadband nature of ship noise can cause masking of the audible range of some odontocetes (Jensen *et al.*, 2009). The masking of echolocation clicks has been linked to reduced foraging efficiency (Dyndo *et al.*, 2015; Tennessen *et al.*, 2024). Additionally, changes in vocalisation patterns, such as increased whistle rates or shifts in frequency, have been documented in bottlenose dolphins in response to elevated background noise, which can lead to energetic costs (Holt *et al.*, 2009).

The impact of underwater radiated noise on pinnipeds is compounded by their relatively broad auditory sensitivity, which overlaps with the frequencies of many human-generated sounds (Götz *et al.*, 2009). In some cases, behavioural responses to noise, such as increased vigilance or avoidance of high-traffic areas, may reduce foraging success and energy reserves, particularly during energetically demanding life stages like lactation or moulting.

For the proposed survey, the likelihood of short-term auditory masking from underwater radiated noise generated by the survey vessel was assessed as Likely (score 3) for marine mammals occurring sufficiently close to the vessel, while severity was assessed as Minimal (score 1). Vessel-generated noise may temporarily reduce the detectability of biologically relevant acoustic signals where received noise levels overlap with species-specific hearing and communication frequencies. However, the survey will be undertaken by a single vessel operating at relatively low acquisition speeds (approximately 3.5 knots; 6.5 km h⁻¹) along predefined survey transects, such that exposure to vessel-generated noise at any particular location will be temporary rather than representative of a persistent stationary source. Accordingly, masking associated specifically with vessel URN is expected to be temporary and reversible as the vessel passes through the area. Following application of the revised population-exposure and receptor-valuation framework, residual masking risk from vessel URN varies among species according to their expected occurrence within the area of biological relevance and their conservation status. Species-specific residual-risk scores are presented in **Table 15**.



Species		Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
Antarctic Blue whale		10	3	3	1	1.20	Negligible
Antarctic whale	Minke	4	2	3	1	0.32	None
Arnoux's whale	beaked	5	3	3	1	0.60	Negligible
Bottlenose dolphin		8	6	3	1	1.92	Minor
Common dolphin		2	8	3	1	0.64	Negligible
Dusky dolphin		2	7	3	1	0.56	Negligible
Dwarf minke whale		5	2	3	1	0.40	None
Fin whale		6	4	3	1	0.96	Negligible
Goose-beaked whale		4	4	3	1	0.64	Negligible
Gray's beaked whale		2	4	3	1	0.32	None
Hector's dolphin		8	9	3	1	2.88	Moderate
Humpback whale		8	6	3	1	1.92	Minor
Killer whale		10	6	3	1	2.40	Minor
Long-finned whale	pilot	2	5	3	1	0.40	None



Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
Māui dolphin	10	1	3	1	0.40	None
New Zealand fur seal	2	8	3	1	0.64	Negligible
Pygmy blue whale	8	4	3	1	1.28	Negligible
Pygmy right whale	5	3	3	1	0.60	Negligible
Pygmy sperm whale	4	3	3	1	0.48	None
Sei whale	8	3	3	1	0.96	Negligible
Shepherd's beaked whale	5	3	3	1	0.60	Negligible
Southern right whale	7	5	3	1	1.40	Negligible
Southern right-whale dolphin	4	3	3	1	0.48	None
Sperm whale	6	7	3	1	1.68	Minor
Strap-toothed whale	5	3	3	1	0.60	Negligible
Striped dolphin	5	3	3	1	0.60	Negligible

Table 15: Residual risk of auditory masking from underwater radiated noise generated by the survey vessel. Residual-risk category is based on the final residual-risk score calculated from the likelihood, severity, population-exposure and valuation scores for each species. *Source:* OSC (2026).

6.2.2.6. Seismic noise

Seismic surveys in marine environments represent a potentially significant source of disturbance to marine mammals through the generation of high-intensity impulsive underwater sound. Depending on received sound levels, exposure duration and the hearing sensitivity of the exposed species, seismic noise may result in behavioural disturbance, auditory masking, temporary or permanent auditory threshold shifts and, under extreme exposure conditions, physical injury (Gordon *et al.*, 2003; Southall *et al.*, 2019). The magnitude and spatial extent of these effects depend both on source characteristics and on environmental factors controlling sound propagation, including bathymetry, water-column properties and seabed composition.

Sound transmission-loss modelling was undertaken to characterise regional propagation behaviour within the SUBTRANS study area and to support evaluation of received sound levels at the mitigation-zone boundaries specified under the 2013 Code of Conduct. The modelling used site-specific bathymetry, representative water-column and seabed properties, and a simplified low-frequency source spectrum. Two representative source locations were evaluated, corresponding to shallow coastal and deep offshore propagation environments. The resulting spatial and radial analyses demonstrate pronounced bathymetric and directional control of sound transmission within Cook Strait and the southern Hikurangi Margin (see **APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING**).

The regional propagation analyses were evaluated using a common 3,600-s assessment period to facilitate consistent comparison among source locations, propagation directions and frequency ranges. The resulting standardised SEL_{cum} fields therefore characterise relative spatial and directional propagation behaviour and are not interpreted as operational cumulative exposure from the planned sequence of discrete seismic shots. For direct comparison with the received-level criteria specified in Appendix 1 of the 2013 Code, receiver-specific levels at 200 m, 1 km and 1.5 km were evaluated separately using the corresponding 1-s reference exposure (Count = 1) and referenced to a representative broadband source SEL of 230.5 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$ @ 1 m for the specified 5,420 in³ G-Gun array.

Under this receiver-specific screening assessment, the highest received levels occurred for the deep-water broadband scenario and were approximately 163.8 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$ at 200 m, 153.0 dB at 1 km and 148.1 dB at 1.5 km. These values are respectively approximately 22.2 dB, 18.0 dB and 22.9 dB below the 2013 Code criteria of 186 dB at 200 m and 171 dB at 1 km and 1.5 km. Accordingly, the modelling does not indicate that expansion of the prescribed mitigation zones is required on the basis of the representative source conditions assessed.

These receiver-specific results should nevertheless be interpreted as a screening assessment rather than as a definitive prediction of operational exposure. The source representation uses a simplified spectral formulation and does not incorporate a fully characterised array-specific source signature, directivity or all operational source-depth effects. The regional modelling also demonstrates that propagation can remain strongly directional, particularly under deep-water conditions. These limitations are considered in the assessment of physical injury, auditory effects, masking and behavioural disturbance presented in the following sections, while the mitigation procedures prescribed under the 2013 Code remain applicable throughout seismic operations.

6.2.2.7. Physical injury (non-auditory)

Physical injury other than auditory damage (see **Section 6.2.2.8**) to marine mammals resulting from seismic survey noise has not been documented (Gordon *et al.*, 2003). Extreme pressure waves generated by blasting can cause trauma in marine mammals, including damage to the inner ear (Ketten, 1995; Siebert *et al.*, 2022). Pressure waves generated by seismic airguns have longer rise times than those produced by explosives and are therefore less likely to cause such injury. One proposed mechanism for acoustically induced injury in diving marine mammals involves the growth of gas bubbles in supersaturated tissues through rectified diffusion, potentially contributing to decompression-related effects (Ridgway and Howard, 1982). Modelling by Crum and Mao (1996) suggested that exposure to 500-Hz sound at an SPL of 210 dB re 1 μ Pa could produce bubble growth sufficient to induce decompression-related symptoms, whereas such effects were considered unlikely at SPLs below 190 dB re 1 μ Pa. Although seismic airgun noise has been hypothesised as a potential source of similar physiological effects, this mechanism has not been demonstrated empirically in marine mammals exposed to seismic surveys.

For the proposed Level 1 seismic survey, the potential for exposure to high received sound levels was evaluated using the receiver-specific screening assessment presented in **APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING**. The highest representative received SEL predicted at the 200 m mitigation-zone boundary was approximately 163.8 dB re 1 μ Pa²·s under the deep-water broadband scenario, approximately 22.2 dB below the 186 dB re 1 μ Pa²·s criterion specified at 200 m in Appendix 1 of the 2013 Code of Conduct. The corresponding modelled levels at 1 km and 1.5 km were also below their respective Code criterion. On this basis, the receiver-specific screening assessment does not indicate that potentially injurious received levels extend to, or beyond, the prescribed mitigation-zone boundaries under the representative source conditions assessed.

This conclusion is supported by, but does not depend solely upon, the acoustic modelling. Implementation of the mitigation measures prescribed under the 2013 Code, including pre-start observations, soft-start procedures, monitoring of the applicable mitigation zones by MMOs and PAMOs, and delayed commencement or shutdown where required, further reduces the probability of a marine mammal being exposed at sufficiently close range to produce non-auditory physical injury. The acoustic results remain a screening assessment based on a simplified representative source formulation rather than a fully characterised array-specific source signature and directivity model; consequently, the possibility of exposure at very close range is not treated as impossible.

A likelihood score of 1 (Unlikely) was therefore retained for all assessed marine mammal species. Severity was retained as 4 (Severe) because, should non-auditory physical injury occur, the biological consequence to the affected individual could be substantial. Incorporating the revised population-exposure and receptor-valuation scores results in residual-risk categories ranging from None to High (**Table 16**). The higher species-specific residual scores principally reflect high population exposure and/or conservation valuation rather than a greater predicted acoustic probability of physical injury.



Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
Antarctic Blue whale	10	3	1	4	1.50	Minor
Antarctic Minke whale	4	2	1	4	0.40	None
Arnoux's beaked whale	5	3	1	4	0.75	Negligible
Bottlenose dolphin	8	6	1	4	2.40	Minor
Common dolphin	2	8	1	4	0.80	Negligible
Dusky dolphin	2	7	1	4	0.70	Negligible
Dwarf minke whale	5	2	1	4	0.50	Negligible
Fin whale	6	4	1	4	1.20	Negligible
Goose-beaked whale	4	4	1	4	0.80	Negligible
Gray's beaked whale	2	4	1	4	0.40	None
Hector's dolphin	8	9	1	4	3.60	High
Humpback whale	8	6	1	4	2.40	Minor
Killer whale	10	6	1	4	3.00	Moderate
Long-finned pilot whale	2	5	1	4	0.50	Negligible
Māui dolphin	10	1	1	4	0.50	Negligible



Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
New Zealand fur seal	2	8	1	4	0.80	Negligible
Pygmy blue whale	8	4	1	4	1.60	Minor
Pygmy right whale	5	3	1	4	0.75	Negligible
Pygmy sperm whale	4	3	1	4	0.60	Negligible
Sei whale	8	3	1	4	1.20	Negligible
Shepherd's beaked whale	5	3	1	4	0.75	Negligible
Southern right whale	7	5	1	4	1.75	Minor
Southern right-whale dolphin	4	3	1	4	0.60	Negligible
Sperm whale	6	7	1	4	2.10	Minor
Strap-toothed whale	5	3	1	4	0.75	Negligible
Striped dolphin	5	3	1	4	0.75	Negligible

Table 16: Residual risk of non-auditory physical injury from the seismic source. Residual risk category is based on the residual risk score, calculated from the likelihood, severity, population-exposure and receptor-valuation scores for each species. *Source:* OSC (2026).

6.2.2.8. Auditory damage

Exposure to intense or prolonged underwater noise can result in auditory threshold shifts in marine mammals, conventionally described as Temporary Threshold Shift (TTS) or Permanent Threshold Shift (PTS). TTS represents a temporary reduction in hearing sensitivity following sufficiently intense acoustic exposure, with recovery depending on the magnitude, duration and frequency content of the exposure (Finneran, 2015). PTS represents a persistent loss of hearing sensitivity associated with irreversible auditory injury and may consequently impair an animal's ability to detect biologically relevant sounds (Southall *et al.*, 2019). The onset of TTS and PTS is dependent not only on received acoustic energy but also on signal characteristics and the frequency-dependent auditory sensitivity of the exposed marine mammal hearing group. Consequently, a single unweighted received SEL value should not be interpreted as a universal biological threshold for the onset of TTS or PTS across all marine mammal species.

For the proposed Level 1 seismic survey, the site-specific sound transmission-loss modelling provides a screening assessment of received sound levels at the mitigation-zone distances specified in Appendix 1 of the 2013 Code of Conduct. As described in **APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING**, the regional 3,600-s standardised SEL_{cum} fields are used to characterise relative spatial and directional propagation behaviour and are not interpreted as operational cumulative exposure from the planned sequence of discrete seismic shots. Receiver-specific levels for comparison with the Code were therefore evaluated separately using the corresponding 1-s reference exposure.

Under this assessment, the highest representative received SEL occurred in the deep-water broadband scenario and was approximately 163.8 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$ at 200 m, 153.0 dB at 1 km and 148.1 dB at 1.5 km. These values are approximately 22.2 dB below the 186 dB criterion at 200 m and 18.0 and 22.9 dB below the 171 dB criterion at 1 km and 1.5 km, respectively. The corrected receiver-specific assessment therefore does not indicate exceedance of the applicable Code criteria at any of the three prescribed receiver distances under the representative source conditions modelled. The 171 dB criterion is used here specifically in the regulatory context defined by the 2013 Code and is not interpreted as a universal TTS or PTS onset threshold. Notwithstanding these results, auditory effects cannot be considered impossible. The modelling represents a screening assessment based on a simplified representative source spectrum rather than a fully characterised array-specific source signature and directivity model, and marine mammals could potentially encounter higher received levels at distances closer to the active source. Compliance with the 2013 Code therefore remains the principal operational control. Pre-start observations, soft-start procedures, monitoring by MMOs and PAMOs, and delayed commencement or shutdown when prescribed conditions are met reduce the probability that animals will remain sufficiently close to the operating array to receive exposures capable of producing auditory effects.

A likelihood score of 1 (Unlikely) was therefore retained for all assessed species. Severity was retained as 3 (Significant) in accordance with the assessment framework, recognising that auditory effects encompass a range from temporary threshold shift to potentially persistent hearing impairment. Incorporating the revised population-exposure and receptor-valuation scores results in residual-risk categories ranging from None to Moderate (**Table 17**). As with non-auditory physical injury, the higher species-specific residual scores principally reflect population exposure and/or conservation valuation rather than evidence of a higher modelled probability of auditory injury.



Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
Antarctic Blue whale	10	3	1	3	1.20	Negligible
Antarctic minke whale	4	2	1	3	0.32	None
Arnoux's beaked whale	5	3	1	3	0.60	Negligible
Bottlenose dolphin	8	6	1	3	1.92	Minor
Common dolphin	2	8	1	3	0.64	Negligible
Dusky dolphin	2	7	1	3	0.56	Negligible
Dwarf minke whale	5	2	1	3	0.40	None
Fin whale	6	4	1	3	0.96	Negligible
Goose-beaked whale	4	4	1	3	0.64	Negligible
Gray's beaked whale	2	4	1	3	0.32	None
Hector's dolphin	8	9	1	3	2.88	Moderate
Humpback whale	8	6	1	3	1.92	Minor
Killer whale	10	6	1	3	2.40	Minor
Long-finned pilot whale	2	5	1	3	0.40	None



Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
Māui dolphin	10	1	1	3	0.40	None
New Zealand fur seal	2	8	1	3	0.64	Negligible
Pygmy blue whale	8	4	1	3	1.28	Negligible
Pygmy right whale	5	3	1	3	0.60	Negligible
Pygmy sperm whale	4	3	1	3	0.48	None
Sei whale	8	3	1	3	0.96	Negligible
Shepherd's beaked whale	5	3	1	3	0.60	Negligible
Southern right whale	7	5	1	3	1.40	Negligible
Southern right-whale dolphin	4	3	1	3	0.48	None
Sperm Whale	6	7	1	3	1.68	Minor
Strap-toothed whale	5	3	1	3	0.60	Negligible
Striped dolphin	5	3	1	3	0.60	Negligible

Table 17: Residual risk of auditory effects, including TTS and PTS, from the seismic source. Residual risk category is based on the residual risk score, calculated from the likelihood, severity, population-exposure and receptor-valuation scores for each species. *Source:* OSC (2026).

6.2.2.9. Masking

Acoustic masking occurs when anthropogenic sound reduces the detectability of biologically relevant acoustic signals by increasing background noise within overlapping frequency bands. In marine mammals, masking may interfere with communication, passive detection of conspecifics, predator or prey detection, navigation and, for odontocetes, components of acoustic foraging behaviour (Clark *et al.*, 2009; Erbe *et al.*, 2016). The magnitude of masking depends on the spectral and temporal overlap between the masking sound and the biologically relevant signal, received sound level, ambient noise conditions, hearing sensitivity, spatial separation between signaller and receiver, and the capacity of animals to compensate behaviourally or acoustically.

Seismic airgun signals are impulsive rather than continuous, and the intervals between successive shots provide periods during which masking is reduced or absent. The proposed survey is expected to use shot intervals of approximately 10–15 s, depending on water depth. Nevertheless, the high source level and predominantly low-frequency energy of seismic signals mean that individual pulses may remain detectable over substantial distances. Potential masking is therefore not necessarily restricted to animals in close proximity to the active source.

This distinction is particularly relevant to low-frequency cetaceans. Baleen-whale vocalisations overlap substantially with the low-frequency energy produced by seismic sources, creating the potential for temporary reduction in communication space during individual seismic pulses. Odontocetes generally communicate and echolocate at higher frequencies and therefore have less spectral overlap with the dominant energy of the seismic source, although broadband components of the signal and species-specific hearing characteristics mean that masking cannot be excluded. The biological significance of any masking event will consequently vary among species, behavioural contexts and propagation environments.

The sound transmission-loss modelling presented in **APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING** demonstrates that regional propagation is strongly directional and dependent on source location, local water depth and bathymetry. In particular, the deep-water scenarios show that elevated standardised SEL_{cum} can persist over comparatively large radial distances along several propagation directions. These standardised 3,600-s fields should not be interpreted as operational cumulative exposure or as direct predictions of masking extent; however, they demonstrate that acoustic energy from the source is not confined to the immediate vicinity of the seismic array. Masking could therefore occur over a wider region than the mitigation zones, particularly along favourable deep-water propagation pathways.

The receiver-specific assessment against the 2013 Code criteria does not alter this conclusion. Those criteria are intended to support mitigation of high received sound levels and are not masking thresholds. Similarly, the present modelling does not define a quantitative masking zone because doing so would require species-specific auditory sensitivity, relevant signal spectra, ambient-noise conditions and appropriate signal-to-noise or critical-ratio criteria that were not incorporated into the propagation assessment. The modelling therefore supports assessment of the potential spatial extent of sound propagation but does not provide a direct prediction of the distance at which biologically significant masking would occur.

Operational mitigation under the 2013 Code reduces exposure to the highest sound levels close to the seismic source but cannot eliminate the potential for lower-level

acoustic masking at greater distances. However, masking from the proposed seismic source will be intermittent because of the impulsive nature of the source and the interval between shots, and individual animals will experience changing received levels as the survey vessel progresses along the survey lines. Consequently, masking effects are expected to be temporary and reversible rather than representing permanent impairment of hearing or acoustic function.

Masking was therefore assigned a likelihood score of 4 (Highly likely) for all assessed marine mammal species, recognising that some degree of acoustic interference may occur whenever animals are present within acoustically affected portions of the study area. Severity was retained as 1 (Minimal) because masking is expected to be intermittent and reversible, with the magnitude and biological relevance of the effect dependent on species, signal overlap, behavioural context and received sound conditions. Incorporating the revised population-exposure and receptor-valuation scores results in residual-risk categories ranging from None to High (**Table 18**). Higher residual-risk scores primarily reflect greater population exposure and/or conservation valuation rather than evidence that all species experience equivalent masking effects.



Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
Antarctic Blue whale	10	3	4	1	1.50	Minor
Antarctic minke whale	4	2	4	1	0.40	None
Arnoux's beaked whale	5	3	4	1	0.75	Negligible
Bottlenose dolphin	8	6	4	1	2.40	Minor
Common dolphin	2	8	4	1	0.80	Negligible
Dusky dolphin	2	7	4	1	0.70	Negligible
Dwarf minke whale	5	2	4	1	0.50	Negligible
Fin whale	6	4	4	1	1.20	Negligible
Goose-beaked whale	4	4	4	1	0.80	Negligible
Gray's beaked whale	2	4	4	1	0.40	None
Hector's dolphin	8	9	4	1	3.60	High
Humpback whale	8	6	4	1	2.40	Minor
Killer whale	10	6	4	1	3.00	Moderate
Long-finned pilot whale	2	5	4	1	0.50	Negligible



Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
Māui dolphin	10	1	4	1	0.50	Negligible
New Zealand fur seal	2	8	4	1	0.80	Negligible
Pygmy blue whale	8	4	4	1	1.60	Minor
Pygmy right whale	5	3	4	1	0.75	Negligible
Pygmy sperm whale	4	3	4	1	0.60	Negligible
Sei whale	8	3	4	1	1.20	Negligible
Shepherd's beaked whale	5	3	4	1	0.75	Negligible
Southern right whale	7	5	4	1	1.75	Minor
Southern right-whale dolphin	4	3	4	1	0.60	Negligible
Sperm whale	6	7	4	1	2.10	Minor
Strap-toothed whale	5	3	4	1	0.75	Negligible
Striped dolphin	5	3	4	1	0.75	Negligible

Table 18: Residual risk of auditory masking from the seismic source. Residual risk category is based on the residual risk score, calculated from the likelihood, severity, population-exposure and receptor-valuation scores for each species. *Source:* OSC (2026).

6.2.2.10. Behavioural disturbance

Exposure to seismic noise may elicit behavioural responses in marine mammals, including changes in movement, diving, vocal behaviour, foraging and habitat use. The biological significance of such responses depends on their magnitude and duration, the behavioural state of the animal and whether exposure occurs during biologically important activities such as feeding, breeding, migration or maternal care. Short-term behavioural responses may have little consequence, whereas repeated or prolonged disruption of biologically important behaviour has greater potential to affect individual fitness.

Baleen whales have exhibited a range of behavioural responses to seismic and other anthropogenic noise, including changes in calling behaviour, swimming speed and direction. Responses can vary considerably among individuals and contexts. Both increases and decreases in calling behaviour have been reported following noise exposure (Di Iorio and Clark, 2010; Blackwell *et al.*, 2015), and changes in humpback-whale singing behaviour have also been documented, although the consequences for reproductive success remain uncertain (Cerchio *et al.*, 2014; Dunlop *et al.*, 2018). Experimental exposure studies of humpback whales have identified changes in movement patterns, dive and respiration parameters and other surface behaviours, with response magnitude dependent on exposure and behavioural context (Dunlop *et al.*, 2017).

Odontocetes may also respond to anthropogenic sound through avoidance, altered diving or changes in foraging behaviour. Beaked whales are considered particularly sensitive to certain intense anthropogenic sound sources, with strong behavioural responses to acoustic disturbance documented in several studies. Mass-stranding events involving beaked whales have been associated particularly with naval sonar exposure (Fernández *et al.*, 2005), although the mechanisms and relevance of these events to seismic-survey exposure should not be assumed to be equivalent. Sperm whales exposed to seismic airgun activity have shown changes in foraging effort and dive behaviour, indicating that seismic sound can affect biologically relevant activities (Miller *et al.*, 2009).

Pinnipeds may also exhibit behavioural responses to seismic activity, although available observations indicate considerable variability. In Alaska, seals showed avoidance responses associated with seismic operations, principally at relatively short ranges (Harris *et al.*, 2001). New Zealand fur seals have also been observed during seismic surveys in New Zealand, although interpretation was complicated by sea-state effects on detectability and the potential influence of the physical presence of survey equipment (Lalas and McConnell, 2016).

The mitigation zones prescribed under the 2013 Code are intended principally to reduce the risk of exposure to high received sound levels and should not be interpreted as defining the spatial limit of possible behavioural responses. For Species of Concern, the applicable mitigation procedures vary according to species and circumstances, including the presence of calves, as described in **Section 6.2.1.4** and **APPENDIX A – MITIGATION REQUIREMENTS**. Behavioural responses to seismic sound may occur beyond these mitigation-zone boundaries and at received levels below those used for the receiver-specific Code assessment.

For the proposed Level 1 seismic survey, the potential for behavioural disturbance was assessed using the regional sound-propagation modelling presented in **APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING** together with available evidence concerning marine-mammal responses to impulsive underwater

sound. The modelling demonstrates pronounced spatial and directional variation in propagation, particularly under deep-water conditions, where elevated standardised SEL_{cum} values can persist over comparatively large radial distances along some azimuths. The standardised 3,600-s fields do not constitute operational cumulative exposures or behavioural-response thresholds, but they demonstrate that seismic sound may remain detectable over a broad and directionally variable region.

The modelling does not provide a quantitative behavioural-disturbance radius. Behavioural response thresholds are not uniform among species or individuals and depend on received level, signal characteristics, behavioural state, prior exposure and environmental context. Accordingly, the receiver-specific values evaluated against the 2013 Code should not be treated as thresholds below which behavioural disturbance cannot occur.

Where behavioural responses occur during the proposed survey, they are expected primarily to comprise temporary avoidance or changes in swimming, diving, vocal or foraging behaviour. The seismic vessel will move continuously along predefined acquisition lines at approximately 3.5 knots, with shots expected at intervals of approximately 10–15 s, so the spatial relationship between an individual animal and the active source will change continuously during acquisition. Implementation of the 2013 Code mitigation procedures will additionally reduce the likelihood of animals remaining within the highest-exposure region close to the active source, although these measures do not eliminate the possibility of behavioural responses at greater distances.

Behavioural disturbance was therefore assigned a likelihood score of 3 (Likely) for all assessed species, recognising that behavioural responses may occur when marine mammals are exposed to seismic sound. Severity was retained as 1 (Minimal) because effects are expected predominantly to be temporary and reversible under the proposed survey conditions, while recognising that biological significance will depend on species, behavioural context and duration of exposure. Incorporating the revised population-exposure and receptor-valuation scores results in residual-risk categories ranging from None to Moderate (**Table 19**). Higher species-specific scores primarily reflect greater population exposure and/or conservation valuation rather than an assumption of equivalent behavioural sensitivity among all species.



Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk Category
Antarctic Blue whale	10	3	3	1	1.20	Negligible
Antarctic minke whale	4	2	3	1	0.32	None
Arnoux's beaked whale	5	3	3	1	0.60	Negligible
Bottlenose dolphin	8	6	3	1	1.92	Minor
Common dolphin	2	8	3	1	0.64	Negligible
Dusky dolphin	2	7	3	1	0.56	Negligible
Dwarf minke whale	5	2	3	1	0.40	None
Fin whale	6	4	3	1	0.96	Negligible
Goose-beaked whale	4	4	3	1	0.64	Negligible
Gray's beaked whale	2	4	3	1	0.32	None
Hector's dolphin	8	9	3	1	2.88	Moderate
Humpback whale	8	6	3	1	1.92	Minor
Killer whale	10	6	3	1	2.40	Minor
Long-finned pilot whale	2	5	3	1	0.40	Negligible
Māui dolphin	10	1	3	1	0.40	None



Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk Category
New Zealand fur seal	2	8	3	1	0.64	Negligible
Pygmy blue whale	8	4	3	1	1.28	Negligible
Pygmy right whale	5	3	3	1	0.60	Negligible
Pygmy sperm whale	4	3	3	1	0.48	None
Sei whale	8	3	3	1	0.96	Negligible
Shepherd's beaked whale	5	3	3	1	0.60	Negligible
Southern right whale	7	5	3	1	1.40	Negligible
Southern right-whale dolphin	4	3	3	1	0.48	None
Sperm whale	6	7	3	1	1.68	Minor
Strap-toothed whale	5	3	3	1	0.60	Negligible
Striped dolphin	5	3	3	1	0.60	Negligible

Table 19: Residual risk of behavioural disturbance from the seismic source. Residual risk category is based on the residual risk score, calculated from the likelihood, severity, population-exposure and receptor-valuation scores for each species. *Source:* OSC (2026).

6.2.2.11. Indirect effects on prey species

Marine mammals within the study area depend on a range of prey taxa that may themselves respond to impulsive underwater sound. Baleen whales consume zooplankton and schooling fish in varying proportions, while odontocetes and pinnipeds depend principally on fish and cephalopods, with diet varying among species, locations and seasons. Consequently, effects of seismic sound on the distribution, behaviour or condition of prey organisms could potentially influence marine mammals indirectly through temporary changes in prey availability or foraging conditions.

Experimental and field studies have documented responses of fish to seismic and other intense impulsive sounds, including startle responses, changes in swimming and schooling behaviour, and displacement or altered catch rates (Engås *et al.*, 1996; Fewtrell and McCauley, 2012; Carroll *et al.*, 2017). The magnitude and persistence of these responses vary considerably among species and experimental conditions, and changes in fishery catch rates should not necessarily be interpreted as direct evidence of mortality or population-level reduction in prey abundance. Nevertheless, temporary redistribution of schooling fish could locally alter prey accessibility for marine mammals that depend on concentrated prey patches.

Cephalopods are also potentially sensitive to intense acoustic exposure. Experimental studies have reported lesions in statocyst tissues following controlled exposure to low-frequency sound (Andre *et al.*, 2011), while reviews of seismic effects on marine fauna identify cephalopods among the invertebrate groups for which physiological and behavioural effects may occur (Carroll *et al.*, 2017). The ecological consequences of such responses under field conditions remain uncertain, and available evidence does not support prediction of a quantitative reduction in cephalopod availability to marine-mammal predators during the proposed survey.

Zooplankton responses require similarly cautious interpretation. McCauley *et al.* (2017) reported increased mortality of zooplankton following exposure to an experimental airgun signal and described effects extending substantially beyond the immediate source vicinity. However, subsequent interpretation of seismic effects on zooplankton has remained an area of scientific uncertainty, particularly with respect to extrapolation from experimental exposure to population- or ecosystem-level consequences. The available evidence therefore supports recognition of a potential effect pathway but does not establish that the proposed survey would cause a spatially extensive or persistent reduction in zooplankton prey availability for marine mammals.

For SUBTRANS, the sound transmission-loss modelling presented in **APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING** demonstrates that propagation of seismic sound may extend over a broad and strongly direction-dependent region, particularly under deep-water conditions. The standardised 3,600-s SEL_{cum} fields do not provide biological effect thresholds for fish, cephalopods or zooplankton and therefore cannot be used to delineate a prey-effect zone. Accordingly, the spatial extent of indirect effects on prey cannot be inferred directly from the acoustic propagation footprint. The modelling nevertheless indicates that potential exposure of prey organisms should not be assumed to be restricted to the immediate vicinity of the seismic source.

The biological significance of this pathway for marine mammals is expected to be lower than that of direct acoustic exposure. The proposed seismic programme is spatially progressive, with the vessel moving continuously along predefined

acquisition lines at approximately 3.5 knots and individual shots occurring at intervals of approximately 10–15 s. Consequently, exposure conditions at any fixed location will change as the source approaches and subsequently moves away. Mobile prey such as fish and cephalopods may redistribute in response to exposure, while planktonic organisms are subject to advection and natural turnover. These characteristics reduce the likelihood that any local prey response would translate into persistent prey depletion at the scale relevant to marine-mammal populations.

Indirect effects on marine mammals through changes in prey availability were therefore assigned a likelihood score of 2 (Possible). Severity was retained as 1 (Minimal) because any resulting effects on marine mammals are expected principally to involve temporary changes in prey accessibility or foraging conditions rather than persistent loss of prey resources. Substantial uncertainty remains because prey responses vary among taxa and exposure conditions, and the acoustic modelling does not incorporate prey-specific effect thresholds. Incorporating the revised population-exposure and receptor-valuation scores results in residual-risk categories ranging from None to Minor (**Table 20**).



Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
Antarctic Blue whale	10	3	2	1	0.90	Negligible
Antarctic minke whale	4	2	2	1	0.24	None
Arnoux's beaked whale	5	3	2	1	0.45	None
Bottlenose dolphin	8	6	2	1	1.44	Negligible
Common dolphin	2	8	2	1	0.48	None
Dusky dolphin	2	7	2	1	0.42	None
Dwarf minke whale	5	2	2	1	0.30	None
Fin whale	6	4	2	1	0.72	Negligible
Goose-beaked whale	4	4	2	1	0.48	None
Gray's beaked whale	2	4	2	1	0.24	None
Hector's dolphin	8	9	2	1	2.16	Minor
Humpback whale	8	6	2	1	1.44	Negligible
Killer whale	10	6	2	1	1.80	Minor
Long-finned pilot whale	2	5	2	1	0.30	None



Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
Māui dolphin	10	1	2	1	0.30	None
New Zealand fur seal	2	8	2	1	0.48	None
Pygmy blue whale	8	4	2	1	0.96	Negligible
Pygmy right whale	5	3	2	1	0.45	None
Pygmy sperm whale	4	3	2	1	0.36	None
Sei whale	8	3	2	1	0.72	Negligible
Shepherd's beaked whale	5	3	2	1	0.45	None
Southern right whale	7	5	2	1	1.05	Negligible
Southern right-whale dolphin	4	3	2	1	0.36	None
Sperm whale	6	7	2	1	1.26	Negligible
Strap-toothed whale	5	3	2	1	0.45	None
Striped dolphin	5	3	2	1	0.45	None

Table 20: Residual risk of indirect effects on marine mammals through changes in prey availability. Residual risk category is based on the residual risk score, calculated from the likelihood, severity, population-exposure and receptor-valuation scores for each species. *Source:* OSC (2026).

6.2.2.12. *In-combination & cumulative effects*

In-combination effects arise where two or more impact pathways associated with the proposed survey act concurrently on the same receptor, potentially producing a combined effect greater than that associated with either pathway considered independently. Cumulative effects arise where impacts from the proposed survey overlap spatially or temporally with those generated by other anthropogenic activities to which the same marine mammal receptors may also be exposed.

For the SUBTRANS survey, potential in-combination effects principally concern the simultaneous or sequential occurrence of vessel-related disturbance, underwater radiated vessel noise and impulsive seismic noise. An individual marine mammal encountering the survey vessel may therefore experience more than one impact pathway, including behavioural disturbance, displacement, masking and, indirectly, changes in prey availability. These effects are not necessarily independent; for example, acoustic disturbance and vessel presence may contribute concurrently to avoidance or altered foraging behaviour. Nevertheless, the principal predicted effects are temporary and reversible, and implementation of the mitigation measures described in **Section 6.2.1.4** will reduce exposure to the highest sound levels close to the active seismic source.

The regional sound transmission-loss modelling presented in **APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING** demonstrates that seismic sound propagation is spatially and directionally variable and, particularly under deep-water conditions, may extend over comparatively large distances along favourable propagation pathways. The modelled 3,600-s standardised SEL_{cum} fields should not be interpreted as operational cumulative exposure, but they demonstrate that the acoustic footprint of the survey cannot be assumed to be confined to the immediate vicinity of the active source. Potential spatial overlap with other anthropogenic sound sources must therefore be considered at a regional rather than solely local scale.

The potential for cumulative effects will depend on the spatial and temporal coincidence of the SUBTRANS survey with other anthropogenic activities, including vessel traffic and any other activities generating substantial underwater noise. Cook Strait is an active maritime environment, and background exposure to vessel noise is therefore expected to occur independently of the proposed survey. However, the information available for this assessment did not identify a specific concurrent activity for which sufficient spatial, temporal and acoustic information was available to predict a material additive or synergistic increase in marine mammal effects during the SUBTRANS acquisition period. This should not be interpreted as demonstrating the absence of other anthropogenic activity, but rather as reflecting the information available at the time of assessment.

The proposed seismic acquisition is temporary and spatially progressive, with a single survey vessel moving continuously along predefined acquisition lines. Survey 1 and Survey 2 comprise approximately 775 and 500 nautical miles of seismic acquisition, respectively, with nominal acquisition durations of approximately 221 and 143 hours at 3.5 knots. Consequently, the location of the active seismic source and its associated acoustic footprint will change continuously throughout the programme rather than remaining concentrated at a single location.

On the basis of the information currently available, no additional residual-risk category has therefore been assigned specifically for in-combination or cumulative effects. The species-specific residual risks identified for the individual pathways in

Sections 6.2.2.2–6.2.2.11 remain applicable. In the absence of evidence for a specific concurrent activity capable of materially increasing exposure during the survey period, no additional increase in those residual-risk categories is predicted. Nevertheless, cumulative effects cannot be excluded, particularly where animals exposed to SUBTRANS seismic sound are simultaneously or sequentially exposed to other anthropogenic noise, and this uncertainty should be recognised when interpreting the overall assessment.

6.2.2.13. Unplanned events

Unplanned events considered relevant to marine mammals include vessel collision or sinking, accidental release of fuel or other hazardous substances, and loss of survey equipment. These events differ from the routine impact pathways assessed in the preceding sections because they are contingent events rather than planned components of the survey and their occurrence, location and magnitude cannot be predicted with sufficient confidence for application of the species-specific residual-risk matrix. They are therefore considered qualitatively, with emphasis on prevention, emergency response and recovery measures.

6.2.2.14. Vessel collision or sinking, and release of hazardous substances

RV Sonne will operate under established maritime safety, bridge watchkeeping, navigation and pollution-prevention procedures throughout transit and survey operations. These measures reduce the likelihood of collision, grounding, sinking or accidental release of fuel or other hazardous substances. Should an incident occur, the potential consequences for marine mammals would depend on the nature, quantity and location of any release and on the presence of animals within the affected area. Exposure to spilled hydrocarbons or other hazardous substances could occur through direct contact, inhalation at the sea surface or indirectly through contamination of prey and habitat.

The probability and magnitude of such an event cannot be quantified from the information available for this MMIA. In the event of an accidental release, the vessel's applicable emergency-response and pollution-control procedures would be implemented to contain the incident and minimise its environmental consequences. Given the preventative controls and contingency measures associated with operation of the research vessel, no additional species-specific residual-risk score is assigned for this pathway. This should not be interpreted as indicating that the consequences of a major accidental release would necessarily be negligible, but rather that such consequences are dependent on the characteristics of an unplanned event that cannot be meaningfully represented by the routine operational risk matrix.

6.2.2.15. Equipment loss

The seismic acquisition system incorporates operational measures intended to minimise the likelihood and consequences of accidental equipment loss. The tail buoy is fitted with a flashing light, allowing visual identification of the end of the streamer array during survey operations. Continuous watchkeeping and real-time monitoring of the acquisition system provide a means of identifying streamer separation or other equipment loss, after which recovery procedures can be initiated.

Lost or detached equipment could present a temporary entanglement or collision hazard to marine fauna and, if not recovered, could contribute to persistent marine debris or localised seabed disturbance. Prompt detection and recovery therefore constitute the principal mitigation measures for this pathway. As with vessel accidents and pollutant release, the location and circumstances of an equipment-loss event cannot be predicted in advance and no species-specific residual-risk score is assigned. With the operational monitoring and recovery measures described above, the likelihood of persistent marine-mammal effects from equipment loss is considered low, although complete absence of risk cannot be assumed.

6.2.3. Impact assessment – other receptors

Potential effects on other marine receptors within the study area are considered below for seabirds, marine reptiles, fish, sharks and rays, invertebrates and zooplankton. As identified during scoping (**Section 6.2.1.3**), these receptors are assessed at broad taxonomic-group level rather than at species level. The species-specific population-exposure and receptor-valuation framework applied to marine mammals in **Section 6.2.2** is therefore not applied quantitatively to these receptor groups. Instead, the assessment is qualitative and considers the available evidence for sensitivity to impulsive underwater sound, the nature and duration of the proposed seismic activity, the regional propagation characteristics identified by the sound transmission-loss modelling, and the potential for physiological, behavioural and ecological effects. Increased vessel presence was scoped out for these receptor groups at the scoping stage; the following assessment consequently focuses principally on potential effects associated with the seismic source.

6.2.3.1. Seabirds

Knowledge of underwater hearing and sensitivity to anthropogenic underwater sound in seabirds remains substantially more limited than for marine mammals and fish, with much of the available auditory research having focused on hearing in air (Mooney *et al.*, 2020; Smith and Barclay, 2024). Nevertheless, experimental studies demonstrate that some diving seabirds, including cormorants, can detect underwater sound (Crowell, 2016; Hansen *et al.*, 2017; Larsen *et al.*, 2020), establishing a potential pathway for behavioural responses to anthropogenic underwater noise.

Field evidence also indicates that seismic-survey activity can affect seabird distribution or foraging behaviour. Pichegru *et al.* (2017) reported displacement of foraging African penguins during seismic operations, while (Seco Pon *et al.*, 2019) identified changes in seabird occurrence associated with seismic-survey activity. Such responses may arise from direct exposure to underwater sound, responses to the survey vessel, changes in prey distribution, or a combination of these mechanisms. Extrapolation among seabird species and regions is therefore uncertain, particularly because diving behaviour, foraging ecology and underwater auditory sensitivity differ substantially among taxa.

The Cook Strait and southern Hikurangi Margin support diverse pelagic and diving seabird assemblages, including species using the region for foraging and transit. Diving birds could be exposed to seismic sound while submerged, and temporary behavioural responses or changes in foraging activity cannot be excluded. Indirect effects could also arise where seismic exposure alters the local distribution or behaviour of fish or other prey. The regional sound transmission-loss modelling demonstrates that seismic sound may propagate over comparatively large and strongly direction-dependent distances, particularly under deep-water conditions;

consequently, potential acoustic exposure should not be assumed to be confined to the immediate vicinity of the seismic source. The modelling does not, however, incorporate seabird-specific hearing characteristics or effect thresholds and cannot be used to predict a seabird disturbance or injury radius.

Overall, the available evidence supports the potential for temporary behavioural or foraging responses in seabirds exposed to seismic-survey activity but is insufficient to predict their magnitude or spatial extent for the seabird assemblage present within the SUBTRANS study area. The survey is temporary and spatially progressive, reducing the duration of exposure at any fixed location, and no persistent population-level effect on seabirds is predicted on the basis of the information available. Considerable uncertainty nevertheless remains because underwater auditory sensitivity and seismic-response data are available for relatively few seabird species.

6.2.3.2. *Marine reptiles*

Marine turtles are capable of detecting underwater sound, with hearing sensitivity concentrated predominantly at low frequencies and therefore overlapping with a substantial component of the energy generated by seismic airgun sources (Piniak *et al.*, 2012; Chapuis *et al.*, 2019). Available auditory studies indicate considerable variation among species and life stages but generally demonstrate greatest sensitivity from tens to several hundreds of hertz, with reduced sensitivity at higher frequencies. This spectral overlap establishes a plausible pathway for both behavioural and, at sufficiently high received exposures, auditory effects from seismic-survey activity.

Behavioural responses of marine turtles to seismic airguns have been reported in experimental and field observations, including changes in swimming behaviour and avoidance of the sound source (Weir, 2007; DeRuiter and Doukara, 2012). However, the received levels associated with particular responses vary among studies, and the available evidence remains insufficient to define a generally applicable behavioural response threshold or disturbance radius for marine turtles. Responses are also likely to depend on behavioural state, source characteristics, exposure history and the spatial relationship between the animal and the operating source.

Exposure to sufficiently intense underwater sound may also produce temporary changes in auditory sensitivity. Experimental studies have demonstrated temporary threshold shifts following controlled acoustic exposure in marine turtles (Nelms *et al.*, 2016), indicating that auditory effects are biologically plausible. Evidence for permanent auditory injury from seismic surveys is substantially more limited, however, and the available literature does not provide a robust basis for defining species-specific PTS or injury thresholds applicable to the proposed survey.

Marine turtles may occur within New Zealand waters, although their occurrence within the SUBTRANS study area is expected to be substantially less frequent than that of the principal marine-mammal receptors considered in **Section 6.2.2**. Where individuals are present, exposure to seismic sound cannot be excluded. The regional sound transmission-loss modelling presented in **APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING** demonstrates that low-frequency seismic energy may propagate over substantial and strongly direction-dependent distances, particularly under deep-water conditions. The standardised 3,600-s SEL_{cum} fields do not incorporate turtle-specific auditory weighting or biological effect

thresholds and therefore cannot be used to delineate behavioural, TTS or injury zones for marine reptiles.

The receiver-specific criteria applied under the 2013 Code of Conduct are similarly not interpreted as biological effect thresholds for marine turtles. Nevertheless, the proposed survey is temporary and spatially progressive, so exposure conditions at any fixed location will change as the active source approaches and moves away. The highest received levels will occur closest to the seismic array, while animals at greater distances may remain exposed to lower-level sound capable of eliciting behavioural responses.

Overall, temporary behavioural responses represent the most plausible effect on marine reptiles potentially encountered during the survey. Auditory effects cannot be excluded for an animal exposed sufficiently close to the operating source, but the available evidence and modelling do not support prediction of a marine-turtle-specific injury radius. Given the expected low occurrence of marine turtles within the study area and the temporary, spatially progressive nature of the survey, persistent population-level effects are not predicted on the basis of the information available. This conclusion remains subject to uncertainty arising from the limited species-specific evidence concerning marine-turtle responses to seismic sound.

6.2.3.3. Fish

Fish detect underwater sound primarily through particle motion, while species possessing anatomical specialisations that couple gas-filled structures to the auditory system may also exhibit enhanced sensitivity to sound pressure. Auditory sensitivity consequently varies substantially among taxa, as does susceptibility to anthropogenic underwater noise (Popper and Hawkins, 2019a). Seismic airgun pulses have the potential to affect fish through behavioural, auditory and, at sufficiently high exposures, physiological pathways, with responses dependent on species, life stage, source characteristics, received exposure and distance from the source (Popper *et al.*, 2014; Carroll *et al.*, 2017).

Behavioural responses reported during exposure to seismic or other impulsive sounds include startle responses, changes in swimming behaviour, altered schooling and displacement from exposed areas. Such responses may temporarily affect foraging, predator avoidance, communication or habitat use, although their magnitude and persistence vary considerably among species and exposure conditions (Carroll *et al.*, 2017; Popper and Hawkins, 2019b). Changes in fish distribution or catch rates following seismic activity have also been reported, but these observations should not necessarily be interpreted as evidence of mortality or persistent reduction in population abundance.

Experimental observations illustrate this variability. Boeger *et al.* (2006) exposed coral-reef fish held in field enclosures to airgun signals and reported no mortality or obvious external injury. Most exposures elicited a startle response, expressed as a temporary increase in swimming velocity and/or change in swimming direction, after which swimming behaviour returned towards pre-exposure conditions. Responses became less pronounced with repeated exposure, suggesting possible habituation under the experimental conditions.

Physiological susceptibility may be greater in eggs, larvae and other early life stages because of their limited capacity to move away from an approaching source (Popper *et al.*, 2005; DNV Energy, 2007). At sufficiently high exposures, physical injury has been reported in fish, including effects associated with rapid pressure

changes and damage to gas-filled structures, with susceptibility influenced strongly by anatomy and exposure conditions (Popper *et al.*, 2014). Auditory effects, including temporary or permanent changes in hearing sensitivity, are also biologically plausible, although effect thresholds vary substantially among species and cannot be represented by a single generally applicable received-level criterion (Popper *et al.*, 2014; Carroll *et al.*, 2017).

Fish assemblages within Cook Strait and the southern Hikurangi Margin comprise diverse pelagic and demersal communities structured by depth, substratum, bathymetric complexity and the region's energetic hydrodynamic regime (Beentjes *et al.*, 2002; Cole *et al.*, 2012; Zintzen *et al.*, 2012; Zintzen *et al.*, 2017). Individuals occurring within the acoustically affected region may therefore experience temporary behavioural responses, while fish in close proximity to the operating source could potentially experience auditory or physiological effects. Eggs and larvae present within the exposed water mass may be comparatively less able to avoid the source.

The sound transmission-loss modelling presented in **APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING** demonstrates that seismic sound propagation can extend over substantial and strongly direction-dependent distances, particularly under deep-water conditions. However, the modelled standardised SEL_{cum} fields describe sound-pressure exposure and do not quantify particle motion. They also do not incorporate species- or life-stage-specific fish effect thresholds. The modelling therefore cannot be used to delineate a general behavioural, auditory or injury radius for fish, and the spatial extent of biological effects should not be inferred directly from the modelled acoustic footprint.

The proposed survey is temporary and spatially progressive, with the active source moving continuously along the acquisition lines. Consequently, exposure at any fixed location will vary as the source approaches and subsequently moves away. Mobile fish may also respond behaviourally by changing position relative to the source, whereas eggs and planktonic larvae have substantially less capacity for active avoidance. Overall, temporary behavioural responses represent the most plausible widespread effect on adult fish, while auditory or physical effects are expected to require comparatively higher exposures and therefore to present greatest concern closer to the active source. Persistent population-level effects on fish assemblages are not predicted on the basis of the available evidence and the nature of the proposed survey, although uncertainty remains substantial for sensitive taxa and early life stages.

6.2.3.4. Sharks & rays

Sharks and rays are capable of detecting low-frequency underwater sound, principally through the particle-motion component of the acoustic field. Unlike many teleost fishes, elasmobranchs lack a gas-filled swim bladder and do not possess specialised structures coupling such a cavity to the inner ear. Their acoustic sensitivity is therefore generally associated with low-frequency particle motion, although hearing capabilities and behavioural responses vary among species (Mickle *et al.*, 2020).

Low-frequency sound can provide biologically relevant information to elasmobranchs, including cues associated with prey, predators and environmental features. Experimental and observational studies have demonstrated behavioural responses by some sharks and rays to acoustic stimuli, including attraction, avoidance and changes in swimming behaviour (Carroll *et al.*, 2017). However,

available evidence concerning responses specifically to seismic airgun exposure remains substantially more limited than for many teleost fishes, and responses observed for one species or acoustic stimulus should not be assumed to apply uniformly across elasmobranch taxa.

Potential effects of seismic activity may include temporary behavioural disturbance or displacement where biologically relevant particle motion is detectable. Physiological or auditory effects at sufficiently high exposures cannot be excluded, but the available evidence does not provide a robust basis for defining generally applicable injury or auditory-effect thresholds for sharks and rays. The absence of a swim bladder may reduce susceptibility to some forms of pressure related barotrauma observed in physoclistous fishes but should not be interpreted as demonstrating absence of sensitivity to intense acoustic exposure.

The sound transmission-loss modelling presented in **APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING** characterises the sound-pressure field generated under the representative modelled scenarios. It does not model acoustic particle motion. Because particle motion is particularly important to sound detection in elasmobranchs, the standardised SEL_{cum} distributions cannot be interpreted directly as maps of biologically relevant acoustic exposure for sharks and rays. The modelling nevertheless demonstrates that the pressure component of seismic sound may propagate over substantial and strongly direction-dependent distances, particularly under deep-water conditions, and therefore provides useful information on the broader propagation environment without defining an elasmobranch-specific effect zone.

The proposed seismic survey is temporary and spatially progressive, so exposure at any fixed location will vary as the source approaches and moves away. Mobile sharks and rays may also alter their position or behaviour in response to the operating source. Overall, temporary behavioural responses are considered the most plausible effect where animals encounter seismic activity. Persistent population-level effects are not predicted on the basis of the available evidence and the nature of the proposed survey, although uncertainty remains because empirical information on species-specific sensitivity and responses of elasmobranchs to seismic airgun exposure is limited.

6.2.3.5. Invertebrates

Marine invertebrates comprise a taxonomically and functionally diverse group, and responses to anthropogenic underwater sound vary substantially among taxa, life stages and exposure conditions. Many marine invertebrates can detect the particle-motion component of underwater sound through mechanosensory structures, and acoustic cues may contribute to orientation, habitat selection, predator avoidance and other biologically relevant behaviours (Jones *et al.*, 2022). Consequently, impulsive sound generated during seismic surveys provides a plausible pathway for behavioural, physiological and, under sufficiently intense exposure conditions, physical effects.

Experimental studies have demonstrated responses to seismic or other impulsive sound in several invertebrate taxa. (Day *et al.*, 2017) reported effects associated with seismic exposure in marine invertebrates, while behavioural responses to impulsive sound have also been demonstrated in cephalopods (Jones *et al.*, 2022). However, extrapolation from experimental exposures to free-ranging animals and natural communities remains difficult because responses depend on species, source characteristics, exposure regime and environmental conditions. (Day *et al.*, 2017)

consequently identified substantial knowledge gaps limiting the development of generally applicable noise-management criteria, and robust harmful-exposure thresholds have not been established across major invertebrate groups (Buscaino *et al.*, 2019; Jones *et al.*, 2019).

Acoustic and vibratory cues may also influence settlement and habitat-selection processes in some invertebrates. Reef-associated organisms can detect low-frequency components of natural soundscapes (Tricas and Boyle, 2014; Jones *et al.*, 2022), and experimental evidence indicates that anthropogenic noise can alter settlement behaviour in coral larvae (Lecchini *et al.*, 2018). These findings demonstrate that effects need not be restricted to direct physical injury and may include disruption of sensory or behavioural processes. Nevertheless, responses documented for reef-associated species should not be assumed to apply directly to the invertebrate assemblages potentially encountered during the SUBTRANS survey.

Available evidence concerning physical and physiological effects is similarly variable. (Heyward *et al.*, 2018), for example, reported no immediate physical damage to tissues or skeletal structures in mesophotic corals exposed during seismic-survey conditions, illustrating that detectable effects are not universal among taxa or exposure scenarios. Conversely, reviews of seismic effects have identified potential impacts on sensory structures and other physiological processes in some marine invertebrates (Carroll *et al.*, 2017). Collectively, the available evidence therefore indicates the potential for effects under some exposure conditions but does not support a single response or effect threshold applicable across marine invertebrates.

The sound transmission-loss modelling presented in **APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING** characterises the sound-pressure component of the seismic field but does not model acoustic particle motion. This is an important limitation for assessment of marine invertebrates, many of which detect sound principally through particle motion rather than sound pressure. The standardised 3,600-s SEL_{cum} fields therefore cannot be interpreted as maps of biologically relevant exposure or used to delineate general behavioural, physiological or injury zones for invertebrates. They nevertheless demonstrate that the pressure component of the seismic field can propagate over substantial and strongly direction-dependent distances, particularly under deep-water conditions. Potential responses during the proposed survey will therefore depend strongly on taxon, life stage, habitat and proximity to the active source. Mobile organisms may exhibit temporary behavioural responses or avoidance where capable of doing so, whereas sessile organisms and planktonic or early life stages cannot actively move away from an approaching source to the same extent. The survey is temporary and spatially progressive, limiting the duration of exposure at any fixed location, although this does not preclude exposure or biological responses while the source is nearby.

Overall, temporary behavioural or physiological responses in some marine invertebrates cannot be excluded, and effects under comparatively high exposure conditions may occur in susceptible taxa. However, the available evidence does not provide a robust basis for defining a general invertebrate effect radius or predicting a uniform response across the diverse taxa potentially exposed. Persistent population- or community-level effects are not predicted on the basis of the available evidence and the nature of the proposed survey, although substantial

uncertainty remains because responses to seismic sound have been investigated in only a limited subset of marine invertebrate taxa.

6.2.3.6. Zooplankton

Zooplankton may be exposed to seismic sound throughout the water column, and their limited capacity for active avoidance distinguishes them from many larger mobile marine receptors. Sensitivity is likely to vary substantially among taxa and developmental stages because zooplankton comprise organisms with diverse body structures, sensory systems and life histories. Consequently, responses observed in particular experimental taxa or exposure conditions should not be assumed to represent zooplankton communities generally.

(McCauley *et al.*, 2017) reported increased zooplankton mortality following exposure to a seismic airgun in a field experiment, with effects detected beyond the immediate vicinity of the source. The study provides evidence that seismic exposure can affect some zooplankton under particular experimental and environmental conditions. However, the reported spatial pattern should not be interpreted as establishing a general 1.2 km mortality radius for seismic surveys. The magnitude and spatial extent of effects are likely to depend on source characteristics, exposure conditions, zooplankton composition and environmental variability, and extrapolation from individual experimental observations to community- or ecosystem-level consequences remains uncertain.

Potential effects on zooplankton are therefore most appropriately considered in terms of short-term changes in survival or abundance among susceptible organisms rather than as a uniform response across the plankton community. Because zooplankton occupy an important trophic position, sufficiently large or persistent reductions could theoretically affect prey availability for planktivorous fish and higher trophic levels. The available evidence does not, however, demonstrate that localised responses to seismic exposure necessarily translate into persistent reductions in zooplankton populations or measurable effects at higher trophic levels.

Zooplankton within the GCS are naturally subject to pronounced spatial and temporal variability associated with water-mass structure, advection, upwelling, tidal mixing and other hydrodynamic processes. Previous studies in the region have demonstrated changes in zooplankton community structure associated with the formation and advection of upwelling plumes, together with areas of elevated zooplankton biomass and active nutrient recycling (James and Wilkinson, 1988; Bradford-Grieve *et al.*, 1993). These naturally dynamic conditions provide important ecological context for assessing any short-term changes associated with the proposed survey but should not be interpreted as demonstrating that anthropogenic effects would necessarily be ecologically insignificant.

The sound transmission-loss modelling presented in **APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING** characterises the sound-pressure field generated under the representative modelled seismic scenarios. It does not incorporate zooplankton-specific biological effect thresholds and therefore cannot be used to delineate a mortality or other biological-effect radius for zooplankton. The standardised 3,600-s SEL_{cum} distributions similarly represent comparative propagation behaviour rather than the operational exposure history of individual planktonic organisms, whose exposure would additionally depend on their position and transport relative to the moving seismic source.

The proposed survey is temporary and spatially progressive, and any individual water mass will therefore experience changing exposure conditions as the active source approaches and moves away. Zooplankton may nevertheless be unable to avoid the source actively, and short-term effects on susceptible organisms cannot be excluded where exposure is sufficiently high. Overall, the available evidence supports the potential for localised effects on zooplankton abundance or survival during seismic acquisition but does not provide a robust basis for predicting their magnitude or spatial extent for the SUBTRANS survey. Persistent community-or ecosystem-level effects are not predicted on the basis of the available evidence, although uncertainty remains because empirical studies of seismic effects on zooplankton are limited and extrapolation across taxa and environmental settings is difficult.

6.3. Summary

The impact assessment evaluated the potential effects of the proposed SUBTRANS Level 1 seismic survey on marine mammals and other marine receptors within Cook Strait and the southern Hikurangi Margin. Potential effects associated with survey-vessel operations and seismic acquisition were considered using published scientific evidence, species-specific ecological information, available records of marine-mammal occurrence, conservation status under the New Zealand Threat Classification System (NZTCS), the requirements of the 2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations, and the sound transmission-loss modelling presented in **APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING**.

For marine mammals, population-exposure scores were developed using the available evidence of occurrence within the area of biological relevance rather than treating modelled relative-distribution indices as measures of relative abundance among species. Receptor valuation was based primarily on current NZTCS status, with international conservation status used where appropriate for non-resident taxa. These revised parameters were incorporated into the species-specific residual-risk assessment together with impact likelihood and severity.

Potential effects associated with vessel operations included collision, behavioural disturbance, displacement from habitat and masking from underwater radiated noise. The relatively low survey speed and use of a single principal survey vessel limit collision opportunity, although susceptibility differs among species and collision cannot be excluded. Temporary behavioural responses, displacement and masking may occur where animals encounter the survey vessel or its radiated noise. Following application of the species-specific exposure and valuation framework and the proposed mitigation measures, the calculated residual risks associated with vessel operations were generally within the lower risk categories, although values varied among species according to occurrence, conservation value and the particular impact pathway.

The principal potential effects associated with seismic acquisition comprised non-auditory physical injury, auditory effects, behavioural disturbance, acoustic masking and indirect effects mediated through prey. The sound transmission-loss modelling demonstrated strongly direction-dependent propagation controlled by water depth, bathymetry and propagation pathway, with the deep-water scenario producing a substantially larger acoustic propagation domain than the shallow-water scenario. The standardised 3,600-s SEL_{cum} fields used for comparative propagation analysis demonstrate that seismic sound may extend over a broad

region in some directions and should not be interpreted as operational cumulative exposure experienced by an individual animal.

For the specific assessment required at the mitigation-zone receiver distances, received SELs were evaluated using a 1-s reference exposure and the representative broadband source level adopted for the current 5,420-in³ G-Gun array. Under these representative modelling conditions, received SEL remained below the 2013 Code criteria of 186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$ at 200 m and 171 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$ at 1 km and 1.5 km for the modelled receiver scenarios. The screening assessment therefore does not indicate a requirement to expand the prescribed mitigation zones on the basis of these modelled receiver levels. This comparison is distinct from the standardised 3,600-s SEL_{cum} propagation fields and remains subject to the modelling assumptions and limitations described in **APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING**.

Compliance with the 2013 Code, including pre-start observations, soft-start procedures, application of the prescribed mitigation zones, shutdown and delayed-start requirements, and monitoring by qualified and trained MMOs and PAMOs as applicable, provides the principal operational framework for reducing the likelihood of close-range exposure. PAM provides an important complement to visual monitoring, particularly for vocalising animals and during conditions in which visual detection is constrained, while its effectiveness remains dependent on species vocal behaviour, source activity and operational conditions.

Auditory masking and behavioural disturbance may occur at received levels substantially below those associated with injury-related criteria and therefore cannot be assumed to be restricted to the immediate vicinity of the seismic source. The regional modelling demonstrates the potential for comparatively broad and anisotropic propagation, particularly under deep-water conditions. The spatial extent and biological significance of masking or behavioural response cannot, however, be derived directly from the modelled SEL_{cum} fields because response depends on species-specific hearing characteristics, vocalisation frequencies, behavioural context, received sound characteristics and exposure history. The species-specific residual-risk assessment consequently treats these pathways separately from close-range physical and auditory injury.

Indirect effects on marine mammals may occur if seismic exposure alters the abundance, distribution or behaviour of prey organisms. Such effects require an ecological pathway from a response in prey organisms through a change in prey availability to a consequential effect on the marine-mammal receptor. On the basis of the available evidence, persistent prey-mediated population effects are not predicted, although uncertainty remains for some prey taxa and early life stages. In-combination effects among SUBTRANS-related pathways and cumulative effects with other anthropogenic activities were also considered. The information available did not identify a specific concurrent activity sufficiently characterised to predict a material additive or synergistic increase in effects, and no separate quantitative cumulative residual-risk category was assigned.

Potential unplanned events, including vessel collision or sinking, accidental release of hazardous materials and loss of equipment, were considered qualitatively because their contingent nature is not appropriately represented by the species-specific residual-risk matrix. These risks are principally addressed through preventative vessel-management, emergency-response and equipment-recovery procedures rather than through assignment of a formal residual-risk category.

Other marine receptors considered comprised seabirds, marine reptiles, fish, sharks and rays, marine invertebrates and zooplankton. These groups were assessed qualitatively because the species-specific population-exposure and receptor-valuation framework applied to marine mammals was not applied to these broad receptor categories. Available evidence indicates that temporary behavioural, physiological or localised effects may occur in susceptible taxa during seismic exposure, while the magnitude and spatial extent of responses vary substantially among taxa, life stages and exposure conditions. The sound-pressure modelling cannot be translated directly into biological-effect zones for these receptors, particularly for fish, elasmobranchs and many invertebrates for which particle motion is an important component of acoustic detection. Persistent population- or community-level effects are not predicted on the basis of the available evidence and the temporary, spatially progressive nature of the proposed survey, although important uncertainties remain.

Overall, the assessment indicates that the proposed SUBTRANS survey has the potential to produce temporary behavioural, acoustic and ecological effects, with the magnitude and spatial extent varying among receptors and impact pathways. The greatest potential for physical or auditory effects occurs at comparatively high exposures close to the active seismic source, whereas behavioural disturbance and masking may extend over substantially greater distances. Application of the mitigation requirements of the 2013 Code reduces the likelihood of close-range exposure of marine mammals, while the revised species-specific assessment accounts explicitly for differences in occurrence and conservation status. The assessment does not predict persistent population-level effects from the proposed survey on the basis of the information available, but recognises uncertainty associated with species occurrence, behavioural responsiveness, acoustic propagation and the limited empirical evidence available for several receptor groups.

7. RESEARCH OPPORTUNITY

The SUBTRANS survey represents a rare opportunity to undertake a comprehensive marine megafauna assessment in offshore waters of central New Zealand that remain comparatively understudied. Dedicated MMOs and PAM effort throughout the survey will provide a unique dataset that extends beyond regulatory mitigation requirements and has the potential to support multiple scientific outputs.

The survey will generate integrated datasets comprising visual observations, PAM detections, photographic records, environmental variables, operational information, and geospatial data collected across a large offshore area. Combined, these datasets facilitate assessment of marine mammal occurrence, distribution, habitat use, and detectability in relation to environmental and operational factors.

From a scientific perspective, the resulting dataset has significant potential to support a peer-reviewed publication. Potential areas of investigation include:

- Characterisation of marine mammal and other marine megafauna species assemblages, and potential previously undocumented sightings within offshore waters of central New Zealand;
- Temporo-spatial patterns of marine mammal occurrence in relation to oceanographic and environmental conditions;

- Comparative analysis of visual and acoustic detection methods for offshore marine mammal monitoring;
- Distribution and acoustic occurrence of deep-diving odontocetes, including beaked and sperm whales, for which regional information remains limited;
- Relationships between marine mammal occurrence and seabed features, bathymetry, oceanographic fronts, and productivity patterns;
- Evaluation of detection probabilities and monitoring effectiveness under varying environmental conditions;
- Examination of marine mammal occurrence during seismic operations and assessment of mitigation effectiveness; and,
- Development of quasi-baseline ⁴ datasets against which future offshore surveys and long-term monitoring programmes may be compared.

The survey is particularly valuable because it combines visual and acoustic monitoring in an area where offshore marine mammal records remain relatively sparse. PAM detections have potential to increase understanding of presence, distribution, and vocal behaviour of cryptic and deep-diving species that are often underrepresented in visual observation datasets. Simultaneously, photographic records collected during the survey may support post-survey species verification, individual identification, and potential contributions to regional photo-identification catalogues. The dataset may also contribute to broader understanding of New Zealand's offshore marine ecosystems by documenting the occurrence of marine mammals alongside other marine fauna, thereby providing insights into community composition and habitat utilisation across a large offshore area. These data could inform future environmental assessments, marine spatial planning initiatives, and conservation management strategies.

Following completion of the survey, a dedicated research report will be produced summarising marine mammal and other fauna observations. Subject to the necessary approvals and permissions, the resulting datasets may be made available to researchers and interested stakeholders, thereby facilitating future collaborative analyses and increasing the scientific value of the survey beyond its primary operational objectives. A potential peer-reviewed paper title could be '*Marine mammal occurrence, habitat associations, and detection effectiveness during an offshore seismic survey in central New Zealand: integrating visual and passive acoustic monitoring datasets*'. That paper would be considerably stronger scientifically than a simple sightings summary because it would combine ecology, habitat modelling, detection methodology, and offshore monitoring effectiveness in a region where published data remain limited.

7.1. Future scientific applications

In addition to valuable data that will be collected during the SUBTRANS survey, several future research opportunities have been identified that could further improve marine mammal mitigation and monitoring during seismic surveys in New Zealand waters. The SUBTRANS survey will provide a rare opportunity to collect high-quality visual, acoustic, environmental, and operational datasets from offshore New Zealand waters. These data could be used to improve understanding of species occurrence, seasonal distribution, habitat use, group composition (but

⁴ A true Before-After-Control-Impact (BACI) study would be required to establish baseline patterns of species occurrence and to quantitatively assess any survey-related effects and could be considered in future work; however, the present study was not intended as an impact assessment. Instead, any anomalous observations were documented within the context of mitigation and monitoring activities and were therefore interpreted qualitatively rather than as evidence of impact.

not interpretation of behavioural responses, which would require a BACI study and/or tagging) to survey activities, and detection probabilities under varying environmental conditions. Value may be derived from detections of rarely observed offshore odontocetes, including beaked whales and other deep-diving species, for which knowledge gaps remain substantial. Future analyses could also investigate relationships between marine mammal detections and environmental variables such as sea state, wind speed, prey distribution (fisheries and AIS data), bathymetry, oceanographic fronts, and vessel operations. Such studies would contribute to improved predictive habitat models and more effective spatial and temporal planning of future offshore activities.

A particularly promising area of future research concerns the continued development of marine mammal monitoring technologies for use during periods of low visibility. OSC recently conducted a study on behalf of the Exploration & Production (E&P) Sound & Marine Life Joint Industry Programme (JIP) examining the effectiveness of marine mammal detection technologies under low-visibility conditions (<https://www.soundandmarinelife.org/low-visibility-marine-mammal-detection/>). During vessel-based field trials, IR, RADAR, and SONAR systems were evaluated, with both IR and RADAR demonstrating considerable potential as complementary marine mammal detection technologies.

Building upon these findings, future seismic surveys off New Zealand could investigate the integration of multi-modal detection technologies and real-time sensor fusion systems that combine visual observations from MMOs with PAM detections, IR and RADAR systems. Such integrated mitigation platforms could improve monitoring effectiveness substantially during darkness, fog, precipitation, glare, and other periods of reduced visibility, thereby increasing overall detection capability and supporting more informed mitigation decisions. Additional research opportunities include development and validation of automated detection algorithms, artificial intelligence-assisted species classification systems, and probabilistic decision-support tools capable of integrating multiple data streams in real time. These technologies could assist operators in rapidly assessing detection confidence and mitigation requirements while reducing observer workload. The large volume of visual and acoustic data generated during future surveys could also support the development of machine-learning approaches for automated recognition of marine mammal vocalisations, particularly for poorly understood species such as beaked whales. Such work could improve species-specific detection performance and contribute to regional acoustic reference libraries for New Zealand waters.

Long-term collaborative research programmes that combine datasets from multiple surveys could further improve understanding of marine mammal distribution patterns, migration routes, habitat use and population connectivity. This would provide an increasingly robust scientific basis for future mitigation measures and marine spatial planning initiatives. Collectively, these research opportunities have potential not only to improve effectiveness of marine mammal mitigation during seismic surveys, but also to contribute significantly to the broader understanding and conservation of marine mammals in New Zealand waters. By integrating emerging technologies, advanced analytical approaches and long-term monitoring datasets, future surveys could help establish New Zealand as a leading region for the development and implementation of next-generation marine mammal mitigation practices.

8. CONCLUSIONS

This MMIA evaluated the potential effects of the proposed SUBTRANS Level 1 seismic survey on marine mammals and other marine ecological receptors within Cook Strait and the southern Hikurangi Margin. The revised assessment incorporates available information on receptor occurrence and conservation status, published evidence concerning responses to vessel activity and impulsive underwater sound, and the sound transmission-loss modelling presented in **APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING**.

For marine mammals, the assessment identified potential effects associated with vessel operations and seismic acquisition, including collision, behavioural disturbance, displacement, masking, physical and auditory effects, and indirect effects mediated through prey. Following revision of the species-specific population-exposure and receptor-valuation parameters, residual risks varied among species and impact pathways but were generally concentrated within the lower risk categories. Other ecological receptors were assessed qualitatively, with temporary behavioural, physiological or localised effects considered possible in susceptible taxa, but persistent population- or community-level effects were not predicted on the basis of the available evidence.

The sound transmission-loss modelling demonstrates that seismic sound propagation is strongly influenced by water depth, bathymetry and direction, with substantially broader propagation under the representative deep-water scenario. The standardised 3,600-s SEL_{cum} fields describe comparative regional propagation behaviour and should not be interpreted as operational cumulative exposure experienced by an individual receptor. For the separate receiver-specific comparison with the 2013 Code of Conduct, representative 1-s received SELs at 200 m, 1 km and 1.5 km remained below the corresponding Code criteria. The modelling therefore does not indicate a requirement to expand the prescribed mitigation zones on the basis of these receiver levels, subject to the assumptions and limitations described in **APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING**.

Compliance with the 2013 Code provides the principal operational framework for reducing the likelihood of close-range exposure of marine mammals through pre-start observations, soft starts, prescribed mitigation zones, delayed starts and shutdowns, supported by MMO and PAM monitoring as applicable. However, compliance with these receiver criteria should not be interpreted as demonstrating the absence of behavioural disturbance or masking beyond the mitigation zones, as such responses may occur at substantially lower received levels and their spatial extent depends on species-specific and contextual factors.

For the most part, the revised assessment indicates that potential effects associated with the proposed SUBTRANS survey are expected to be predominantly temporary and context-dependent. On the basis of the revised impact assessment, representative acoustic modelling and proposed mitigation framework, persistent population-level effects on the assessed receptors are not predicted. This conclusion is conditional on implementation of the applicable regulatory and mitigation requirements and recognises the uncertainties inherent in species occurrence, behavioural responsiveness, acoustic propagation and the available empirical evidence.

9. REFERENCES

- Aaron, K.D., Greer, A.T., Duffy, P.I., Treible, L.M., and Frischer, M.E. (2025): Stratification intensity structures zooplankton functional trait composition in a continental shelf system. *ICES Journal of Marine Science* **82**, fsaf089.
- Abraham, E., Agnew, D., Agnew, P., Aikman, H., Allen, N., Angus, I., Baird, K., Baker, B., Barnard, T., and Bartle, S. (2014): New Zealand Seabirds: Important Bird Areas and Conservation. The Royal Forest & Bird Protection Society of New Zealand.
- Abraham, E.R., and Berkenbusch, K. (2017): *Estimated Captures of New Zealand Fur Seal, New Zealand Sea Lion, Common Dolphin, and Turtles in New Zealand Commercial Fisheries, 1995-96 to 2014-15*. Ministry for Primary Industries, Manatū Ahu Matua.
- Acevedo, J., Olavarria, C., Plana, J., Aguayo-Lobo, A., Larrea, A., and Pastene, L.A. (2011): Occurrence of dwarf minke whales (*Balaenoptera acutorostrata* subsp.) around the Antarctic Peninsula. *Polar Biology* **34**, 313–318.
- Aguilar, A. (2000): Population biology, conservation threats and status of Mediterranean striped dolphins (*Stenella coeruleoalba*). *Cetacean Resource Management* **2**, 17–26.
- Ainslie, M.A. (2010): *Principles of sonar performance modelling*. Springer.
- Alafaro-Shigueto, J., Crespo, E., Elwen, S., Lundquist, D., and Mangel, J. (2019): *Lagenorhynchus obscurus* (amended version of 2019 assessment). The IUCN Red List of Threatened Species 2019: e. T11146A160698904.
- Alestra, T., Gerrity, S., Dunmore, R., Crossett, D., Orchard, S., and Schiel, D.R. (2021): *Rocky reef impacts of the 2016 Kaikōura earthquake: Extended monitoring of nearshore habitats and communities to 3.5 years*. Ministry for Primary Industries.
- Alvarez-Costes, S., Baker, C., Constantine, R., Carroll, E., Guhlin, J., Dutoit, L., Ferreira, S., Heimeier, D., Gemmell, N., and Gillum, J. (2025): Leveraging synteny to generate reference genomes for conservation: assembling the genomes of Hector's and Māui dolphins. *Molecular Ecology Resources* **25**, e14109.
- Alves, D., Amorim, M., and Fonseca, P. (2025): The swimbladder does not enhance hearing in the Lusitanian toadfish. *Marine Biology* **172**, 131.
- Amaral, A.R., Beheregaray, L.B., Bilgmann, K., Boutov, D., Freitas, L., Robertson, K.M., Sequeira, M., Stockin, K.A., Coelho, M.M., and Möller, L.M. (2012): Seascape genetics of a globally distributed, highly mobile marine mammal: the short-beaked common dolphin (genus *Delphinus*). *PLoS ONE* **7**, e31482.
- Andersen, S.M., Teilmann, J., Dietz, R., Schmidt, N.M., and Miller, L.A. (2012): Behavioural responses of harbour seals to human-induced disturbances. *Aquatic Conservation: Marine and Freshwater Ecosystems* **22**, 113–121.
- Anderson, A. (2025): *The Welcome of Strangers: A History of Southern Māori*. Bridget Williams Books.
- Anderson, M.J., and Millar, R.B. (2004): Spatial variation and effects of habitat on temperate reef fish assemblages in northeastern New Zealand. *Journal of Experimental Marine Biology and Ecology* **305**, 191–221.
- Anderwald, P., Brandecker, A., Coleman, M., Collins, C., Denniston, H., Haberlin, M.D., Donovan, M., Pinfield, R., Visser, F., and Walshe, L. (2013): Displacement responses of a mysticete, an odontocete, and a phocid seal to construction-related vessel traffic. *Endangered Species Research* **21**, 231–240.
- Andre, M., Sole, M., Lenoir, M., Durfort, M., Quero, C., Mas, A., Lombarte, A., van der Schaar, M., Lopez-Bejar, M., Morell, M., Zaugg, S., and Houegnigan, L. (2011): Low-frequency sounds induce acoustic trauma in cephalopods. *Frontiers in Ecology and the Environment* **9**, 489–493.

- André, M., van der Schaar, M., Zaugg, S., Houégnigan, L., Sánchez, A., Mas, A., and Castell, J.V. (2010): Real-time monitoring of noise in cetacean acoustic niches. 2nd International Conference on the effects of noise on aquatic marine life on 15-20th August, Cork, pp. 7.
- Archer II, F.I. (2018): Striped dolphin: *Stenella coeruleoalba*: *Encyclopedia of marine mammals*. Elsevier, pp. 954–956.
- Arrial, L.G.R., Correa, T.d.P., de Castilho, P.V., and Machado, R. (2024): New record of the southern right whale dolphin, *Lissodelphis peronii* (Lacépède, 1804), in the coastal waters of Brazil. *Polar Biology* **47**, 1169–1173.
- Austin, H. (2021): Sei whale (*Balaenoptera borealis*) 5-year review: Summary and evaluation. NOAA, National Marine Fisheries Service Office of Protected Resources.
- Australian Museum (2024): Strap-toothed Whale. Available at: <https://australian.museum/learn/animals/mammals/strap-toothed-whale/>
- Authority, G.B.R.M.P. (2011): A vulnerability assessment for the Great Barrier Reef: Dwarf minke whales.
- Azzolin, M., Arcangeli, A., Cipriano, G., Crosti, R., Maglietta, R., Pietroluongo, G., Saintingan, S., Zampollo, A., Fanizza, C., and Carlucci, R. (2020): Spatial distribution modelling of striped dolphin (*Stenella coeruleoalba*) at different geographical scales within the EU Adriatic and Ionian Sea Region, central-eastern Mediterranean Sea. *Aquatic Conservation: Marine and Freshwater Ecosystems* **30**, 1194–1207.
- Baird, R.W., Brownell Jr., R.L., and Taylor, B.L. (2020): *Ziphius cavirostris*, Vol. e.T23211A50379111. IUCN, The IUCN Red List of Threatened Species.
- Baker, C.S., Boren, L.J., Childerhouse, S., Constantine, R., Van Helden, A., Lundquist, D., Rayment, W., and Rolfe, J.R. (2019): *Conservation status of New Zealand marine mammals, 2019*. Publishing Team, Department of Conservation.
- Barlow, D.R., Torres, L.G., Hodge, K.B., Steel, D., Baker, C.S., Chandler, T.E., Bott, N., Constantine, R., Double, M.C., and Gill, P. (2018): Documentation of a New Zealand blue whale population based on multiple lines of evidence. *Endangered Species Research* **36**, 27–40.
- Barlow, D.R. (2022): Ecology and distribution of blue whales in New Zealand across spatial and temporal scales.
- Barlow, D.R., Klinck, H., Ponirakis, D., Holt Colberg, M., and Torres, L.G. (2023): Temporal occurrence of three blue whale populations in New Zealand waters from passive acoustic monitoring. *Journal of Mammalogy* **104**, 29–38.
- Barnes, P.M., de Lépinay, B.M., Collot, J.Y., Delteil, J., and Audru, J.C. (1998): Strain partitioning in the transition area between oblique subduction and continental collision, Hikurangi margin, New Zealand. *Tectonics* **17**, 534–557.
- Barnes, P.M., Lamarche, G., Bialas, J., Henrys, S., Pecher, I., Netzeband, G.L., Greinert, J., Mountjoy, J.J., Pedley, K., and Crutchley, G. (2010): Tectonic and geological framework for gas hydrates and cold seeps on the Hikurangi subduction margin, New Zealand. *Marine Geology* **272**, 26–48.
- Bary, B.M. (1959): Plankton. *Proceedings of the New Zealand Ecological Society* **4**, 28–29.
- Basan, F., Fischer, J.G., Putland, R., Brinkkemper, J., de Jong, C.A.F., Binnerts, B., Norro, A., Kühnel, D., Ødegaard, L.A., Andersson, M., and Lalander, E. (2024): The underwater soundscape of the North Sea. *Marine Pollution Bulletin* **198**, 115891.
- Bayrakci, G., and Klingelhoefer, F. (2023): *Noisy Oceans: Monitoring Seismic and Acoustic Signals in the Marine Environment*. John Wiley & Sons.

- Beentjes, M.P., Bull, B., Hurst, R.J., and Bagley, N.W. (2002): Demersal fish assemblages along the continental shelf and upper slope of the east coast of the South Island. *New Zealand Journal of Marine and Freshwater Research* **36**.
- Behrenfeld, M.J., O'Malley, R.T., Siegel, D.A., McClain, C.R., Sarmiento, J.L., Feldman, G.C., Milligan, A.J., Falkowski, P.G., Letelier, R.M., and Boss, E.S. (2006): Climate-driven trends in contemporary ocean productivity. *Nature* **444**, 752–5.
- Bejder, L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R., Heithaus, M., Watson-capps, J., Flaherty, C., and Krützen, M. (2006): Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conservation Biology* **20**, 1791–1798.
- Benda-Beckmann, A.M.v., Wensveen, P.J., Prior, M., Ainslie, M.A., Hansen, R.R., Isojunno, S., Lam, F.P.A., Kvadsheim, P.H., and Miller, P.J.O. (2019): Predicting acoustic dose associated with marine mammal behavioural responses to sound as detected with fixed acoustic recorders and satellite tags. *The Journal of the Acoustical Society of America* **145**, 1401–1416.
- Berkenbusch, K., Abraham, E.R., and Torres, L.G. (2013): *New Zealand marine mammals and commercial fisheries*. Ministry for Primary Industries.
- Best, P.B., Meyer, M.A., Thornton, M., Kotze, P.J.H., Seakamela, S.M., Hofmeyr, G.J.G., Wintner, S., Weland, C.D., and Steinke, D. (2014): Confirmation of the occurrence of a second killer whale morphotype in South African waters. *African Journal of Marine Science* **36**, 215–224.
- Betty, E.L., Stockin, K.A., Hinton, B., Bollard, B.A., Orams, M.B., and Murphy, S. (2023): Age-and sex-specific survivorship of the Southern Hemisphere long-finned pilot whale (*Globicephala melas edwardii*). *Journal of Mammalogy* **104**, 39–48.
- Bilich, A., Frohlich, C., and Mann, P. (2001): Global seismicity characteristics of subduction-to-strike-slip transitions. *Journal of Geophysical Research: Solid Earth* **106**, 19443–19452.
- Blackwell, S.B., Nations, C.S., McDonald, T.L., Thode, A.M., Mathias, D., Kim, K.H., Greene, C.R., Jr., and Macrander, A.M. (2015): Effects of airgun sounds on bowhead whale calling rates: evidence for two behavioral thresholds. *PLoS ONE* **10**, e0125720.
- Blair, H.B., Merchant, N.D., Friedlaender, A.S., Wiley, D.N., and Parks, S.E. (2016): Evidence for ship noise impacts on humpback whale foraging behaviour. *Biology Letters* **12**, 20160005.
- Boeger, W.A., Pie, M.R., Ostrensky, A., and Cardoso, M.F. (2006): The effect of exposure to seismic prospecting on coral reef fishes. *Brazilian Journal of Oceanography* **54**, 235–239.
- Bolam, S., Fernandes, T., and Huxham, M. (2002): Diversity, biomass, and ecosystem processes in the marine benthos. *Ecological Monographs* **72**, 599–615.
- Boschen-Rose, R.E., Clark, M.R., Rowden, A.A., and Gardner, J.P.A. (2021): Assessing the ecological risk to deep-sea megafaunal assemblages from seafloor massive sulfide mining using a functional traits sensitivity approach. *Ocean & Coastal Management* **210**, 105656.
- Bowman, M., Kibblewhite, A., Murtagh, R., Chiswell, S., and Sanderson, B. (1983): Circulation and mixing in greater Cook Strait, New-Zealand. *Oceanologica Acta* **6**, 383–391.
- Bradford-Grieve, J.M., Murdoch, R.C., and Chapman, B.E. (1993): Composition of macrozooplankton assemblages associated with the formation and decay of pulses within an upwelling plume in greater Cook Strait, New Zealand. *New Zealand Journal of Marine and Freshwater Research* **27**, 1–22.

- Bradford, J., Lapennas, P., Murtagh, R., Chang, F., and Wilkinson, V. (1986): Factors controlling summer phytoplankton production in greater Cook Strait, New Zealand. *New Zealand Journal of Marine and Freshwater Research* **20**, 253–279.
- Braithwaite, J.E., Meeuwig, J.J., and Hipsey, M.R. (2015): Optimal migration energetics of humpback whales and the implications of disturbance. *Conservation physiology* **3**, cov001–cov001.
- Branch, T.A., Abubaker, E.M.N., Mkango, S., and Butterworth, D.S. (2007a): Separating southern blue whale subspecies based on length frequencies of sexually mature females. *Marine Mammal Science* **23**, 803–833.
- Branch, T.A., Stafford, K.M., Palacios, D.M., Allison, C., Bannister, J.L., Burton, C.L.K., Cabrera, E., Carlson, C.A., Galletti Vernazzani, B., and Gill, P.C. (2007b): Past and present distribution, densities and movements of blue whales *Balaenoptera musculus* in the Southern Hemisphere and northern Indian Ocean. *Mammal Review* **37**, 116–175.
- Brand, D., Edelist, D., Goffman, O., Hadar, N., Scheinin, A., and Kerem, D. (2021): Common dolphins, common in neritic waters off southern Israel, demonstrate uncommon dietary habits. *Aquatic Conservation: Marine and Freshwater Ecosystems* **31**, 15–21.
- Braulik, G. (2018a): *Lissodelphis peronii*, Vol. e.T12126A50362558. IUCN, The IUCN Red List of Threatened Species.
- Braulik, G. (2018b): *Tasmacetus shepherdii*, Shepherd's Beaked Whale.
- Braulik, G. (2019): *Stenella coeruleoalba*, Vol. e.T20731A50374282. IUCN, The IUCN Red List of Threatened Species.
- Braulik, G., Jefferson, T.A., and Bearzi, G. (2021): *Delphinus delphis*, Vol. e.T134817215A199893039. IUCN, The IUCN Red List of Threatened Species.
- Brough, T., Kereopa, H., Shirkey, T., Zaeschmar, J., Leunissen, E., Milner, D., and Chetham, J. (2025): Tere Tohorā, Karanga Tāngata: Weaving Māori Knowledge With Conventional Science to Characterise a Biodiversity Hotspot for Marine Megafauna in an Area Facing Multiple Anthropogenic Impacts. *Ecology and Evolution* **15**, e72558.
- Brownell Jr., R.L., and Taylor, B.L. (2021): *Berardius arnuxii*, Vol. e.T2762A197190014. IUCN, The IUCN Red List of Threatened Species.
- Buscaino, G., Ceraulo, M., Giacalone, V.M., Papale, E., Gregoriotti, M., Mazzola, S., Rosario, G., Moyano MP, S., Di Fiore, V., Dioguardi, M., Mauro, M., Celi, M., and Vazzana, M. (2019): Effect of water gun on echinoderms: biochemical changes in sea urchin (*Arbacia lixula*) and sea cucumber (*Holothuria tubulosa*). Effects of Noise on Aquatic Life, Den Haag, The Netherlands.
- Butman, B. (1981): Currents and sediment movement on Georges Bank: *Georges Bank*. CRC Press, pp. 31–59.
- Caputo, M., Elwen, S., Gridley, T., Kohler, S.A., Roux, J.-P., Froneman, P.W., and Kiszka, J.J. (2021): Dietary plasticity of two coastal dolphin species in the Benguela upwelling ecosystem. *Marine Ecology Progress Series* **669**, 227–240.
- Carome, W., Rayment, W., Slooten, E., Bowman, M.H., and Dawson, S.M. (2023): Vessel traffic influences distribution of Aotearoa New Zealand's endemic dolphin (*Cephalorhynchus hectori*). *Marine Mammal Science* **39**, 626–647.
- Carroll, A.G., Przeslawski, R., Duncan, A., Gunning, M., and Bruce, B. (2017): A critical review of the potential impacts of marine seismic surveys on fish & invertebrates. *Marine Pollution Bulletin* **114**, 9–24.
- Carroll, E.L., Rayment, W.J., Alexander, A.M., Baker, C.S., Patenaude, N.J., Steel, D., Constantine, R., Cole, R., Boren, L.J., and Childerhouse, S. (2014):

- Reestablishment of former wintering grounds by New Zealand southern right whales. *Marine Mammal Science* **30**, 206–220.
- Carter, L. (1992): Acoustical characterisation of seafloor sediments and its relationship to active sedimentary processes in Cook Strait, New Zealand. *New Zealand Journal of Geology and Geophysics* **35**, 289–300.
- Cerchio, S., Strindberg, S., Collins, T., Bennett, C., and Rosenbaum, H.C. (2014): Seismic surveys negatively affect humpback whale singing activity off Northern Angola. *PLoS ONE* **9**, e86464.
- Chandel, P., Mahajan, D., Thakur, K., Kumar, R., Kumar, S., Brar, B., Sharma, D., and Sharma, A.K. (2024): A review on plankton as a bioindicator: A promising tool for monitoring water quality. *World Water Policy* **10**, 213–232.
- Chapuis, L., Kerr, C.C., Collin, S.P., Hart, N.S., and Sanders, K.L. (2019): Underwater hearing in sea snakes (Hydrophiinae): first evidence of auditory evoked potential thresholds. *Journal of Experimental Biology* **222**, jeb198184.
- Childerhouse, S., Jackson, J., Baker, C.S., Gales, N., Clapham, P.J., and Brownell Jr., R.L. (2008): *Megaptera novaeangliae* (Oceania subpopulation). International Union for Conservation of Nature and Natural Resources.
- Chilvers, B.L., and Goldsworthy, S.D. (2015): *Arctocephalus forsteri*. The IUCN Red List of Threatened Species, pp. e. T41664A45230026.
- Chiswell, S.M., and Roemmich, D. (1998): The East Cape Current and two eddies: a mechanism for larval retention? *New Zealand Journal of Marine and Freshwater Research* **32**, 385–397.
- Chiswell, S.M., Bostock, H.C., Sutton, P.J.H., and Williams, M.J.M. (2015a): Physical oceanography of the deep seas around New Zealand: a review. *New Zealand Journal of Marine and Freshwater Research* **49**, 286–317.
- Chiswell, S.M., Calil, P.H., and Boyd, P.W. (2015b): Spring blooms and annual cycles of phytoplankton: a unified perspective. *Journal of Plankton Research* **37**, 500–508.
- Choat, J., and Ayling, A. (1987): The relationship between habitat structure and fish faunas on New Zealand reefs. *Journal of Experimental Marine Biology and Ecology* **110**, 257–284.
- Christiansen, B., Denda, A., and Christiansen, S. (2020): Potential effects of deep seabed mining on pelagic and benthopelagic biota. *Marine Policy* **114**, 103442.
- Christiansen, F., Rasmussen, M.H., and Lusseau, D. (2013): Inferring activity budgets in wild animals to estimate the consequences of disturbances. *Behavioural Ecology* **24**, 1415–1425.
- CIEEM (2018): Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater, Coastal and Marine version 1.3. Chartered Institute of Ecology and Environmental Management, Winchester.
- Clapham, P.J., and Baker, C.S. (2002): Modern whaling. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds): *Encyclopedia of Marine Mammals*. Academic Press, New York, pp. 1328–1332.
- Clark, C.W., Ellison, W.T., Southall, B.L., Hatch, L., Van Parijs, S.M., Frankel, A., and Ponirakis, D. (2009): Acoustic masking in marine ecosystems: intuitions, analysis, and implication. *Marine Ecology Progress Series* **395**, 201–222.
- Clark, K., Nissen, E., Howarth, J., Hamling, I., Mountjoy, J., Ries, W., Jones, K., Goldstien, S., Cochran, U., and Villamor, P. (2017): Highly variable coastal deformation in the 2016 MW7. 8 Kaikōura earthquake reflects rupture

- complexity along a transpressional plate boundary. *Earth and Planetary Science Letters* **474**, 334–344.
- Clement, D. (2024): Underwater noise/ocean sound. Cawthrn Institute on behalf of the Ministry for the Environment, New Zealand.
- Cole, R.G., Davey, N.K., Carbines, G.D., and Stewart, R. (2012): Fish-habitat associations in New Zealand: geographical contrasts. *Marine Ecology Progress Series* **450**, 131–145.
- Comesaña, A., Fernández-Castro, B., Chouciño, P., Fernández, E., Fuentes-Lema, A., Gilcoto, M., Pérez-Lorenzo, M., and Mouriño-Carballido, B. (2021): Mixing and phytoplankton growth in an upwelling system. *Frontiers in Marine Science* **8**, 712342.
- Conn, P.B., and Silber, G.K. (2013): Vessel speed restrictions reduce risk of collision-related mortality for North Atlantic right whales. *Ecosphere* **4**, art43.
- Connolly, T.P., and Hickey, B.M. (2014): Regional impact of submarine canyons during seasonal upwelling. *Journal of Geophysical Research: Oceans* **119**, 953–975.
- Constantine, R., Russell, K., Gibbs, N., Childerhouse, S., and Baker, C.S. (2007): Photo-identification of humpback whales (*Megaptera novaeangliae*) in New Zealand waters and their migratory connections to breeding grounds of Oceania. *Marine Mammal Science* **23**.
- Constantine, R., Johnson, M., Riekkola, L., Jervis, S., Kozmian-Ledward, L., Dennis, T., Torres, L.G., and de Soto, N.A. (2015): Mitigation of vessel-strike mortality of endangered Bryde's whales in the Hauraki Gulf, New Zealand. *Biological Conservation* **186**, 149–157.
- Constantine, R., Anderson, M., Andrews, O., Andrew-Goff, V., Baker, C., Childerhouse, S., Clapham, P., Dodemont, R., Donnelly, D., and Double, M. (2016): Humpback whale connectivity: preliminary findings on the Oceania to Antarctica migration path via the Kermadec Islands. *Paper submitted to the IWC Scientific Committee. SC/66b/SH*.
- Constantine, R. (2023): *Cephalorhynchus hectori* ssp. *maui*. The IUCN Red List of Threatened Species.
- Constaratas, A.N., McDonald, M.A., Goetz, K.T., and Giorli, G. (2021): Fin whale acoustic populations present in New Zealand waters: Description of song types, occurrence and seasonality using passive acoustic monitoring. *PLoS ONE* **16**, e0253737.
- Cooke, J.G. (2018a): *Caperea marginata*, Vol. e.T3778A50351626. IUCN, The IUCN Red List of Threatened Species.
- Cooke, J.G. (2018b): *Megaptera novaeangliae*, Vol. e.T13006A50362794. IUCN, The IUCN Red List of Threatened Species.
- Cooke, J.G. (2018c): *Balaenoptera borealis*, Vol. e.T2475A130482064. IUCN, The IUCN Red List of Threatened Species.
- Cooke, J.G. (2018d): *Balaenoptera musculus* (errata version published in 2019), Vol. e.T2477A156923585. IUCN, The IUCN Red List of Threatened Species.
- Courts of New Zealand (2026): Marine and Coastal Area (Takutai Moana) Act 2011 applications for recognition orders. Available at: <https://www.courtsofnz.govt.nz/the-courts/high-court/high-court-lists/marine-and-coastal-area-takutai-moana-act-2011-applications-for-recognition-orders>
- Covich, A.P., Palmer, M.A., and Cowl, T.A. (1999): The role of benthic invertebrate species in freshwater ecosystems: zoobenthic species influence energy flows and nutrient cycling. *BioScience* **49**, 119–127.
- Crowell, S.C. (2016): Measuring In-Air and Underwater Hearing in Seabirds. The Effects of Noise on Aquatic Life II, 2016//, New York, NY, pp. 1155–1160.

- Crum, L.A., and Mao, Y. (1996): Acoustically enhanced bubble growth at low frequencies and its implications for human diver and marine mammal safety. *The Journal of the Acoustical Society of America* **99**, 2898–2907.
- Crutchley, G.J., Klaeschen, D., Henrys, S., Pecher, I., Mountjoy, J., and Woelz, S. (2020): Subducted sediments, upper-plate deformation and dewatering at New Zealand's southern Hikurangi subduction margin. *Earth and Planetary Science Letters* **530**, 115945.
- Currie, J.J., McCordic, J.A., Olson, G.L., Machernis, A.F., and Stack, S.H. (2021): The impact of vessels on humpback whale behavior: the benefit of added whale watching guidelines. *Frontiers in Marine Science* **8**.
- Day, A. (2004): Fisheries in New Zealand: the Maori and the quota management system. *Report prepared for The First Nation Panel on Fisheries*.
- Day, R.D., McCauley, R.D., Fitzgibbon, Q.P., Hartmann, K., and Semmens, J.M. (2017): Exposure to seismic air gun signals causes physiological harm and alters behaviour in the scallop *Pecten fumatus*. *Proceedings of the National Academy of Sciences* **114**.
- dBSeaLtd (2026): dBSea. dBSea Ltd, United Kingdom.
- de Jong, K., Amorim, M.C.P., Fonseca, P.J., and Heubel, K.U. (2018): Noise affects multimodal communication during courtship in a marine fish. *Frontiers in Ecology and Evolution* **6**.
- De Leo, F.C., Smith, C.R., Rowden, A.A., Bowden, D.A., and Clark, M.R. (2010): Submarine canyons: hotspots of benthic biomass and productivity in the deep sea. *Proceedings of the Royal Society B: Biological Sciences* **277**, 2783–2792.
- Dedden, A.V., Kemper, C.M., Truong, G., McCurry, M.R., van Ruth, P.D., and Rogers, T.L. (2023): Stable isotopes infer the diet and habitat of the enigmatic pygmy right whale (*Caperea marginata*) off southern Australia. *Frontiers in Marine Science* **10**, 1190623.
- Degrati, M., Loizaga, R., Coscarella, M.A., Sueyro, N., Crespo, E.A., and Dans, S.L. (2020): Integrating multiple techniques to estimate population size of an impacted dusky dolphin's population in Patagonia, Argentina. *Frontiers in Marine Science* **7**, 289.
- Department of Conservation, N.Z. (1978): Marine mammals protection act 1978 (amended 2021). In D. o. Conservation (Ed.).
- DeRuiter, S.L., and Doukara, K.L. (2012): Loggerhead turtles dive in response to airgun sound exposure. *Endangered Species Research* **16**, 55–63.
- Derville, S., Torres, L.G., Newsome, S.D., Somes, C.J., Valenzuela, L.O., Vander Zanden, H.B., Baker, C.S., Bérubé, M., Busquets-Vass, G., and Carlyon, K. (2023): Long-term stability in the circumpolar foraging range of a Southern Ocean predator between the eras of whaling and rapid climate change. *Proceedings of the National Academy of Sciences* **120**, e2214035120.
- Di-Meglio, N., David, L., and Monestiez, P. (2018): Sperm whale ship strikes in the Pelagos Sanctuary and adjacent waters: assessing and mapping collision risks in summer. *Cetacean Resource Management* **18**, 135–147.
- Di Iorio, L., and Clark, C.W. (2010): Exposure to seismic survey alters blue whale acoustic communication. *Biology Letters* **6**, 51–54.
- Dinets, V. (2021): Apparent Surface Feeding by Pygmy Sperm Whales (*Kogia breviceps*). *Aquatic Mammals* **47**, 111–113.
- DNV Energy (2007): Effects of seismic surveys on fish, fish catches and sea mammals. *Report no.: 2007-0512*. Høvik, Norway. 30 pp.
- DOC (2012a): 2012 Code of conduct for minimising acoustic disturbance to marine mammals from seismic survey operations. Publishing Team, Department of Conservation, Wellington, New Zealand, pp. 38.

- DOC (2012b): 2012 Code of conduct for minimising acoustic disturbance to marine mammals from seismic survey operations - reference document. Publishing Team, Department of Conservation, Wellington, New Zealand, pp. 28.
- DOC (2013): 2013 Code of conduct for minimising acoustic disturbance to marine mammals from seismic survey operations. Publishing Team, Department of Conservation, Wellington, New Zealand, pp. 36.
- DOC (2019): New Zealand marine protected areas : gap analysis. Department of Conservation, Wellington, New Zealand. 75 pp.
- DOC (2025): Whales. Available at: <https://www.doc.govt.nz/nature/native-animals/marine-mammals/whales/> [Accessed 21/02/2025].
- DOC (2026): Other marine protection tools. Available at: <https://www.doc.govt.nz/nature/habitats/marine/other-marine-protection/>
- Dodgshun, T.J., Taylor, M.D., and Forrest, B.M. (2007): *Human-mediated pathways of spread for non-indigenous marine species in New Zealand*. Science & Technical Pub. Department of Conservation.
- Downs, S.-M. (2020): Nga Taumata o te Moana-A return to rangatiratanga over the takutai moana. The University of Waikato.
- Drazen, J.C., Smith, C.R., Gjerde, K.M., Haddock, S.H.D., Carter, G.S., Choy, C.A., Clark, M.R., Dutrieux, P., Goetze, E., and Hauton, C. (2020): Midwater ecosystems must be considered when evaluating environmental risks of deep-sea mining. *Proceedings of the National Academy of Sciences* **117**, 17455–17460.
- Duffy, C.A., Baker, C.S., and Constantine, R. (2015): Observation and identification of marine mammals during two recent expeditions to the Kermadec Islands, New Zealand. *Bulletin of the Auckland Museum* **20**, 501–510.
- Dunlop, R.A., Noad, M.J., McCauley, R.D., Kniest, E., Slade, R., Paton, D., and Cato, D.H. (2017): The behavioural response of migrating humpback whales to a full seismic airgun array. *Proceedings of the Royal Society B: Biological Sciences* **284**, 20171901.
- Dunlop, R.A., Noad, M.J., McCauley, R.D., Kniest, E., Slade, R., Paton, D., and Cato, D.H. (2018): A behavioural dose-response model for migrating humpback whales and seismic air gun noise. *Marine Pollution Bulletin* **133**, 506–516.
- Dyndo, M., Wiśniewska, D.M., Rojano-Doñate, L., and Madsen, P.T. (2015): Harbour porpoises react to low levels of high frequency vessel noise. *Scientific Reports* **5**, 9.
- Eddy, T.D., Heneghan, R.F., Bryndum-Buchholz, A., Fulton, E.A., Harrison, C.S., Tittensor, D.P., Lotze, H.K., Ortega-Cisneros, K., Novaglio, C., and Bianchi, D. (2025): Global and regional marine ecosystem models reveal key uncertainties in climate change projections. *Earth's Future* **13**, e2024EF005537.
- Edwards, C. (2023): Development of spatial fisheries risk assessment methods for sharks and turtles in New Zealand waters. *New Zealand aquatic environment and biodiversity Report*, 94.
- Edwards, E.F., Hall, C., Moore, T.J., Sheredy, C., and Redfern, J.V. (2015): Global distribution of fin whales *Balaenoptera physalus* in the post-whaling era (1980-2012). *Mammal Review* **45**, 197–214.
- Elmahdy, Y.M., Orams, M., Lück, M., and Schänzel, H. (2025): Indigenous communities and marine mammal tourism management: incorporating the perspectives of the indigenous Māori people of Aotearoa/New Zealand. *Frontiers in Sustainable Tourism* **4**, 1510025.
- Engås, A., Løkkeborg, S., Ona, E., and Soldal, A.V. (1996): Effects of seismic shooting on local abundance and catch rates of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). *Canadian Journal of Fisheries and Aquatic Sciences* **53**, 2238–2249.

- EPA (2026): Environmental Protection Authority (EPA). Marine seismic survey regulatory requirements. Wellington: New Zealand Government. Available at: EPA marine seismic survey guidance [www6.austlii.edu.au].
- Erbe, C., Reichmuth, C., Cunningham, K., Lucke, K., and Dooling, R. (2016): Communicating masking in marine mammals: A review and research strategy. *Marine Pollution Bulletin* **103**, 15–38.
- Erbe, C., Dunlop, R., and Dolman, S. (2018): Effects of noise on marine mammals. In H. Slabbekoorn, R. J. Dooling, A. N. Popper, and R. R. Fay (Eds): *Effects of anthropogenic noise on animals*. Springer New York, New York, NY, pp. 277–309.
- Erbe, C., Dähne, M., Gordon, J., Herata, H., Houser, D.S., Koschinski, S., Leaper, R., McCauley, R., Miller, B., Müller, M., Murray, A., Oswald, J.N., Scholik-Schlomer, A.R., Schuster, M., Van Opzeeland, I.C., and Janik, V.M. (2019): Managing the effects of noise from ship traffic, seismic surveying and construction on marine mammals in Antarctica. *Frontiers in Marine Science* **6**.
- Fairall, C.W., Bradley, E.F., Rogers, D.P., Edson, J.B., and Young, G.S. (1996): Bulk parameterization of air-sea fluxes for tropical ocean-global atmosphere coupled-ocean atmosphere response experiment. *Journal of Geophysical Research: Oceans* **101**, 3747–3764.
- Falkowski, P.G., Barber, R.T., and Smetacek, V. (1998): Biogeochemical controls and feedbacks on ocean primary production. *Science* **281**, 200–206.
- Feij, B., Kühn, S., Meijboom, A., van Franeker, J.A., Bornemann, H., Kelly, N., and Schaafsma, F.L. (2024): Distribution of Arnoux's beaked whales.
- Fernandes, M.G.M.C. (2016): Acoustic analysis of slow click function and foraging in sperm whales (*Physeter macrocephalus*) off Kaikoura, New Zealand, Vol. Doctor of Philosophy in Zoology. University of Canterbury, pp. 160.
- Fernández, A., Edwards, J.F., Rodriguez, F., Espinosa de los Monteros, A., Herráez, P., Castro, P., Jaber, J.R., Martin, V., and Arbelo, M. (2005): "Gas and fat embolic syndrome" involving a mass stranding of beaked whales (Family *Ziphiidae*) exposed to anthropogenic sonar signals. *Veterinary Pathology* **42**, 446–457.
- Fewtrell, J.L., and McCauley, R.D. (2012): Impact of air gun noise on the behaviour of marine fish and squid. *Marine Pollution Bulletin* **64**, 984–993.
- Feyrer, L.J., Stanistreet, J.E., and Moors-Murphy, H.B. (2024): Navigating the unknown: assessing anthropogenic threats to beaked whales, family *Ziphiidae*. *Royal Society Open Science* **11**, 240058.
- Finneran, J.J. (2015): Noise-induced hearing loss in marine mammals: A review of temporary threshold shift studies from 1996 to 2015. *The Journal of the Acoustical Society of America* **138**, 1702–1726.
- Fisheries New Zealand (2025): Protected Species: Marine mammals in Aquatic Environment and Biodiversity Annual Review. Compiled by the Aquatic Environment Team, Fisheries Science and Information. Fisheries New Zealand, Wellington, New Zealand.
- Fleming, C. (1957): Biogeography of Cook Strait Seabirds. *Proceedings of the New Zealand Ecological Society*, 33.
- Francis, M.P., Hurst, R.J., McArdle, B.H., Bagley, N.W., and Anderson, O.F. (2002): New Zealand demersal fish assemblages. *Environmental Biology of Fishes* **65**, 215–234.
- Franklin, W., Franklin, T., Gibbs, N., Childerhouse, S., Garrigue, C., Constantine, R., Brooks, L., Burns, D., Paton, D., and Poole, M. (2014): Photo-identification confirms that humpback whales (*Megaptera novaeangliae*) from eastern Australia migrate past New Zealand but indicates low levels of

- interchange with breeding grounds of Oceania. *Cetacean Resource Management* **14**, 133–140.
- Frantzis, A., Leaper, R., Alexiadou, P., Prospathopoulos, A.M., and Lekkas, D. (2019): Shipping routes through core habitat of endangered sperm whales along the Hellenic Trench, Greece: can we reduce collision risks? *PLoS ONE* **14**, 21.
- Galka, J.M. (2025): "The nodules are alive and well on the sea floor": deep ocean minerals, invertebrate traces, and multispecies histories of abyssal environments: JM Galka. *History and Philosophy of the Life Sciences* **47**, 18.
- Gallop, S.L., Collins, M., Pattiaratchi, C.B., Eliot, M.J., Bosserelle, C., Ghisalberti, M., Collins, L.B., Eliot, I., Erftemeijer, P.L., and Larcombe, P. (2015): Challenges in transferring knowledge between scales in coastal sediment dynamics. *Frontiers in Marine Science* **2**, 82.
- Garner, D. (1959): The sub-tropical convergence in New Zealand surface waters. *New Zealand Journal of Geology and Geophysics* **2**, 315–337.
- Garner, D.M. (1956): Physical oceanography of Cook Strait. *Proceedings of the New Zealand Ecological Society* **4**, 28.
- GEBCO (2024): The GEBCO_2024 Grid Collection - a continuous terrain model of the global oceans and land. Available at: <https://www.gebco.net/data-products-gridded-bathymetry-data/gebco2024-grid> [Accessed 29/06/2026].
- Geijer, C.K., Notarbartolo di Sciara, G., and Panigada, S. (2016): Mysticete migration revisited: are Mediterranean fin whales an anomaly? *Mammal Review* **46**, 284–296.
- Georgiades, E., and Kluza, D. (2017): Evidence-based decision making to underpin the thresholds in New Zealand's craft risk management standard: biofouling on vessels arriving to New Zealand. *Marine Technology Society Journal* **51**, 76–88.
- Gerrity, S., Virgin, S., and Ladds, M. (2025): Hikurangi Marine Reserve - assessing the effects of protection on key subtidal reef species and the intertidal reef community, 2016 - 2024. Department of Conservation, Wellington. 29 pp.
- Gill, B.J. (1997): Records of turtles and sea snakes in New Zealand, 1837–1996. *New Zealand Journal of Marine and Freshwater Research* **31**, 477–486.
- Giorli, G., and Goetz, K.T. (2020): Acoustically estimated size distribution of sperm whales (*Physeter macrocephalus*) off the east coast of New Zealand. *New Zealand Journal of Marine and Freshwater Research* **54**, 177–188.
- Godoi, V.A., Bryan, K.R., Stephens, S.A., and Gorman, R.M. (2017): Extreme waves in New Zealand waters. *Ocean Modelling* **117**, 97–110.
- Godoy, D.A., Smith, A.N.H., Limpus, C., and Stockin, K.A. (2016): The spatio-temporal distribution and population structure of green turtles (*Chelonia mydas*) in New Zealand. *New Zealand Journal of Marine and Freshwater Research* **50**, 549–565.
- Goetz, K., and Hupman, K. (2017): Passive Acoustic Monitoring in the greater Cook Strait region with particular focus on Queen Charlotte Sound/Tōtaranui. *Report for the Marlborough District Council* **150**, p21.
- Gordon, J., Gillespie, D., Potter, J., Frantzis, A., Simmonds, M.P., Swift, R., and Thompson, D. (2003): A review of the effects of seismic surveys on marine mammals. *Marine Technology Society Journal* **37**, 16–34.
- Gorman, R.M., Bryan, K.R., and Laing, A.K. (2003): Wave hindcast for the New Zealand region: nearshore validation and coastal wave climate. *New Zealand Journal of Marine and Freshwater Research* **37**, 567–588.
- Götz, T., Hastie, G., Hatch, L.T., Raustein, O., Southall, B.L., Tasker, M., and Thomsen, F. (2009): Overview of the impacts of anthropogenic underwater sound in the marine environment. OSPAR Commission. 134 pp.

- Grigoratou, M., Menden-Deuer, S., McQuatters-Gollop, A., Arhonditsis, G., Artigas, L.F., Ayata, S.-D., Bedikoğlu, D., Beisner, B.E., Chen, B., and Davies, C. (2025): The immeasurable value of plankton to humanity. *BioScience* **75**, 706–721.
- Guan, S., Roberts, L., Haxel, J., Sisneros, J.A., and Popper, A.N. (2025): Approaches to understanding effects from particle motion and substrate-borne vibration on fishes and invertebrates. *The Journal of the Acoustical Society of America* **158**, 2464–2477.
- Hadfield, M.G., and Stevens, C.L. (2021): A modelling synthesis of the volume flux through Cook Strait. *New Zealand Journal of Marine and Freshwater Research* **55**, 65–93.
- Hale, R., Thompson, D., Brough, T., Kregting, L., Hayden, M., Parsons, D., Nodder, S.D., Beaumont, J., Anderson, O., and Stevens, C. (2024): Environmental implications of future offshore renewable energy development in Aotearoa New Zealand. *Journal of the Royal Society of New Zealand*, 1–34.
- Hall, A.A., Chilvers, B.L., Weir, J.S., and Boren, L.J. (2024): Earthquake impacts on a protected pinniped in New Zealand. *Aquatic Conservation: Marine and Freshwater Ecosystems* **34**, e4055.
- Hall, A.A., Chilvers, B.L., and Weir, J.S. (2025a): Towards an abundance estimate for New Zealand fur seal in New Zealand. *Aquatic Conservation: Marine and Freshwater Ecosystems* **35**, e70142.
- Hall, A.A., Neale, D., Roberts, J., Chilvers, B.L., and Weir, J.S. (2025b): Declining Abundance and Variable Condition of Fur Seal (*Arctocephalus forsteri*) Pups on the West Coast of New Zealand's South Island. *Animals* **16**, 121.
- Hamner, R., Constantine, R., Mattlin, R., Waples, R., and Baker, C. (2013): Genotype capture-recapture estimates of abundance and effective population size of Hector's dolphins in Cloudy Bay, New Zealand. *Submitted to the Scientific Committee of the International Whaling Commission, Jeju, South Korea*.
- Hamner, R.M., Oremus, M., Stanley, M., Brown, P., Constantine, R., and Baker, C.S. (2012a): Estimating the abundance and effective population size of Maui's dolphins using microsatellite genotypes in 2010–2011, with retrospective matching to 2001–07. *Department of Conservation, Auckland*.
- Hamner, R.M., Pichler, F.B., Heimeier, D., Constantine, R., and Baker, C.S. (2012b): Genetic differentiation and limited gene flow among fragmented populations of New Zealand endemic Hector's and Maui's dolphins. *Conservation Genetics* **13**, 987–1002.
- Hamner, R.M., Steel, D., Constantine, R., Morrissey, M., Ogle, M., Weir, J., Olavarria, C., Baxter, A., Arlidge, W., and Boren, L. (2016): Local population structure and abundance of Hector's dolphins off Kaikoura–2014 and 2015. *Unpublished Report to the Department of Conservation, Wellington, New Zealand*.
- Hansen, K.A., Maxwell, A., Siebert, U., Larsen, O.N., and Wahlberg, M. (2017): Great cormorants (*Phalacrocorax carbo*) can detect auditory cues while diving. *The Science of Nature* **104**, 1–7.
- Harris, R.E., Miller, G.W., and Richardson, W.J. (2001): Seal responses to airgun sounds during summer seismic surveys in the Alaskan Beaufort Sea. *Marine Mammal Science* **17**, 795–812.
- Hartel, E.F. (2010): Habitat use by bottlenose dolphins (*Tursiops truncatus*) in the Bay of Islands, New Zealand. University of Auckland.
- Hawkins, E.R., and Gartside, D.F. (2009): Interactive behaviours of bottlenose dolphins (*Tursiops aduncus*) during encounters with vessels. *Aquatic Mammals* **35**, 259.

- Heinemann, A., and Gray, A. (2024): National Panel Survey of Marine Recreational Fishers 2022–23. *New Zealand Fisheries Assessment Report* **51**, 50.
- Henrys, S., Eberhart-Phillips, D., Bassett, D., Sutherland, R., Okaya, D., Savage, M., Evanzia, D., Stern, T., Sato, H., and Mochizuki, K. (2020): Upper plate heterogeneity along the southern Hikurangi Margin, New Zealand. *Geophysical Research Letters* **47**, e2019GL085511.
- Hermannsen, L., Mikkelsen, L., Tougaard, J., Beedholm, K., Johnson, M., and Madsen, P.T. (2019): Recreational vessels without Automatic Identification System (AIS) dominate anthropogenic noise contributions to a shallow water soundscape. *Scientific Reports* **9**, 15477.
- Heyward, A., Colquhoun, J., Cripps, E., McCorry, D., Stowar, M., Radford, B., Miller, K., Miller, I., and Battershill, C. (2018): No evidence of damage to the soft tissue or skeletal integrity of mesophotic corals exposed to a 3D marine seismic survey. *Marine Pollution Bulletin* **129**, 8–13.
- Hildebrand, J.A. (2009): Anthropogenic and natural sources of ambient noise in the ocean. *Marine Ecology Progress Series* **395**, 5–20.
- Hilliam, K., Treml, E.A., Stevenson, S., and Floerl, O. (2024): Recreational vessel networks reveal potential hot spots for marine pest introduction and spread. *Journal of Applied Ecology*.
- Hinton, B., Stockin, K.A., Bury, S.J., Peters, K.J., and Betty, E.L. (2022): Isotopic niche analysis of long-finned pilot whales (*Globicephala melas edwardii*) in Aotearoa New Zealand waters. *Biology* **11**, 1414.
- Holles, S., Simpson, S.D., Radford, A.N., Berten, L., and Lecchini, D. (2013): Boat noise disrupts orientation behaviour in a coral reef fish. *Marine Ecology Progress Series* **485**, 295–300.
- Holt, M.M., Noren, D.P., Veirs, V., Emmons, C.K., and Veirs, S. (2009): Speaking up: killer whales (*Orcinus orca*) increase their call amplitude in response to vessel noise. *Journal of the Acoustical Society of America* **125**.
- Huang, C.J., and Qiao, F. (2010): Wave-turbulence interaction and its induced mixing in the upper ocean. *Journal of Geophysical Research: Oceans* **115**.
- Hudson, D.M., Krumholz, J.S., Pochtar, D.L., Dickenson, N.C., Dossot, G., Phillips, G., Baker, E.P., and Moll, T.E. (2022): Potential impacts from simulated vessel noise and sonar on commercially important invertebrates. *PeerJ* **10**, e12841.
- Jackson, J.A., Carroll, E.L., Smith, T.D., Zerbini, A.N., Patenaude, N.J., and Baker, C.S. (2016): An integrated approach to historical population assessment of the great whales: case of the New Zealand southern right whale. *Royal Society open science* **3**.
- James, M.R., and Wilkinson, V.H. (1988): Biomass, carbon ingestion, and ammonia excretion by zooplankton associated with an upwelling plume in western Cook Strait, New Zealand. *New Zealand Journal of Marine and Freshwater Research* **22**, 249–257.
- Jansen, J.K., Boveng, P.L., Dahle, S.P., and Bengtson, J.L. (2010): Reaction of harbor seals to cruise ships. *The Journal of Wildlife Management* **74**, 1186–1194.
- Jensen, F., Kuperman, W., Porter, M., and Schmidt, H. (2011): *Computational ocean acoustics*. Springer, New York.
- Jensen, F.H., Bejder, L., Wahlberg, M., Aguilar Soto, N., Johnson, M., and Madsen, P.T. (2009): Vessel noise effects on delphinid communication. *Marine Ecology Progress Series* **395**, 161–175.
- Jhugroo, K., O'Callaghan, J., Stevens, C.L., Macdonald, H.S., Elliott, F., and Hadfield, M.G. (2020): Spatial structure of low salinity submesoscale features and their interactions with a coastal current. *Frontiers in Marine Science* **7**, 557360.

- Jhugroo, K., O'Callaghan, J.M., and Stevens, C.L. (2025): The impact of high rainfall events on the submesoscale salinity field in a coastal sea: Greater Cook Strait, New Zealand. *New Zealand Journal of Marine and Freshwater Research* **59**, 735–761.
- Johnston, D., Bowers, M., Friedlaender, A., and Lavigne, D.M. (2012): The effects of climate change on harp seals (*Pagophilus groenlandicus*). *PLoS ONE* **7**.
- Johnston, S.T., and Painter, K.J. (2024): Avoidance, confusion or solitude? Modelling how noise pollution affects whale migration. *Movement Ecology* **12**, 17.
- Jones, I., Stanley, J.A., and Mooney, A. (2019): Impulsive pile driving noise elicits alarm responses in squid (*Doryteuthis pealeii*). *Marine Pollution Bulletin* **150**.
- Jones, I.T., D Gray, M., and Mooney, T.A. (2022): Soundscapes as heard by invertebrates: particle motion measurements in marine habitats. *The Journal of the Acoustical Society of America* **152**, 399–415.
- Jones, I.T., Bonnel, J., and Flamant, J. (2025): Particle motion polarization of offshore fish vocalizations versus ambient and ship noise. *The Journal of the Acoustical Society of America* **158**, 1723–1736.
- Kaikkonen, L., Clark, M.R., Leduc, D., Nodder, S.D., Rowden, A.A., Bowden, D.A., Beaumont, J., and Cummings, V. (2025): Probabilistic ecological risk assessment for deep-sea mining: A Bayesian network for Chatham Rise, Pacific Ocean. *Ecological Applications* **35**, e3064.
- Kalybekova, A. (2025): A review of advancements and applications of satellite-derived bathymetry. *Engineered Science* **35**, 1541.
- Karabashev, G. (2023): Effects of Mesoscale Mixing on Phytopigment Determinations in the Photoc Zone from Multispectral Ocean Color Data (The Case of the Tasman Sea). *Oceanology* **63**, 35–44.
- Kemper, C.M., Middleton, J.F., and van Ruth, P.D. (2013): Association between pygmy right whales (*Caperea marginata*) and areas of high marine productivity off Australia and New Zealand. *New Zealand Journal of Zoology* **40**, 102–128.
- Ketten, D.R. (1995): Estimates of blast injury and acoustic trauma zones for marine mammals from underwater explosions. In R. A. Kastelein, J. A. Thomas, and P. E. Nachtigall (Eds): *Sensory systems in aquatic mammals*. De Spil, Woerden, Amsterdam, pp. 391–407.
- Khan, A., and Rountos, K.J. (2025): Evaluation of microplastics in marine selective and non-selective suspension-feeding benthic invertebrates. *Marine Environmental Research* **209**, 107205.
- King, C.M. (2024): Biogeography and history of the Prehuman native mammal fauna of the New Zealand Region. *Diversity* **16**, 45.
- Kiszka, J., and Braulik, G. (2020): *Kogia breviceps*, Vol. e. T11047A50358334. IUCN, The IUCN Red List of Threatened Species.
- Kōrero Takutai (2026): High Court Application AreasTe Kete Kōrero a Te Takutai Moana, Vol. 2026.
- Ladich, F., and Schulz-Mirbach, T. (2016): Diversity in fish auditory systems: one of the riddles of sensory biology. *Frontiers in Ecology and Evolution* **4**, 28.
- Laist, D.W., Knowlton, A.R., Mead, J.G., Collet, A.S., and Podesta, M. (2001): Collisions between ships and whales. *Marine Mammal Science* **17**, 35–75.
- Lalas, C., and McConnell, H. (2016): Effects of seismic surveys on New Zealand fur seals during daylight hours: Do fur seals respond to obstacles rather than airgun noise? *Marine Mammal Science* **32**, 643–663.
- Lamarche, G., Rowden, A.A., Mountjoy, J., Lucieer, V., and Verdier, A.-L. (2012): The Cook Strait Canyon, New Zealand: Geomorphology and seafloor biodiversity of a large bedrock canyon system in a tectonically active

- environment: *Seafloor Geomorphology as Benthic Habitat*. Elsevier, pp. 727–737.
- Land Information New Zealand (2026): Marine and Coastal Area Register. Available at: <https://www.linz.govt.nz/our-work/maori-and-iwi-development/marine-and-coastal-area-register>
- Larsen, O.N., Wahlberg, M., and Christensen-Dalsgaard, J. (2020): Amphibious hearing in a diving bird, the great cormorant (*Phalacrocorax carbo sinensis*). *Journal of Experimental Biology* **223**, jeb217265.
- Leaper, R., Bannister, J.L., Branch, T.A., Clapham, P., Donovan, G., Reilly, S., and Zerbini, A. (2008): A review of abundance, trends and foraging parameters of baleen whales in the Southern Hemisphere. *Paper SC/60. EM3 presented to the IWC Scientific Committee June*.
- Lecchini, D., Bertucci, F., Gache, C., Khalife, A., Besson, M., Roux, N., Berthe, C., Singh, S., Parmentier, E., and Nugues, M.M. (2018): Boat noise prevents soundscape-based habitat selection by coral planulae. *Scientific Reports* **8**, 9283.
- Lewis, K. (1980): *Quaternary sedimentation on the Hikurangi oblique-subduction and transform margin, New Zealand*.
- Lewis, K.B., Carter, L., and Davey, F.J. (1994): The opening of Cook Strait: interglacial tidal scour and aligning basins at a subduction to transform plate edge. *Marine Geology* **116**, 293–312.
- Lhériaux-Nice, A., Kozmian-Ledward, L., Milesi-Gaches, D.P., and Della Penna, A. (2025): Plankton distribution patterns across fine-scale fronts in the Tikapa Moana Te Moana Nui a Toi Hauraki Gulf, Aotearoa New Zealand. *Marine and Freshwater Research* **76**, MF24214.
- Lucke, K., Clement, D., Todd, V.L.G., Williamson, L., Johnston, O., Floerl, L., Cox, S., Todd, I.B., and McPherson, C. (2019): Potential impacts of petroleum and mineral exploration and production on Hector's and Māui dolphins: a literature review. *Document 01725*. JASCO Applied Sciences (Australia) Pty Ltd, Capalaba, Queensland. 148 pp.
- Lundquist, D., Gemmell, N.J., and Würsig, B. (2012): Behavioural responses of dusky dolphin groups (*Lagenorhynchus obscurus*) to tour vessels off Kaikoura, New Zealand. *PLoS ONE* **7**, 1–9.
- Lundquist, D., Boren, L., Childerhouse, S., Constantine, R., van Helden, A., Hitchmough, R., Michel, P., Rayment, W., and Baker, C.S. (2025): Conservation status of marine mammals in Aotearoa New Zealand, 2024. *Department of Conservation Report*.
- Lusseau, D. (2004): The hidden cost of tourism: detecting long-term effects of tourism using behavioral information. *Ecology and Society* **9**.
- Lusseau, D. (2007): Evidence for social role in a dolphin social network. *Evolutionary Ecology* **21**, 357–366.
- Lusseau, D., and Bejder, L. (2007): The long-term consequences of short-term responses to disturbance: Experiences from whalewatching impact assessment. *International Journal of Comparative Psychology* **20**, 228–236.
- Lusseau, S.M. (2003): Diet of bottlenose dolphins in Doubtful Sound, New Zealand; evidence from stable carbon and nitrogen isotope analysis. *Unpublished MSc thesis. University of Otago, Dunedin, New Zealand*.
- Machernis, A.F., Powell, J.R., Engleby, L., and Spradlin, T.R. (2018): An updated literature review examining the impacts of tourism on marine mammals over the last fifteen years (2000–2015) to inform research and management programs.
- Maiditsch, I.P., Schulz-Mirbach, T., Heß, M., Ladich, F., Stampanoni, M., and Schlepütz, C.M. (2025): A standing wave tube-like setup designed for

- tomographic imaging of the sound-induced motion patterns in fish hearing structures. *Bmc Biology* **23**, 277.
- Manni, L., Sabbadin, G., Domenichi, S., Ballarin, L., Zaffaroni-Caorsi, V., and Zambon, G. (2025): New Methods for Studying Underwater Noise Effects on Microscopic Sessile Marine Invertebrates: Challenges and Perspectives. *Proceedings of Forum Acusticum-Euronoise 2025*, pp. 6117–6124.
- Marçalo, A., Nicolau, L., Giménez, J., Ferreira, M., Santos, J., Araújo, H., Silva, A., Vingada, J., and Pierce, G.J. (2018): Feeding ecology of the common dolphin (*Delphinus delphis*) in Western Iberian waters: has the decline in sardine (*Sardina pilchardus*) affected dolphin diet? *Marine Biology* **165**, 44.
- Markowitz, T.M., Harlin, A.D., Würsig, B., and McFadden, C.J. (2004): Dusky dolphin foraging habitat: overlap with aquaculture in New Zealand. *Aquatic Conservation: Marine and Freshwater Ecosystems* **14**, 133–149.
- Markowitz, T.M., Dans, S.L., Crespo, E.A., Lundquist, D.J., and Duprey, N.M. (2010): Human interactions with dusky dolphins: harvest, fisheries, habitat alteration, and tourism: *The Dusky Dolphin*. Elsevier, pp. 211–244.
- Markowitz, T.M., Richter, C., and Gordon, J. (2011): Effects of tourism on the behaviour of sperm whales inhabiting the Kaikoura Canyon. *Report to New Zealand Department of Conservation* **123**.
- Martinez, E., and Stockin, K. (2013): Blunt trauma observed in a common dolphin *delphinus* sp. Likely caused by a vessel collision in the Hauraki Gulf, New Zealand. *Pacific Conservation Biology* **19**, 19–27.
- Matsuoka, K., Pitman, R.L., and Marquez, F.F.C. (2005): A note on a pygmy right whale (*Caperea marginata*) sighting in the southwestern Pacific Ocean. *Cetacean Resource Management* **7**, 71–73.
- Mayaud, R., Castrillon, J., Wilson, C., Peel, D., Smith, J.N., Dalle Luche, G., Allen, J., and Nash, S.B. (2022): Traffic in a nursery: Ship strike risk from commercial vessels to migrating humpback whales (*Megaptera novaeangliae*) in a rapidly developing Australian urban embayment. *Marine Policy* **146**, 105332.
- McCauley, R.D., Day, R.D., Swadlow, K.M., Fitzgibbon, Q.P., Watson, R.A., and Semmens, J.M. (2017): Widely used marine seismic survey air gun operations negatively impact zooplankton. *Nature Ecology and Evolution* **1**.
- McIlroy, S.E., Guibert, I., Archana, A., Chung, W.Y.H., Duffy, J.E., Gotama, R., Hui, J., Knowlton, N., Leray, M., and Meyer, C. (2024): Life goes on: Spatial heterogeneity promotes biodiversity in an urbanized coastal marine ecosystem. *Global Change Biology* **30**, e17248.
- McKenna, M.F., Ross, D., Wiggins, S.M., and Hildebrand, J.A. (2012): Underwater radiated noise from modern commercial ships. *J Acoust Soc Am* **131**, 92–103.
- McPhee-Frew, J., Dedden, A.V., Pirotta, V., Marshall, A., Waples, K., Raudino, H.C., and Rogers, T.L. (2025): Humpback whales (*Megaptera novaeangliae*) continue migration after giving birth in temperate waters in Australia and New Zealand. *Frontiers in Marine Science* **12**, 1545526.
- Merchant, N.D., Faulkner, R.C., and Martinez, R. (2018): Marine noise budgets in practice. *Conservation Letters* **11**, e12420.
- Merriman, M.G., Markowitz, T.M., Harlin-Cognato, A.D., and Stockin, K.A. (2009): Bottlenose dolphin (*Tursiops truncatus*) abundance, site fidelity, and group dynamics in the marlborough sounds, New Zealand. *Aquatic Mammals* **35**.
- Meyer, C. (2020): Population Demographics, Social Structure and Interspecific Associations of Free-ranging Long-finned Pilot Whales (*Globicephala Melas*) in New Zealand, Vol. MSc in Marine Science. University of Auckland.
- Meyer, C.E., Zaeschmar, J.R., and Constantine, R. (2025): Occurrence, site-fidelity and photo-identification of long-finned pilot whales in Aotearoa New

- Zealand. *New Zealand Journal of Marine and Freshwater Research* **59**, 398–417.
- Micallef, A., Mountjoy, J.J., Barnes, P.M., Canals, M., and Lastras, G. (2014): Geomorphic response of submarine canyons to tectonic activity: Insights from the Cook Strait canyon system, New Zealand. *Geosphere* **10**, 905–929.
- Michie, C.A.G. (2023): Variation in larval dispersal patterns and its power in predicting genetic divergence of benthic marine invertebrates around New Zealand. ResearchSpace@ Auckland.
- Mickle, M.F., Pieniazek, R.H., and Higgs, D.M. (2020): Field assessment of behavioural responses of southern stingrays (*Hypanus americanus*) to acoustic stimuli. *Royal Society Open Science* **7**, 191544.
- Mikkelsen, L., Johnson, M., Wisniewska, D.M., van Neer, A., Siebert, U., Madsen, P.T., and Teilmann, J. (2019): Long-term sound and movement recording tags to study natural behavior and reaction to ship noise of seals. *Ecology and Evolution* **9**, 2588–2601.
- Miller, E.J. (2015): Ecology of Hector's dolphin (*Cephalorhynchus hectori*): Quantifying diet and investigating habitat selection at Banks Peninsula. University of Otago.
- Miller, P.J.O., Johnson, M.P., Madsen, P.T., Biassoni, N., Quero, M., and Tyack, P.L. (2009): Using at-sea experiments to study the effects of airguns on the foraging behavior of sperm whales in the Gulf of Mexico. *Deep Sea Research Part I: Oceanographic Research Papers* **56**, 1168–1181.
- Ministry of Transport (2023): Domestic Transport Costs and Charges (DTCC) Study – Cook Strait Ferries, Working Paper C15, Prepared by Rockpoint Corporate Finance Ltd in association with Ian Wallis Associates Ltd, Wellington: Te Manatū Waka Ministry of Transport, New Zealand. Te Manatū Waka Ministry of Transport, Wellington.
- Minton, G., Reeves, R., and Braulik, G. (2018): *Globicephala melas*, Vol. e.T9250A50356171. IUCN, The IUCN Red List of Threatened Species.
- Moon, P. (2019): From Tasman to Cook: the proto-intelligence phase of New Zealand's colonisation. *Journal of Intelligence History* **18**, 253–268.
- Mooney, T.A., Smith, A., Larsen, O.N., Hansen, K.A., and Rasmussen, M. (2020): A field study of auditory sensitivity of the Atlantic puffin, *Fratercula arctica*. *Journal of Experimental Biology* **223**, jeb228270.
- Mormede, S. (2023): Spatial-temporal Distribution of Inshore Fish and Cephalopod Species of Interest to Selected Top Predators. Fisheries New Zealand, Ministry for Primary Industries. 102 pp.
- MOT (2026): Freight and logistics. Available at: <https://www.transport.govt.nz/statistics-and-insights/freight-and-logistics/sheet/figs-overseas-ship-visits> [Accessed 10/04/2026].
- Mountjoy, J.J. (2009): Development of submarine canyon systems on active margins: Hikurangi Margin, New Zealand: *Geological Sciences*, Vol. Ph.D. University of Canterbury.
- MPI (2026): Ministry of Primary Industries - Open Geospatial Data Portal. Available at: <https://data-mpi.opendata.arcgis.com/>
- Mullen, K.A., Peterson, M.L., and Todd, S.K. (2013): Has designating and protecting critical habitat had an impact on endangered North Atlantic right whale ship strike mortality? *Marine Policy* **42**, 293–304.
- Nabi, G., McLaughlin, R.W., Hao, Y., Wang, K., Zeng, X., Khan, S., and Wang, D. (2018): The possible effects of anthropogenic acoustic pollution on marine mammals' reproduction: an emerging threat to animal extinction. *Environmental Science and Pollution Research* **25**, 19338–19345.

- Natoli, A., Cañadas, A., Peddemors, V.M., Aguilar, A., Vaquero, C., Fernández-Piqueras, P., and Hoelzel, A.R. (2006): Phylogeography and alpha taxonomy of the common dolphin (*Delphinus sp.*). *Journal of Evoluy Biology* **19**, 943–954.
- Neil, H., Lamarche, G., Mitchell, J., MacKay, K., and Pallentin, A. (2016): Multibeam echosounder mapping to identify seafloor habitats. *New Zealand*.
- Nelms, S.E., Piniak, W.E.D., Weir, C.R., and Godley, B.J. (2016): Seismic surveys and marine turtles: An underestimated global threat? *Biological Conservation* **193**, 49–65.
- New Zealand Birds Online (2026): Cook Strait coastal waters. Available at: <https://www.nzbirdsonline.org.nz/>
- New Zealand Ministry of Primary Industries (2023): Aquaculture Decision for coastal permit U190438 in the Cook Strait. In M. o. P. Industries (Ed.).
- New Zealand Ministry of Primary Industries (2025): Hoki (Hok). In M. o. P. Industries (Ed.).
- New Zealand Ministry of Transport (1996): Submarine Cables and Pipelines Protection Act 1996. In M. o. Transport (Ed.).
- New Zealand Ministry of Transport (2009): Submarine Cables and Pipelines Protection Order 2009. In M. o. Transport (Ed.).
- New Zealand Parliamentary Counsel Office (1994): Maritime Transport Act 1994.
- New Zealand Parliamentary Counsel Office (2011): Marine and Coastal Area (Takutai Moana) Act 2011. New Zealand Government.
- New Zealand Parliamentary Counsel Office (2012): Exclusive economic zone and continental shelf (environmental effects) act 2012 (amended 2022). In M. f. t. Environment (Ed.).
- Nguyen Hong Duc, P., Lefebvre, G., Quimbert, M., Gavrilov, A.N., McCauley, R.D., Jenner, C., Jenner, M.N., Davenport, A., Browne, C.E., and Ward, R. (2026): Geographical and seasonal distribution of Australian pygmy right whales (*Caperea marginata*) based on passive acoustics. *Marine Mammal Science* **42**, e70132.
- NIWA (2016a): NIWA New Zealand bathymetric contours.
- NIWA (2016b): New Zealand bathymetry - Further information. Available at: <https://niwa.co.nz/oceans/new-zealand-bathymetry-further-information>
- NIWA (2016–2017): Acoustic monitoring of whales and dolphins in New Zealand's Cook Strait region. Available at: <https://niwa.co.nz/oceans/acoustic-monitoring-whales-and-dolphins-new-zealands-cook-strait-region>
- NMFS (2018): 2018 Revisions to: Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (Version 2.0): underwater thresholds for onset of permanent and temporary threshold shifts. *NOAA Technical Memorandum NMFS-OPR-59*. National Marine Fisheries Service, U.S. Department of Commerce, and National Oceanic and Atmospheric Administration, Silver Springs, Maryland. 167 pp.
- NMFS (2024): 2024 Update to: Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (version 3.0): underwater and in-air criteria for onset of auditory injury and temporary threshold shifts. *NOAA Technical Memorandum NMFS-OPR-71*. National Marine Fisheries Service, U.S. Department of Commerce, and National Oceanic and Atmospheric Administration, Silver Springs, Maryland. 193 pp.
- NOAA Fisheries (2024): LONG-FINNED PILOT WHALE (*Globicephala melas melas*): Western North Atlantic Stock.
- Nowacek, D.P., Wells, R.S., and Solow, A.R. (2001): Short-term effects of boat traffic on bottlenosed dolphins in Sarasota Bay, Florida. *Marine Mammal Science* **17**, 673–688.

- Nowacek, D.P., Thorne, L.H., Johnston, D.W., and Tyack, P.L. (2007): Responses of cetaceans to anthropogenic noise. *Mammal Review* **37**, 81–115.
- Nowak, R.M. (2003): *Walker's marine mammals of the world*. JHU Press.
- NZ EPA (2015): Decision on marine consent application by Chatham Rock Phosphate Limited to mine phosphorite nodules on the Chatham Rise.
- NZPM (2021): History of petroleum. Available at: <https://www.nzpam.govt.nz/nz-industry/nz-petroleum/history> [Accessed 27 March 2025].
- Ogilvy, C., Constantine, R., and Carroll, E.L. (2023): Spatial variation in isotope values of Hector's dolphins from the north coast of the South Island, New Zealand. *Marine Ecology Progress Series* **711**, 61–75.
- Oliveira, C., Pérez-Jorge, S., Prieto, R., Cascão, I., Wensveen, P.J., and Silva, M.A. (2022): Exposure to whale watching vessels affects dive ascents and resting behavior in sperm whales. *Frontiers in Marine Science* **9**, 914397.
- Olson, J.K., Lambourn, D.M., Huggins, J.L., Raverty, S., Scott, A.A., and Gaydos, J.K. (2021): Trends in propeller strike-induced mortality in harbor seals (*Phoca vitulina*) of the Salish Sea. *The Journal of Wildlife Diseases* **57**, 689–693.
- Orbach, D.N., Pearson, H.C., Beier-Engelhaupt, A., Deutsch, S., Srinivasan, M., Weir, J.S., Yin, S., and Würsig, B. (2018): Long-term assessment of spatio-temporal association patterns of dusky dolphins (*Lagenorhynchus obscurus*) off Kaikoura, New Zealand. *Aquatic Mammals* **44**.
- Oremus, M., Hamner, R.M., Stanley, M., Brown, P., Baker, C.S., and Constantine, R. (2012): Distribution, group characteristics and movements of the Critically Endangered Maui's dolphin *Cephalorhynchus hectori maui*. *Endangered Species Research* **19**, 1–10.
- Packard, A., Karlsen, H.E., and Sand, O. (1990): Low frequency hearing in cephalopods. *Journal of Comparative Physiology* **166**, 501–505.
- Page, B., McKenzie, J., and Goldsworthy, S.D. (2005): Inter-sexual differences in New Zealand fur seal diving behaviour. *Marine Ecology Progress Series* **304**, 249–264.
- Palmer, E.I., Betty, E.L., Murphy, S., Perrott, M.R., Smith, A.N.H., and Stockin, K.A. (2022): Reproductive biology of female common dolphins (*Delphinus delphis*) in New Zealand waters. *Marine Biology* **169**, 158.
- Palmer, E.I., Betty, E.L., Murphy, S., Perrott, M.R., Smith, A.N.H., and Stockin, K.A. (2023): Reproductive biology of male common dolphins (*Delphinus delphis*) in New Zealand waters. *Marine Biology* **170**, 153.
- Parsons, E.C.M. (2012): The negative impacts of whale-watching. *Journal of Marine Biology* **2012**, 9.
- Parsons, E.C.M. (2024): Māui's dolphin (*Cephalorhynchus hectori maui*) and South Island Hector's dolphin (*Cephalorhynchus hectori hectori*) 5-Year Review: Summary and Evaluation.
- Patiño-Pérez, J., Edirisinghe, H., Guerra, M., and Brunton, D.H. (2024): Evidence of geographic variation in the non-signature whistle repertoires of two isolated populations of New Zealand common bottlenose dolphin. *New Zealand Journal of Zoology* **51**, 130–150.
- Pavanato, H., Schattschneider, J., Childerhouse, S., and Briscoe, D. (2023): Assessment of New Zealand fur Seal/Kekeno Bycatch by Trawlers in the Cook Strait Hoki Fishery. *POP2021-06 final report prepared for Department of Conservation. Cawthron Report*.
- Pearson, H.C., Vaughn-Hirshorn, R.L., Srinivasan, M., and Würsig, B. (2012): Avoidance of mussel farms by dusky dolphins (*Lagenorhynchus obscurus*) in New Zealand. *New Zealand Journal of Marine and Freshwater Research* **46**, 567–574.

- Peters, K.J., Bury, S.J., Hinton, B., Betty, E.L., Casano-Bally, D., Parra, G.J., and Stockin, K.A. (2022): Too close for comfort? Isotopic niche segregation in New Zealand's odontocetes. *Biology* **11**, 1179.
- Pichegru, L., Nyengera, R., McInnes, A.M., and Pistorius, P. (2017): Avoidance of seismic survey activities by penguins. *Scientific Reports* **7**, 16305.
- Pine, M.K., Wilson, L., Jeffs, A.G., McWhinnie, L., Juanes, F., Scuderi, A., and Radford, C.A. (2021): A Gulf in lockdown: How an enforced ban on recreational vessels increased dolphin and fish communication ranges. *Global Change Biology* **27**, 4839–4848.
- Piniak, W.E.D., Eckert, S.A., Harms, C.A., and Stringer, E.M. (2012): Underwater hearing sensitivity of the leatherback sea turtle (*Dermochelys coriacea*): assessing the potential effect of anthropogenic noise. U.S. Department of the Interior Bureau of Ocean Energy.
- Pirotta, E., Brookes, K.L., Graham, I.M., and Thompson, P.M. (2014): Variation in harbour porpoise activity in response to seismic survey noise. *Biology Letters* **10**.
- Pirotta, E., Thompson, P.M., Cheney, B., Donovan, C.R., and Lusseau, D. (2015): Estimating spatial, temporal and individual variability in dolphin cumulative exposure to boat traffic using spatially explicit capture-recapture methods. *Animal Conservation* **18**, 20–31.
- Pirotta, V., Grech, A., Jonsen, I.D., Laurant, W.F., and Harcourt, R.G. (2019): Consequences of global shipping traffic for marine giants. *Frontiers in Ecology and the Environment* **17**, 39–47.
- Pitman, R.L., Van Helden, A.L., Best, P.B., and Pym, A. (2006): Shepherd's beaked whale (*Tasmacetus shepherdi*): information on appearance and biology based on strandings and at-sea observations. *Marine Mammal Science* **22**, 744–755.
- Pitman, R.L., Totterdell, J., Wellard, R., Cullen, P., and de Boer, M. (2019): Long in the tooth: Biological observations from at-sea sightings of strap-toothed beaked whales (*Mesoplodon layardii*).
- Pitman, R.L., and Taylor, B.L. (2020): *Mesoplodon grayi*, Vol. e.T13247A50366236. IUCN, The IUCN Red List of Threatened Species.
- Piwetz, S., Pearson, H.C., Honkus, K.A., and Würsig, B. (2025): Dusky dolphin (*Lagenorhynchus obscurus*) habitat use in a mussel farming region and changes over time. *New Zealand Journal of Marine and Freshwater Research* **59**, 418–440.
- Plön, S., Best, P.B., Duignan, P., Lavery, S.D., Bernard, R.T., Van Waerebeek, K., and Baker, C.S. (2023): Population structure of pygmy (*Kogia breviceps*) and dwarf (*Kogia sima*) sperm whales in the Southern Hemisphere may reflect foraging ecology and dispersal patterns: *Advances in Marine Biology*, Vol. 96. Elsevier, pp. 85–114.
- Poloczanska, E.S., Limpus, C.J., and Hays, G.C. (2009): Vulnerability of marine turtles to climate change. *Advances in Marine Biology* **56**, 151–211.
- Ponte, R.M. (2006a): Low frequency sea level variability and the inverted barometer effect. *Journal of Atmospheric and Oceanic Technology* **23**, 619–629.
- Ponte, R.M. (2006b): Oceanic response to surface loading effects neglected in volume-conserving models. *Journal of Physical Oceanography* **36**, 426–434.
- Popper, A., and Hawkins, A.D. (2020): Hearing. In S. Currie, and D. H. Evans (Eds): *The physiology of fishes*. CRC Press.
- Popper, A.N., Smith, M.E., Cott, P.A., Hanna, B.W., MacGillivray, A.O., Austin, M.E., and Mann, D.A. (2005): Effects of exposure to seismic airgun use on hearing of three fish species. *Journal of the Acoustical Society of America* **117**, 3958–3971.

- Popper, A.N., and Fay, R.R. (2011): Rethinking sound detection by fishes. *Hearing Research* **273**, 25–36.
- Popper, A.N., Hawkins, A.D., Fay, R.R., Mann, D.A., Bartol, S., Carlson, T.J., Coombs, S., Ellison, W.T., Gentry, R.L., and Halvorsen, M.B. (2014): *ASA S3/SC1.4 TR-2014 Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report Prepared by ANSI-Accredited Standards Committee S3/SC1 and Registered with ANSI*. Springer.
- Popper, A.N., and Hawkins, A.D. (2018): The importance of particle motion to fishes and invertebrates. *The Journal of the Acoustical Society of America* **143**, 470–488.
- Popper, A.N., and Hawkins, A.D. (2019a): An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes. *Journal of Fish Biology* **94**, 692–713.
- Popper, A.N., and Hawkins, A.D. (2019b): An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes. *J Fish Biol* **94**, 692–713.
- Popper, A.N., Hawkins, A.D., Sand, O., and Sisneros, J.A. (2019): Examining the hearing abilities of fishes. *The Journal of the Acoustical Society of America* **146**, 948–955.
- Power, W., Wallace, L.M., Mueller, C., Henrys, S., Clark, K., Fry, B., Wang, X., and Williams, C. (2016): Understanding the potential for tsunami generated by earthquakes on the southern Hikurangi subduction interface. *New Zealand Journal of Geology and Geophysics* **59**, 70–85.
- Proctor, R., and Carter, L. (1989): Tidal and sedimentary response to the late Quaternary closure and opening of Cook Strait, New Zealand: results from numerical modeling. *Paleoceanography* **4**, 167–180.
- Putland, R.L., Constantine, R., and Radford, C.A. (2017): Exploring spatial and temporal trends in the soundscape of an ecologically significant embayment. *Sci Rep* **7**, 5713.
- Putland, R.L., Merchant, N.D., Farcas, A., and Radford, C.A. (2018): Vessel noise cuts down communication space for vocalizing fish and marine mammals. *Global Change Biology* **24**, 1708–1721.
- Radford, C.A., Stanley, J.A., Simpson, S.D., and Jeffs, A.G. (2011): Juvenile coral reef fish use sound to locate habitats. *Coral Reefs* **30**, 295–305.
- Radford, C.A., Montgomery, J.C., Caiger, P., and Higgs, D.M. (2012): Pressure and particle motion detection thresholds in fish: a re-examination of salient auditory cues in teleosts. *Journal of Experimental Biology* **215**, 3429–3435.
- Ratnarajah, L., Abu-Alhaija, R., Atkinson, A., Batten, S., Bax, N.J., Bernard, K.S., Canonico, G., Cornils, A., Everett, J.D., and Grigoratou, M. (2023): Monitoring and modelling marine zooplankton in a changing climate. *Nature Communications* **14**, 564.
- Rayment, W., Davidson, A., Dawson, S., Slooten, E., and Webster, T. (2012): Distribution of southern right whales on the Auckland Islands calving grounds. *New Zealand Journal of Marine and Freshwater Research* **46**, 431–436.
- Reeves, I.M., Totterdell, J.A., Barceló, A., Sandoval-Castillo, J., Batley, K.C., Stockin, K.A., Betty, E.L., Donnelly, D.M., Wellard, R., and Beheregaray, L.B. (2022): Population genomic structure of killer whales (*Orcinus orca*) in Australian and New Zealand waters. *Marine Mammal Science* **38**, 151–174.
- Reeves, R., Pitman, R.L., and Ford, J.K.B. (2017): *Orcinus orca*, Vol. e.T15421A50368125. IUCN, The IUCN Red List of Threatened Species.
- Reichmuth, C., Holt, M.M., Mulsow, J., Sills, J.M., and Southall, B.L. (2013): Comparative assessment of amphibious hearing in pinnipeds. *Journal of Comparative Physiology A* **1999**, 491–507.
- Reid, J., Rout, M., and Mika, J.P. (2019): Mapping the Māori marine economy.

- Revell, M.J., and Gorman, R.M. (2003): The “Wahine storm”: Evaluation of a numerical forecast of a severe wind and wave event for the New Zealand coast. *New Zealand Journal of Marine and Freshwater Research* **37**, 251–266.
- Rhoads, D.C., and Young, D.K. (1970): The influence of deposit-feeding organisms on sediment stability and community trophic structure. *Journal of Marine Research* **28**, 150–178.
- Richard, Y., and Berkenbusch, K. (2024): Sightings of marine mammals in New Zealand waters by government fisheries observers. Department of Conservation. 24 pp.
- Richards, R. (2009): Past and present distributions of southern right whales (*Eubalaena australis*). *New Zealand Journal of Zoology* **36**, 447–459.
- Richardson, W.J., Greene, C.R.J., Malme, C.I., and Thomson, D.H. (1995): *Marine mammals and noise*. Academic Press, San Diego, California, USA.
- Ridgway, S., and Howard, R. (1982): Response: Dolphins and the Bends. *Science* **216**, 651–651.
- Riekkola, L., Sprogis, K.R., Della Penna, A., Andrews-Goff, V., Harcourt, R., Cole, R., Constantine, R., Goetz, K.T., Lundquist, D., and Stuck, E. (2025): Large-scale differences, mesoscale similarities: Neighbouring marine predator populations provide insights into Southern Ocean productivity. *Global Ecology and Conservation*, e03788.
- Risch, D., Gales, N.J., Gedamke, J., Kindermann, L., Nowacek, D.P., Read, A.J., Siebert, U., Van Opzeeland, I.C., Van Parijs, S.M., and Friedlaender, A.S. (2014): Mysterious bio-duck sound attributed to the Antarctic minke whale (*Balaenoptera bonaerensis*). *Biology Letters* **10**.
- Risch, D., Norris, T., Curnock, M., and Friedlaender, A. (2019): Common and Antarctic minke whales: conservation status and future research directions. *Frontiers in Marine Science* **6**, 247.
- Roberts, J., and Hendriks, H. (2022): *Potential climate change effects on New Zealand marine mammals: a review*. Department of Conservation- Te Papa Atawhai.
- Robertson, C.J.R., Bell, E.A., Sinclair, N., and Bell, B.D. (2003): Distribution of seabirds from New Zealand that overlap with fisheries worldwide. *Science for Conservation* **233**, 102.
- Robertson, H.A., Baird, K.A., Elliott, G., Hitchmough, R., McArthur, N., Makan, T., Miskelly, C., O'Donnell, C.F.J., Sagar, P.M., and Scofield, R.P. (2021): *Conservation status of birds in Aotearoa New Zealand, 2021*. Department of Conservation, Te Papa Atawhai Wellington, New Zealand.
- Rogers, P., Debusschere, E., Haan, D.d., Martin, B., and Slabbekoorn, H. (2021): North Sea soundscapes from a fish perspective: Directional patterns in particle motion and masking potential from anthropogenic noise. *The Journal of the Acoustical Society of America* **150**, 2174–2188.
- Rovellini, A., and Shaffer, M.R. (2020): A review of the objectives of New Zealand marine reserves. *Prepared for the Department of Conservation. Wellington, New Zealand*.
- Saavedra, C., García-Polo, M., Giménez, J., Mons, J.L., Castillo, J.J., Fernández-Maldonado, C., de Stephanis, R., Pierce, G.J., and Santos, M.B. (2022): Diet of striped dolphins (*Stenella coeruleoalba*) in southern Spanish waters. *Marine Mammal Science* **38**, 1566–1582.
- Saeedi, H. (2026): Gaps and drivers of global marine animal biodiversity from the surface to abyss. *Nature Communications* **17**, 4553.
- Salinger, M., and Mullan, A. (1999): New Zealand climate: temperature and precipitation variations and their links with atmospheric circulation 1930–

1994. *International Journal of Climatology: A Journal of the Royal Meteorological Society* **19**, 1049–1071.
- Santos-Carvalho, M., Barilari, F., Pérez-Alvarez, M.J., Gutiérrez, L., Pavez, G., Araya, H., Anguita, C., Cerda, C., and Sepúlveda, M. (2021): Impacts of whale-watching on the short-term behavior of Fin Whales (*Balaenoptera physalus*) in a marine protected area in the southeastern pacific. *Frontiers in Marine Science* **8**, 623954.
- Schenone, S., Azhar, M., Delmas, P., and Thrush, S.F. (2023): Towards time and cost-efficient habitat assessment: challenges and opportunities for benthic ecology and management. *Aquatic Conservation: Marine and Freshwater Ecosystems* **33**, 1603–1614.
- Schiel, D.R. (2004): The structure and replenishment of rocky shore intertidal communities and biogeographic comparisons. *Journal of experimental marine biology and ecology* **300**, 309–342.
- Schiel, D.R., Alestra, T., Gerrity, S., Orchard, S., Dunmore, R., Pirker, J., Lilley, S., Tait, L., Hickford, M., and Thomsen, M. (2019): The Kaikōura earthquake in southern New Zealand: Loss of connectivity of marine communities and the necessity of a cross-ecosystem perspective. *Aquatic Conservation: Marine and Freshwater Ecosystems* **29**, 1520–1534.
- Schoeman, R.P., Patterson-Abrolat, C., and Plön, S. (2020): A global review of vessel collisions with marine animals. *Frontiers in Marine Science* **7**.
- Schulz-Mirbach, T., Ladich, F., Mittone, A., Olbinado, M., Bravin, A., Maiditsch, I.P., Melzer, R.R., Krysl, P., and Heß, M. (2020): Auditory chain reaction: effects of sound pressure and particle motion on auditory structures in fishes. *PLoS ONE* **15**, e0230578.
- Schusterman, R.J., and van Parijs, S.M. (2003): Pinniped vocal communication: an introduction. *Aquatic Mammals* **29**, 177–180.
- Seco Pon, J.P., Bastida, J., Giardino, G.V., Favero, M., and Copello, S. (2019): Seabirds east of Tierra del Fuego, Argentina during a 3D seismic survey. *Ornitologia Neotropical* **30**, 103–111.
- Sharoni, S., Inomura, K., Dutkiewicz, S., Jahn, O., Finkel, Z.V., Irwin, A., M. Amirian, M., Monier, E., and Follows, M.J. (2026): Biochemical remodelling of phytoplankton cell composition under climate change. *Nature Climate Change*, 1–7.
- Sharples, J., Moore, C.M., and Abraham, E.R. (2001): Internal tide dissipation, mixing, and vertical nitrate flux at the shelf edge of NE New Zealand. *Journal of Geophysical Research: Oceans* **106**, 14069–14081.
- Siders, Z.A., Murray, C., Puloka, C., Harley, S., Duffy, C., Long, C.A., Ahrens, R.N., and Jones, T.T. (2024): Potential of dynamic ocean management strategies for western Pacific leatherback sea turtle bycatch mitigation in New Zealand. *Frontiers in Marine Science* **11**, 1342475.
- Siebert, U., Stürznickel, J., Schaffeld, T., Oheim, R., Rolvien, T., Prenger-Berninghoff, E., Wohlsein, P., Lakemeyer, J., Rohner, S., and Schick, L.A. (2022): Blast injury on harbour porpoises (*Phocoena phocoena*) from the Baltic Sea after explosions of deposits of World War II ammunition. *Environment International* **159**, 107014.
- Sills, J.M., Ruscher, B., Packard, N., Jones, R.A., Southall, B.L., and Reichmuth, C. (2025): Low-frequency hearing and masking parameters in representative seals and sea lions. *The Journal of the Acoustical Society of America* **158**, 1585–1599.
- Silva, A.d.O.d., Teixeira, A.S., Silva, Í.M.d., Sampaio, T.C.T.d., Silva, V.G.d., and Pontual, E.V. (2025): Biological Impacts of Climate Change on Sea Turtles: A Review. *Advances in Research* **26**, 81–93.

- Simpson, S.D., Meekan, M.G., Larsen, N.J., McCauley, R.D., and Jeffs, A. (2010): Behavioral plasticity in larval reef fish: orientation is influenced by recent acoustic experiences. *Behavioral Ecology* **21**, 1098–1105.
- Slooten, E., and Dawson, S.M. (2021): Delays in protecting a small endangered cetacean: lessons learned for science and management. *Frontiers in Marine Science* **8**, 606547.
- Smith, B., and Barclay, D. (2024): The Sound of Hydrothermal Vents. *Noisy Oceans: Monitoring Seismic and Acoustic Signals in the Marine Environment*, 97–118.
- Snelder, T., Leathwick, J., Dey, K., Weatherhead, M., Fenwick, G., Francis, M., Gorman, R., Grieve, J., Hadfield, M., and Hewitt, J. (2005): The New Zealand marine environment classification. *Wellington, Ministry for the Environment*.
- Snelgrove, P., and Butman, C. (1994): Animal-sediment relationships revisited: cause versus effect. *Oceanographic Literature Review* **8**, 668.
- Solé, M., Kaifu, K., Mooney, T.A., Nedelec, S.L., Olivier, F., Radford, A.N., Vazzana, M., Wale, M.A., Semmens, J.M., and Simpson, S.D. (2023): Marine invertebrates and noise. *Frontiers in Marine Science* **10**, 1129057.
- Somerford, T.R., Dawson, S.M., Slooten, E., Guerra, M., Childerhouse, S.J., Richter, C.F., van Der Linde, M.L., and Rayment, W.J. (2022): Long-term decline in abundance of male sperm whales visiting Kaikōura, New Zealand. *Marine Mammal Science* **38**, 606–625.
- Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J.J., Gentry, R.L., Greene, C.R., Kastak, D., Ketten, D.R., Miller, J.H., Nachtigall, P.E., Richardson, W.J., Thomas, J.A., and Tyack, P.L. (2007): Marine mammal noise exposure criteria, initial scientific recommendations. *Aquatic Mammals* **33**, 411–414.
- Southall, B.L., Finneran, J.J., Reichmuth, C., Nachtigall, P.E., Ketten, D.R., Bowles, A.E., Ellison, W.T., Nowacek, D.P., and Tyack, P.L. (2019): Marine mammal noise exposure criteria: Updated scientific recommendations for residual hearing effects. *Aquatic Mammals* **45**, 125–232.
- Srinivasan, M. (2023): Social strategies of a consummate marine predator: mammal-hunting killer whales: *Social strategies of carnivorous mammalian predators: hunting and surviving as families*. Springer, pp. 229–281.
- Steel, D., Anderson, M., Garrigue, C., Olavarria, C., Caballero, S., Childerhouse, S., Clapham, P., Constantine, R., Dawson, S., and Donoghue, M. (2018): Migratory interchange of humpback whales (*Megaptera novaeangliae*) among breeding grounds of Oceania and connections to Antarctic feeding areas based on genotype matching. *Polar Biology* **41**, 653–662.
- Steel, D.J., Carroll, E.L., Baker, C.S., Caballero, S., Childerhouse, S., Corne, C., Garrigue, C., Gibbs, N., Kinsey, R., and K, N. (2025): Genetic differentiation and population connectivity of humpback whales migrating through Aotearoa New Zealand waters. *Pacific Conservation Biology* **31**, PC25026.
- Steidl, W., Guerra, M., Jowett, T., and Rayment, W.J. (2026): Characterizing the Distribution and Behavior of Sperm Whales, *Physeter macrocephalus*, Over the Otago Submarine Canyons, New Zealand. *Marine Mammal Science* **42**, e70157.
- Steidl, W.M. (2024): Distribution and behaviour of sperm whales, *Physeter macrocephalus*, over the Otago submarine canyons, New Zealand. University of Otago.
- Steinberg, D.K., and Landry, M.R. (2017): Zooplankton and the ocean carbon cycle. *Annual Review of Marine Science* **9**, 413–444.
- Stephenson, F., Goetz, K., Sharp, B.R., Mouton, T.L., Beets, F.L., Roberts, J., MacDiarmid, A.B., Constantine, R., and Lundquist, C.J. (2020): Modelling

- the spatial distribution of cetaceans in New Zealand waters. *Diversity and Distributions* **26**, 495–516.
- Stephenson, F., Hewitt, J.E., Torres, L.G., Mouton, T.L., Brough, T., Goetz, K.T., Lundquist, C.J., MacDiarmid, A.B., Ellis, J., and Constantine, R. (2021): Cetacean conservation planning in a global diversity hotspot: dealing with uncertainty and data deficiencies. *Ecosphere* **12**, e03633.
- Stevens, C. (2014): Residual flows in Cook Strait, a large tidally dominated strait. *Journal of Physical Oceanography* **44**, 1654–1670.
- Stevens, C.L. (2018): Turbulent length scales in a fast-flowing, weakly stratified, strait: Cook Strait, New Zealand. *Ocean Science* **14**, 801–812.
- Stevens, C.L., O'Callaghan, J.M., Chiswell, S.M., and Hadfield, M.G. (2021a): Physical oceanography of New Zealand/Aotearoa shelf seas—a review. *New Zealand Journal of Marine and Freshwater Research* **55**, 6–45.
- Stevens, C.L., Paul-Burke, K., and Russell, P. (2021b): Pūtahitanga: the intersection of western science and mātauranga Māori in the context of Aotearoa New Zealand's physical oceanography. *New Zealand Journal of Marine and Freshwater Research* **55**, 249–263.
- Stevens, D.E., McNeill, L., Henstock, T., Barnes, P., Crutchley, G., Bangs, N., Henrys, S., and Van Avendonk, H. (2024): Structural variation along the southern Hikurangi subduction zone, Aotearoa New Zealand, from seismic reflection and retro-deformation analysis. *Tectonics* **43**, e2023TC008212.
- Stockin, K.A., Pierce, G.J., Binedell, V., Wiseman, N., and Orams, M.B. (2008): Factors affecting the occurrence and demographics of common dolphins (*Delphinus* sp.) in the Hauraki Gulf, New Zealand. *Aquatic Mammals* **34**, 200–211.
- Stockin, K.A., Duignan, P.J., Roe, W.D., Meynier, L., Alley, M., and Fettermann, T. (2009): Causes of mortality in stranded common dolphin (*Delphinus* sp.) from New Zealand waters between 1998 and 2008. *Pacific Conservation Biology* **15**, 217–227.
- Stoecker, D.K., Hansen, P.J., Caron, D.A., and Mitra, A. (2017): Mixotrophy in the marine plankton. *Annual Review of Marine Science* **9**, 311–335.
- Szesciorka, A.R., Allen, A.N., Calambokidis, J., Fahlbusch, J., McKenna, M.F., and Southall, B. (2019): A case study of a near vessel strike of a blue whale: perceptual cues and fine-scale aspects of behavioral avoidance. *Frontiers in Marine Science* **6**, 761.
- Tadeo, M.P., Gammell, M., and O'Briend, J. (2021): Assessment of anthropogenic disturbances due to ecotourism on a grey seal (*Halichoerus grypus*) colony in the Blasket Islands SAC, Southwest Ireland and recommendations on best practices. *Aquatic Mammals* **47**, 268–282.
- Taylor, B.L., Baird, R., Barlow, J., Dawson, S.M., Ford, J., Mead, J.G., Notarbartolo di Sciarra, G., Wade, P., and Pitman, R.L. (2019): *Physeter macrocephalus*, Vol. e.T41755A160983555. IUCN, The IUCN Red List of Threatened Species.
- Tennessen, J.B., Holt, M.M., Wright, B.M., Hanson, M.B., Emmons, C.K., Giles, D.A., Hogan, J.T., Thornton, S.J., and Deecke, V.B. (2024): Males miss and females forgo: Auditory masking from vessel noise impairs foraging efficiency and success in killer whales. *Global Change Biology* **30**, e17490.
- Tepsich, P., Rosso, M., Halpin, P.N., and Moulins, A. (2014): Habitat preferences of two deep-diving cetacean species in the northern Ligurian Sea. *Marine Ecology Progress Series* **508**, 247–260.
- Thompson, K.F., Millar, C.D., Scott Baker, C., Dalebout, M., Steel, D., van Helden, A.L., and Constantine, R. (2013): A novel conservation approach provides insights into the management of rare cetaceans. *Biological Conservation* **157**, 331–340.

- Thompson, K.F., Patel, S., Baker, C.S., Constantine, R., and Millar, C.D. (2016): Bucking the trend: genetic analysis reveals high diversity, large population size and low differentiation in a deep ocean cetacean. *Heredity* **116**, 8.
- Thomsen, M.S., Metcalfe, I., Siciliano, A., South, P.M., Gerrity, S., Alestra, T., and Schiel, D.R. (2020): Earthquake-driven destruction of an intertidal habitat cascade. *Aquatic Botany* **164**, 103217.
- Thrush, S., Hewitt, J., Cummings, V., Dayton, P., Cryer, M., Turner, S., Funnell, G., Budd, R., Milburn, C., and Wilkinson, M. (1998): Disturbance of the marine benthic habitat by commercial fishing: impacts at the scale of the fishery. *Ecological Applications* **8**, 866–879.
- Thrush, S.F., Hewitt, J.E., Norkko, A., Cummings, V.J., and Funnell, G.A. (2003): Macrobenthic recovery processes following catastrophic sedimentation on estuarine sandflats. *Ecological Applications* **13**, 1433–1455.
- Tixier, P., Lea, M.-A., Hindell, M.A., Guinet, C., Gasco, N., Duhamel, G., and Arnould, J.P.Y. (2018): Killer whale (*Orcinus orca*) interactions with blue-eye trevalla (*Hyperoglyphe antarctica*) longline fisheries. *PeerJ* **6**, e5306.
- Todd, V.L.G., Todd, I.B., Gardiner, J.C., Morrin, E.C.N., MacPherson, N.A., DiMarzio, N.A., and Thomsen, F. (2015): A review of direct and indirect impacts of marine dredging activities on marine mammals. *ICES Journal of Marine Science* **72**, 328–340.
- Todd, V.L.G. (2016): Mitigation of underwater anthropogenic noise and marine mammals: the 'death of a thousand' cuts and/or mundane adjustment? *Marine Pollution Bulletin Editorial* **102**, 1–3.
- Torres, L.G. (2013): Evidence for an unrecognised blue whale foraging ground in New Zealand. *New Zealand Journal of Marine and Freshwater Research* **47**, 235–248.
- Torres, L.G., Smith, T.D., Sutton, P., MacDiarmid, A., Bannister, J., and Miyashita, T. (2013): From exploitation to conservation: habitat models using whaling data predict distribution patterns and threat exposure of an endangered whale. *Diversity and Distributions* **19**, 1138–1152.
- Torres, L.G., Rayment, W., Olavarria, C., Thompson, D.R., Graham, B., Baker, C.S., Patenaude, N., Bury, S.J., Boren, L., and Parker, G. (2017): Demography and ecology of southern right whales *Eubalaena australis* wintering at sub-Antarctic Campbell Island, New Zealand. *Polar Biology* **40**, 95–106.
- Towers, J.R., and Tixier, P. (2022): Indian Ocean sighting of Shepherd's beaked whale (*Tasmacetus shepherdi*) helps confirm circumpolar distribution in southern hemisphere. *Aquatic Mammals* **48**, 462–467.
- Tracey, D.M., Rowden, A.A., Mackay, K.A., and Compton, T. (2011): Habitat-forming cold-water corals show affinity for seamounts in the New Zealand region. *Marine Ecology Progress Series* **430**, 1–22.
- Transpower (2022): Cook Strait Cable Protection Zone (CPZ).
- Tricas, T.C., and Boyle, K.S. (2014): Acoustic behaviors in Hawaiian coral reef fish communities. *Marine Ecology Progress Series* **511**.
- Urick, R.J. (1983): *Principles of underwater sound*. McGraw-Hill, New York, USA.
- Valcarcel, A.F., Stevens, C.L., O'Callaghan, J.M., and Suanda, S.H. (2025): Overlapping turbulent boundary layers in an energetic coastal sea. *Ocean Science* **21**, 965–987.
- Valenzuela, L.O., Rowntree, V.J., Sironi, M., and Seger, J. (2018): Stable isotopes ($\delta^{15}\text{N}$, $\delta^{13}\text{C}$, $\delta^{34}\text{S}$) in skin reveal diverse food sources used by southern right whales *Eubalaena australis*. *Marine Ecology Progress Series* **603**, 243–255.
- Van Waerebeek, K., A. N. Baker, F. Félix, J. Gedamke, M. Iñiguez, G. P. Sanino, E. Secchi, D. Sutaria, A. van Helden, and Wang, Y. (2007): Vessel collisions with small cetaceans worldwide and with large whales in the Southern

- Hemisphere, an initial assessment. *Latin American Journal of Aquatic Mammals* **6**, 43–69.
- Vanderlaan, A.S.M., and Taggart, C.T. (2007): Vessel collisions with whales: the probability of lethal injury based on vessel speed. *Marine Mammal Science* **23**, 144–156.
- Vincenzi, G.d., Parisi, I., Torri, M., Papale, E., Mazzola, S., Nuth, C., and Buscaino, G. (2019): Influence of environmental parameters on the use and spatiotemporal distribution of the vocalizations of bearded seals (*Erignathus barbatus*) in Kongsfjorden, Spitsbergen. *Polar Biology* **42**, 1241–1254.
- Visser, I.N. (1999): A summary of interactions between orca (*Orcinus orca*) and other cetaceans in New Zealand waters.
- Visser, I.N. (2000): Killer whale (*Orcinus orca*) interactions with longline fisheries in New Zealand waters. *Aquatic Mammals* **26**, 241–252.
- Visser, I.N., Fertl, D., and Pusser, L.T. (2004): Melanistic southern right-whale dolphins (*Lissodelphis peronii*) off Kaikoura, New Zealand, with records of other anomalously all-black cetaceans. *New Zealand Journal of Marine and Freshwater Research* **38**, 833–836.
- Visser, I.N. (2007): Killer whales in New Zealand waters: status and distribution with comments on foraging.
- Wale, M.A., Briers, R.A., Hartl, M.G.J., Bryson, D., and Diele, K. (2019): From DNA to ecological performance: Effects of anthropogenic noise on a reef-building mussel. *Science of The Total Environment* **689**, 126–132.
- Wallace, L.M., Barnes, P., Beavan, J., Van Dissen, R., Litchfield, N., Mountjoy, J., Langridge, R., Lamarche, G., and Pondard, N. (2012): The kinematics of a transition from subduction to strike-slip: An example from the central New Zealand plate boundary. *Journal of Geophysical Research: Solid Earth* **117**.
- Walters, R.A., Goring, D.G., and Bell, R.G. (2001): Ocean tides around New Zealand. *New Zealand Journal of Marine and Freshwater Research* **35**, 567–579.
- Walters, R.A., Gillibrand, P.A., Bell, R.G., and Lane, E.M. (2010): A study of tides and currents in Cook Strait, New Zealand. *Ocean Dynamics* **60**, 1559–1580.
- Warren, V. (2020): Temporal and spatial distributions of baleen whales in central New Zealand, based on passive acoustic monitoring. University of Auckland.
- Warren, V.E., Constantine, R., Noad, M., Garrigue, C., and Garland, E.C. (2020): Migratory insights from singing humpback whales recorded around central New Zealand. *Royal Society Open Science* **7**, 201084.
- Warren, V.E., McPherson, C., Giorli, G., Goetz, K.T., and Radford, C.A. (2021a): Marine soundscape variation reveals insights into baleen whales and their environment: a case study in central New Zealand. *Royal Society Open Science* **8**.
- Warren, V.E., Širović, A., McPherson, C., Goetz, K.T., Radford, C.A., and Constantine, R. (2021b): Passive acoustic monitoring reveals spatio-temporal distributions of Antarctic and pygmy blue whales around central New Zealand. *Frontiers in Marine Science* **7**, 1162.
- Wassilieff, M. (2009): Common plankton groups in New Zealand. Available at: <https://teara.govt.nz/en/table/5131/common-plankton-groups-in-new-zealand>
- Weir, C.R. (2007): Observations of marine turtles in relation to seismic airgun sound off Angola. *Marine Turtle Newsletter* **116**, 17–20.
- Wells, R.S., Natoli, A., and Braulik, G. (2019): *Tursiops truncatus*, Vol. e.T22563A156932432. IUCN, The IUCN Red List of Threatened Species.
- Wiernicki, C.J., Liang, D., Bailey, H., and Secor, D.H. (2020): The effect of swim bladder presence and morphology on sound frequency detection for fishes. *Reviews in Fisheries Science & Aquaculture* **28**, 459–477.

- Williams, G.J., Cameron, M.J., Turner, J.R., and Ford, R.B. (2008): Quantitative characterisation of reef fish diversity among nearshore habitats in a northeastern New Zealand marine reserve. *New Zealand Journal of Marine and Freshwater Research* **42**, 33–46.
- Williams, R., Lusseau, D., and Hammond, P.S. (2006): Estimating relative energetic costs of human disturbance to killer whales (*Orcinus orca*). *Biological Conservation* **133**, 301–311.
- Williams, R., Kelly, N., Boebel, O., Friedlaender, A.S., Herr, H., Kock, K.H., Lehnert, L.S., Maksym, T., Roberts, J., Scheidat, M., Siebert, U., and Brierley, A.S. (2014): Counting whales in a challenging, changing environment. *Scientific Reports* **4**.
- Williamson, M. (2026): Property, Power and the Pacific: Fast-Tracking Seabed Mining in Aotearoa New Zealand. *Law and Development Review*.
- Winkler, C., Panigada, S., Murphy, S., and Ritter, F. (2020): Global numbers of ship strikes: an assessment of collisions between vessels and cetaceans using available data in the IWC ship strike database. *IWC B* **68**.
- Wright, A.J., Aguilar Soto, N., Baldwin, A.L., Bateson, M., Beale, C.M., Clark, C., Deak, T., Edwards, E.F., Fernandez, A., Godinho, A., Hatch, L.T., Kakuschke, A., Lusseau, D., Martineau, D., Romero, L.M., Weilgart, L.S., Wintle, B.A., Notarbartolo-di-Sciara, G., and Martin, V. (2007): Do marine mammals experience stress related to anthropogenic noise? *International Journal of Comparative Psychology* **20**, 274–316.
- Zaeschar, J.R., Tezanos-Pinto, G., Dwyer, S.L., Peters, C.H., Berghan, J., Donnelly, D., Meissner, A.M., Visser, I.N., Weir, J.S., and Judkins, A.G. (2020): Occurrence, site fidelity, and associations of oceanic common bottlenose dolphins (*Tursiops truncatus*) off northeastern New Zealand. *Marine Mammal Science* **36**, 1180–1195.
- Zintzen, V., Anderson, M.J., Roberts, C.D., Harvey, E.S., Stewart, A.L., and Struthers, C.D. (2012): Diversity and composition of demersal fishes along a depth gradient assessed by baited remote underwater stereo-video. *PLoS ONE* **7**, e48522.
- Zintzen, V., Anderson, M.J., Roberts, C.D., Harvey, E.S., and Stewart, A.L. (2017): Effects of latitude and depth on the beta diversity of New Zealand fish communities. *Scientific Reports* **7**, 8081.

APPENDIX A – MITIGATION PROTOCOL

This appendix outlines comprehensive mitigation strategies and protocols for the proposed seismic survey of Cook Strait offshore region, aiming to minimise potential impacts on marine mammals in New Zealand waters. These procedures align with the '2013 Code of Conduct for minimising acoustic disturbance to marine mammals from seismic survey operations' released by the Department of Conservation (DOC, 2013). It serves as a guide for observers and crew to ensure operations comply with the 2013 Code of Conduct.

A.1. Procedures of seismic operations - notification

The Director-General of Conservation at the DOC must be notified in writing of GEOMAR's intention to conduct the seismic survey at the earliest opportunity, but no later than three months before the survey commences. This initial notification may simply indicate a potential intent to initiate the communication process and does not require the submission of all necessary information at this stage.

In exceptional circumstances, or in the case of an opportunistic survey arising within the three-month notification period, the proponent must notify the Director-General at the earliest opportunity, but no later than two weeks before the survey commences. This notification must be accompanied by evidence demonstrating the exceptional or opportunistic nature of the survey, along with a written MMIA.

An MMIA must be submitted when surveying within a sanctuary area a minimum of three months in advance of operations.

A.2. Observer requirements

A team of four observers will be onboard *RV Sonne* throughout the survey, comprising two MMOs and two PAMOs in accordance with the requirements of the 2013 Code. Under the Code, observers who have successfully completed a DOC-recognised training and assessment course are considered "trained", while "qualified" observers must additionally meet the relevant experience requirements, including a minimum of 12 weeks of observer experience in New Zealand waters. All observers will also hold the required sea-survival and offshore medical certification and will be provided with appropriate Personal Protective Equipment (PPE) along with the following equipment: Reticule binoculars, range finder stick, angle board, compass, Global Positioning System (GPS), deck forms, recording forms and laptop, necessary to undertake their duties.

A.2.1. PAM specifications

Acoustic monitoring will be conducted using a purpose-built towed array (as an example shown in **Figure 40** and **Table 21**) in conjunction with specialised software (PAMGuard) to enable detection and monitoring of vocalising marine mammals. PAMOs are encouraged to familiarise themselves with acoustic recordings of marine mammals that are likely to be present in the operational area. All PAM equipment will be provided with 100% redundancy. Components of a PAM system are as shown in **Figure 41**.

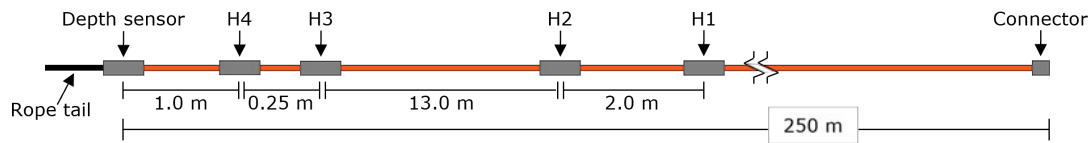


Figure 40: Example schematic of a towed hydrophone array. H1 and H2 are the broadband hydrophone (H) element and H3 and H4 are the high frequency hydrophone elements. *Source:* OSC (2025).

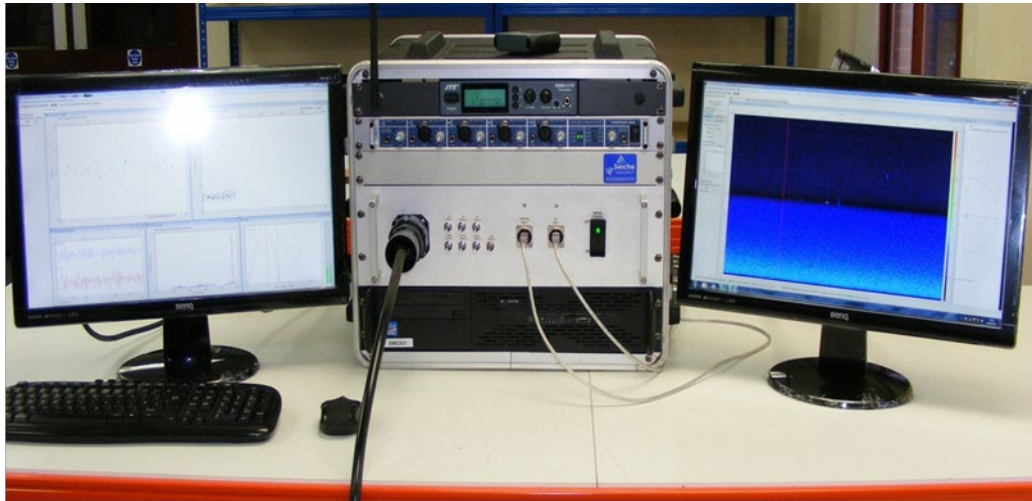
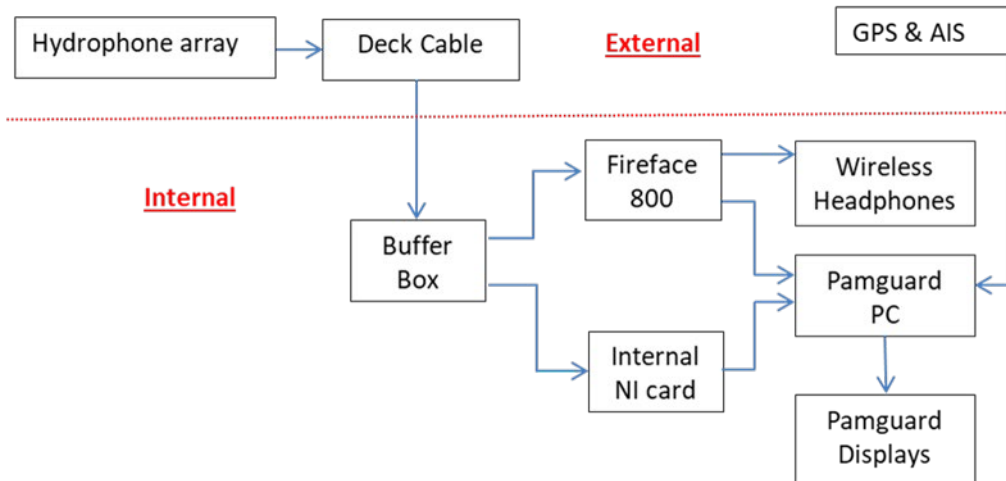


Figure 41: Schematic of internal PAM system components, including the PAM base (top panel, centre), which consists of a buffer box and a PAMGuard PC, as well as PAMGuard displays (top panel, sides). External components are not shown. *Source:* OSC (2026).

Item	Quantity	Specifications
Seiche PAM system with 250 m of cable (100% redundant)	2	Broadband: receiving sensitivity (at output of preamplifier): -166 dB re 1 V/μPa Usable frequency range: 200 Hz to 200 kHz ±3 dB High frequency: receiving sensitivity (at output of preamplifier): -166 dB re 1 V/μPa Usable frequency range: 2 kHz to 200 kHz ±3 dB
NI USB-6251 DAQ card	2	16-bit digital output, 8 BNC analogue input
Fireface 800 soundcard	2	24-bit Firewire output to PC
Windows PC	2	Custom build with Intel quad core i5 processor with 8 GB RAM

Table 21: Specifications of hydrophone system. DAQ = Data Acquisition, PC = Personal Computer. *Source:* OSC (2025).

A.2.2. PAMGuard configuration

PAMGuard will be configured with a specific data model for SUBTRANS survey. As informed by the MMIA, PAMGuard will be configured to specifically detect and classify echolocation clicks from deep diving species such as beaked whales and sperm whales. This will be achieved by having two click detector modules, one will be configured to detect the specific frequency range of sperm whale clicks that are an order of magnitude lower than beaked whales and dolphins. A second click detector module will be configured for higher frequency odontocete clicks and will use available click classifiers to identify beaked whales and the narrow band high frequency clicks of dwarf and pygmy sperm whale. Unclassified clicks will be retained so that PAMOs can detect odontocete echolocation clicks (regardless of classification) based on temporal patterns (identification of click trains), this will allow for the detection of dolphin clicks that will remain unclassified. A whistle and moan detector will also be configured to identify the tonal calls of odontocetes (whistles) and low frequency cetaceans that use frequencies within the sensitivity range of the hydrophones (*i.e.* humpback whales).

A.3. Observer duties

MMOs are responsible for monitoring for the presence of marine mammals within designated mitigation zone (minimum 200 m, but up to 1–1.5 km for species of concern). The MMOs will systematically record sightings, environmental conditions (including wind direction and speed, swell height, sea state, and visibility), and ensure compliance with mitigation measures and regulatory requirements to avoid the risk of acoustic or physical impacts on marine mammals. Similarly, the PAMOs are accountable for the detection and monitoring of underwater vocalisations and sounds produced by marine mammals as well as ensuring compliance.

All observers on duty have the authority to delay or postpone the beginning of operations, or to shut down an active source entirely, if they determine it is necessary.

Duties of MMOs onboard are as follows:

- Provide comprehensive briefings to all crew members and survey teams whilst establishing clear communication protocols and operational procedures for onboard activities;

- Continuously survey the water's surface in all directions inside the mitigation zone, for the presence of marine mammals, utilising a combination of direct visual observation and high-quality binoculars from optimal vantage points onboard the vessel to ensure clear and undistracted visual observations;
- Employ tools such as GPS, reticule binoculars, compass, measuring stick, angle boards, or other appropriate tools to accurately determine the distances, angles, and positions of sighted marine mammals where possible;
- Where possible, document all marine mammal sightings, noting species, group size, behaviours, direction of travel in relation to the vessel, and the presence of calves;
- Record environmental data, including Beaufort Sea State, swell height, visibility, rain, fog, and sun glare at the beginning of each observation period, as well as when significant weather conditions occur or change;
- Monitor and document the power output of acoustic sources during operations, along with any mitigation measures implemented during observations;
- Implement appropriate mitigation actions such as delayed starts and shut downs; and,
- Record and report any deviations from the guidelines as well as any non-compliances.

The duties of PAMOs onboard are as follows:

- Provide comprehensive briefings to all crew members and survey teams whilst establishing clear communication protocols and operational procedures for onboard activities;
- Test, deploy, and retrieve PAM equipment to ensure effective and smooth data collection;
- Maintain continuous focus on listening to received sounds and monitoring PAM display screens for cetacean detection. Non-work-related activities, including listening to music, watching videos, and reading books, are not permitted during observation windows. Work-related tasks, such as completing reports whilst monitoring the equipment may be accepted under certain circumstances, but this is not a given;
- Document all cetacean detections, including, when possible, species or group identification, position, distance, and bearing relative to the vessel;
- Record general environmental conditions that might affect detection capabilities;
- Monitor and document the power output of acoustic sources during operations, along with any mitigation measures implemented during observations;
- Implement appropriate mitigation actions such as delayed starts and shut downs; and,
- Record and report any deviations from the guidelines as well as any non-compliances.

A.4. Observer effort

Two MMOs and two PAMOs will be present onboard the survey vessel. PAM will provide 24-hour acoustic monitoring where necessary during operational periods. MMO visual monitoring will be conducted from a suitable viewing platform allowing maximum visibility of the mitigation zone (typically the vessel bridge, top deck, or helipad) commencing 30 minutes before sunrise continuing until 30 minutes after

sunset (health and safety permitting) with two MMOs on effort during operational periods in accordance with the requirements of the 2013 Code.

A.4.1. Pre-start observations

The sound source may only be activated within the operational area defined for the survey. Within this area, source activation may only commence once the observer confirms that there are no marine mammal detections within the mitigation zone.

The source cannot be activated during daylight hours unless:

- At least one qualified MMO has continuously made visual observations all around the source for the presence of marine mammals, from the bridge (or preferably an even higher vantage point) using both binoculars and the naked eye, and no marine mammals (other than fur seals) have been observed in the relevant mitigation zone for at least 30 minutes, and no fur seals have been observed in the relevant mitigation zones for at least 10 minutes, and;
- Passive Acoustic Monitoring for the presence of marine mammals has been carried out by a qualified PAM operator for at least 30 minutes before activation and no vocalising cetaceans have been detected in the relevant mitigation zones.

The source cannot be activated during night-time hours or poor sighting conditions unless:

- Passive Acoustic Monitoring for the presence of marine mammals has been carried out by a qualified PAM operator for at least 30 minutes before activation, and;
- The qualified observer has not detected vocalising cetaceans in the relevant mitigation zones.

When arriving at a new location in the operational area for the first time, the initial acoustic source activation must not be undertaken at night or during poor sighting conditions unless either:

- MMOs have undertaken observations within 20 nautical miles of the planned start up position for at least the last two hours of good sighting conditions prior to proposed operations, and no marine mammals have been detected; or,
- Where there have been less than two hours of good sighting conditions preceding proposed operations (within 20 nautical miles (37.4 km) of the planned start up position), the source may only be activated if:
 - PAM monitoring has been conducted for the two hours immediately preceding proposed operations;
 - Two MMOs have conducted visual monitoring in the two hours immediately preceding proposed operations;
 - No Species of Concern have been sighted during visual monitoring or detected during acoustic monitoring in the relevant mitigation zones in the two hours immediately preceding proposed operations;
 - No fur seals have been sighted within the relevant mitigation zone during the preceding 10 minutes; and,
 - No other marine mammals have been sighted during visual monitoring or detected during acoustic monitoring in the relevant mitigation zones in the 30 minutes immediately preceding proposed operations (DOC, 2013).

A.5. *Soft-starts*

Soft-starts are required when activating the acoustic source. The exception is when the source is being reactivated after a break in operations of less than 10 minutes, not in response to a marine mammal observation in the mitigation zone. This provision must not be used repeatedly to avoid undertaking a full soft-start procedure: repeated short interruptions to source activity do not remove the requirement for a full soft start where otherwise applicable. Marine mammals must not be in the mitigation zone prior to reactivation of the sound source. The soft start procedure involves a gradual ramp up of the source power, starting at the lowest output level and increasing gradually over a 20–40 minute period. The following considerations must be adhered to during the soft-start procedures: the operational power of the source must not exceed its specified capacity during the soft-start procedure or during any testing and, the observers are responsible for communicating all requirements effectively to the seismic and vessel crew.

A.6. *Acoustic source testing*

Acoustic source testing will follow the applicable soft-start procedures. The source power should be gradually ramped up to the required test level at a rate no faster than the standard soft-start requirement and may not exceed the operational capacity of the source. The minimum 20-minute duration does not apply to testing and testing may not be used as a substitute for mitigation measures or as a way to bypass the implementation of a soft-start procedure.

A.7. *Delayed or shut down operations - species of concern*

If, during pre-start operations or while the acoustic source is active, including during a soft-start, a qualified observer detects at least one Species of Concern (**APPENDIX C - SPECIES OF CONCERN**) with a calf within 1.5 km from the sound source, operations must be delayed or shut down immediately. Reactivation may only occur once the observer confirms that the animals have vacated the area and are beyond 1.5 km from the acoustic source, or after 30 minutes have passed since the last detection during continual observations.

If, during the pre-start operations or while the acoustic source is active, including during a soft-start, a Species of Concern has been detected by a qualified observer within 1 km of the acoustic source, the operations must be delayed or shut down immediately. Reactivation may only occur once the observer confirms that the animal(s) have vacated the area and are beyond 1 km from the acoustic source, or after 30 minutes have passed since the last detection during continuous observations.

A.7.1. Other marine mammals (not Species of Concern)

If an MMO/PAMO detects a marine mammal within 200 m of the source during pre-start observations prior to initiation of a Level 1 acoustic source soft-start, soft-start will be delayed until:

- MMO/PAMO confirms the marine mammal has moved to a point that is more than 200 m from the source; or,
- Despite continuous observation, 10 minutes has passed since the last detection of a New Zealand fur seal within 200 m of the source and 30

minutes has elapsed since the last detection of any other marine mammal within 200 m of the source, and the mitigation zone remains clear.

If all mammals detected within the relevant mitigation zones are observed moving beyond the respective areas, there will be no further delays to initiation of soft start.

A.8. PAM operations

If PAM equipment experiences technical issues, malfunctions, or damage, survey operations may continue for up to 20 minutes whilst the issues are being assessed. If it is determined that the PAM equipment requires repair to resolve the issue, operations may continue for up to two hours without PAM providing that the following is met:

- The operations are conducted during daylight hours with two MMOs on watch and with sea conditions not exceeding Beaufort 4;
- No marine mammals have been detected by PAM alone within the past two hours inside the mitigation zone;
- Two MMOs maintain watch at all times during seismic operations when PAM is not operational;
- The DOC is notified as soon as possible, including the time and location when operations began without an active PAM system. If it is not possible to repair the PAM equipment, the DOC will be consulted for advice on how to proceed; and,
- The total duration of operations with an active source but without PAM does not exceed four hours in any 24-hour period.

A.9. Reporting requirements

MMOs and PAMOs are jointly responsible for recording and reporting all detection data collected during the survey, along with a summary report. This report must include the required information in a standardised format, following the template available on the Department of Conservation website: <http://www.doc.govt.nz/notifications>. It is important to distinguish between records made by MMOs, PAMOs, qualified observers, and others, as well as between observational data collected during survey and non-survey periods.

All raw datasheets must be submitted to DOC at the earliest opportunity and no later than 14 days after the survey's completion. Likewise, the final written report should be provided as soon as possible and no later than 60 days after the survey's completion.

If a qualified observer determines that the number of marine mammals encountered during the survey is higher than expected, they must immediately notify the Director-General. If the Director-General deems additional measures necessary, the MMO and PAM team, along with the crew, must implement adaptive management actions without delay. Any non-compliance with the 2013 Code of Conduct must be reported to DOC immediately.

A.10. Key contacts and communication protocol

All enquiries or notifications to DOC must be directed to [REDACTED] via phone at [REDACTED] or email at [REDACTED]. Any communication made via phone must be promptly followed by a confirmation email. Additionally,



GEOMAR Helmholtz Centre for Ocean Research Kiel must be kept informed of all correspondence with DOC; therefore, all emails, including follow-ups to phone calls, should be copied to [REDACTED].

A.11. Navigational safety

The vessel will transit from Wellington harbour (Aotea Quay) through the Cook Strait to the operational area. The transit is expected to take eight hours.

APPENDIX B – SOUND TRANSMISSION-LOSS MODELLING

This appendix presents the sound (noise) transmission-loss modelling undertaken to investigate propagation characteristics of underwater sound within the Cook Strait region under a range of representative source and environmental conditions. Modelling was commissioned to support the assessment of the spatial distribution of acoustic energy associated with the proposed offshore survey activities and to provide a technical basis for understanding how regional bathymetry, source depth, and frequency content may influence sound propagation throughout the study area.

The present survey was undertaken within central New Zealand, across Cook Strait and the southern Hikurangi Margin, one of the world's most complex SSST zones (Bilich *et al.*, 2001; Wallace *et al.*, 2012). This tectonic setting represents the transition between oblique subduction along the Hikurangi Margin and dextral strike-slip deformation accommodated by the Marlborough Fault System before continuing southwards along the Alpine Fault (Barnes *et al.*, 1998; Wallace *et al.*, 2012). Owing to its exceptional structural complexity and seismic significance, the region has become the focus of extensive multidisciplinary geophysical investigations aimed at improving the understanding of crustal architecture, fault connectivity and seismic hazards (Crutchley *et al.*, 2020; Henrys *et al.*, 2020; Stevens *et al.*, 2024).

As described extensively in **Section 5.1**, the Cook Strait is characterised by highly variable bathymetry, including extensive continental shelf areas, steep shelf-break transitions, deep offshore basins exceeding 2,500 m water depth, and complex submarine canyon systems (Barnes *et al.*, 2010; Crutchley *et al.*, 2020). Such environmental heterogeneity influences acoustic wave propagation through strong variations in bathymetric confinement, reflection geometry, mode conversion and propagation-path characteristics, resulting in substantial spatial variability in transmission loss (Ainslie, 2010; Jensen *et al.*, 2011). Consequently, site-specific numerical modelling is required to adequately characterise the expected acoustic footprint and identify the principal physical controls governing sound propagation within the region.

Unlike previous studies in which detailed source-characterisation modelling was available through dedicated source-modelling software, the present assessment focuses specifically on regional-scale sound propagation and transmission-loss behaviour. The primary objective is therefore not to reconstruct the detailed acoustic signature of the seismic source itself, but rather to evaluate how acoustic energy propagates through the Cook Strait environment once radiated into the water column. The modelling was also designed to evaluate predicted received sound levels at the applicable mitigation zone boundaries specified by the 2013 Code of Conduct. To investigate these processes, a series of fixed-source transmission-loss simulations were undertaken using the dBSea acoustic-propagation modelling platform. Two representative source locations were evaluated: a shallow-water coastal source situated on the continental shelf and a deep-water offshore source located within the principal offshore basin. For each source location, broadband propagation simulations were conducted across two frequency ranges extending from 12.5 Hz to 250 Hz and from 12.5 Hz to 1 kHz, respectively. These frequency limits were selected to investigate the relative influence of low-frequency and extended-frequency propagation behaviour within the study area and to provide a basis for comparing the sensitivity of propagation patterns to increasing frequency content.

To facilitate quantitative comparison between propagation conditions, identical sets of virtual receivers were established for every scenario at radial distances of 200 m, 1 km and 1.5 km from each source location. In addition, complete radial transmission-loss profiles were extracted along all propagation azimuths generated by the numerical model, allowing the influence of propagation direction and regional bathymetry to be evaluated consistently across all simulations. These receiver distances also correspond to the locations relevant to assessment of received sound levels at the mitigation-zone boundaries specified under the 2013 Code, thereby allowing the model outputs to support the required evaluation of received SEL at those distances.

The following sections describe the environmental inputs, modelling methodology, scenario definitions and modelling results, followed by an interpretation of the principal propagation mechanisms identified within Cook Strait and their implications for regional acoustic transmission.

B.1. Modelling approach

Numerical sound propagation modelling was undertaken to evaluate transmission characteristics of underwater sound within the Cook Strait region under a range of representative environmental and source conditions. Modelling was performed using dBSea Version 3.0.24 (dBSeaLtd, 2026), a widely used underwater acoustic propagation platform capable (with advanced primary user acoustical knowledge) of simulating sound transmission in range-dependent marine environments through a variety of propagation algorithms. Given the large spatial extent of the study area, the highly variable bathymetry and the predominance of low-frequency sound propagation over regional scales, the Parabolic Equation (PE) solver was selected as the primary propagation algorithm. The PE method is regarded widely as one of the most appropriate numerical approaches for modelling long-range underwater sound propagation in complex marine environments because it accounts for range-dependent bathymetry, variable seabed properties, and frequency-dependent propagation effects while maintaining computational efficiency over large modelling domains (Jensen *et al.*, 2011).

The modelling domain encompassed the central Cook Strait region and adjacent offshore areas surrounding the proposed survey corridor. The computational area was designed to include both shallow continental shelf environments surrounding the Strait and deeper offshore basins located to the east and southeast of the survey area. This configuration ensured that principal bathymetric features capable of influencing acoustic propagation were represented within the modelled environment.

All model calculations were undertaken using bathymetric data derived from the General Bathymetric Chart of the Oceans (GEBCO, 2024), provided on a 15 arc-second-interval grid and imported directly into the dBSea modelling environment. The bathymetric surface was projected using the WGS'84/UTM Zone 60S coordinate reference system (EPSG: 32760), providing a consistent spatial framework for all transmission-loss calculations. The resulting propagation environment was therefore represented as a fully range-dependent acoustic domain, allowing transmission-loss predictions to account for the pronounced bathymetric variability that characterises Cook Strait and the surrounding offshore basins.

To investigate the influence of source location on regional propagation behaviour, two representative scenarios were evaluated. The first condition consisted of a shallow-water source positioned at Station 49 (Survey 1, End Line 03, 174.1500° E, 41.4205° S), corresponding to a local water depth of approximately 25 m. This location was selected to represent acoustic emissions originating within the continental shelf environment near the western entrance of Cook Strait, where propagation was expected to be influenced strongly by repeated seabed interaction, bathymetric confinement, and proximity to coastal boundaries. The second scenario consisted of a deep-water source positioned at Station 10 (deployment location of OBS 09, 175.5927° E, 41.8442° S), situated at the intersection of Line 8 of Survey 1 and Line 1 of Survey 2. The local water depth at this location is approximately 2,372 m, placing the source within the principal offshore basin east of Cook Strait. This configuration was selected to investigate propagation under deep-water conditions where acoustic energy may propagate through a substantially larger water column and interact with regional-scale bathymetric features over much greater distances than in the shallow-water scenario.

For each source location, broadband simulations were undertaken across two frequency ranges extending from 12.5 Hz to 250 Hz and from 12.5 Hz to 1 kHz, respectively. These frequency limits were selected to examine the sensitivity of propagation behaviour to increasing frequency content while remaining representative of the low-frequency acoustic energy typically associated with offshore geophysical survey activities (Richardson *et al.*, 1995). The lower frequency limit of 12.5 Hz was adopted as the minimum modelling frequency, providing a consistent basis for comparison across all scenarios while encompassing the dominant low-frequency energy associated with seismic survey sources.

Propagation outputs were generated using both SPL and cumulative Sound Exposure Level (SEL_{cum}) metrics. SPL results provide an instantaneous representation of the predicted acoustic field, whereas SEL_{cum} incorporates cumulative acoustic energy received over the specified exposure period and therefore provides a useful metric for assessing spatial distribution of total acoustic energy. Following verification of model outputs and consistency checks between scenarios, SEL_{cum} was adopted as the principal metric for comparative analysis within this appendix because it provides the most representative measure of cumulative acoustic exposure associated with the modelled source conditions.

Model outputs were subsequently extracted and analysed using four complementary approaches. Firstly, spatial propagation maps were generated to characterise geographical distribution of acoustic energy throughout the study area. Secondly, radial transmission-loss profiles were extracted to quantify directional differences in propagation performance. Thirdly, to facilitate quantitative comparison between propagation conditions, identical sets of virtual receivers were established for every scenario at radial distances of 200 m, 1 km and 1.5 km from each source location. Finally, cross-sectional propagation plots were examined along selected azimuths to investigate interaction between acoustic energy and the underlying bathymetric structure. Together, these analyses provided a comprehensive assessment of the principal physical controls governing underwater sound propagation within Cook Strait and form the basis for interpretation presented in the subsequent sections of this appendix.

For the spatial propagation analyses, model outputs were evaluated using a standardised assessment period of 3,600 s. This common assessment period was applied consistently across all scenarios to facilitate comparison of relative

propagation behaviour between source locations and frequency ranges. The resulting SEL_{cum} fields presented in **Figure 42–49** therefore represent standardised model outputs for comparative propagation analysis and should not be interpreted as operational cumulative exposure from the planned seismic sequence. The proposed survey source will operate impulsively, with shots separated by approximately 10–15 s, rather than as a continuously active source over the 3,600 s assessment period. For comparison with the received SEL criteria specified at the mitigation-zone boundaries under the 2013 Code, receiver specific levels were therefore evaluated separately using the corresponding 1-s reference exposure, as described in **Section B.2.5**.

The transmission-loss modelling presented in this appendix is intended to provide a first-order assessment of regional sound-propagation behaviour within the Cook Strait environment and should not be interpreted as a prediction of actual acoustic exposure during survey operations. Simulations are based on a deliberately simplified representation of the physical environment and were designed primarily to investigate the relative influence of source depth, frequency content, and regional bathymetric structure on sound transmission. Consequently, several important environmental variables known to influence underwater sound propagation within Cook Strait, including temporally variable sound-speed structure, tidal currents, tidal elevation, water-column stratification, spatially heterogeneous seabed properties, and transient oceanographic processes, were not represented explicitly within the model. Furthermore, modelling was undertaken using representative source conditions rather than a fully characterised seismic-source signature derived from dedicated airgun-array modelling or field measurements. As with all numerical propagation models, results represent a mathematical approximation of a highly complex natural system and should therefore be regarded as indicative rather than predictive. The model is most appropriately interpreted as a tool for examining relative propagation behaviour and identifying the principal environmental controls governing regional sound transmission. Accurate quantification of operational acoustic exposure would require empirical field validation, including measurement of the source signature in the near field, verification of source levels and spectral characteristics, and acoustic monitoring at multiple ranges and directions from the operational source under representative environmental conditions. Such measurements would allow comparison between predicted and observed propagation characteristics and provide the basis for refinement and calibration of the modelling framework. Consequently, outputs presented herein should be considered a regional scale screening assessment of potential propagation behaviour rather than a definitive prediction of acoustic levels that would occur during the proposed survey.

B.1.1. Bathymetry

Bathymetry constitutes the primary environmental control on underwater sound propagation within Cook Strait and was therefore treated as the principal spatially varying parameter within the transmission-loss model. The bathymetric dataset incorporated into the modelling domain represented the full extent of Cook Strait and the adjacent offshore regions, encompassing shallow continental shelf environments, steep shelf-break transitions, submarine canyon systems and deep offshore basins exceeding 2,500 m water depth (as explained in detail in **Section 5.1.1**). Consequently, the resulting bathymetric model captured the pronounced topographic complexity that characterises the region. Water depths varied from less than 50 m within the nearshore shelf environments to more than 2,500 m within the principal offshore basin east of Cook Strait. This substantial depth

gradient provided an ideal setting for examining the influence of large-scale seabed morphology on sound propagation and enabled assessment of propagation pathways across both shallow-water and deep-water environments. The imported bathymetric surface was used directly by the PE solver to define the range-dependent propagation environment. Consequently, all transmission-loss predictions accounted explicitly for changes in seabed elevation along each propagation path and for associated interactions between acoustic energy and underlying bathymetric structure.

B.1.2. Water column properties

To isolate influence of bathymetry and source geometry on propagation behaviour, a simplified and spatially homogeneous water-column environment was adopted throughout the modelling domain. A constant compressional sound speed of 1,580 ms⁻¹ was specified across the entire water column, thereby eliminating influence of vertical sound-speed gradients, seasonal stratification, and local hydrographic variability. This approach allowed resulting propagation patterns to be interpreted primarily in terms of bathymetric controls rather than refraction associated with water-column structure.

Environmental parameters used to define the water column included a temperature of 10°C, salinity of 35 parts per thousand (ppt) and power of Hydrogen (pH) of 8.0. No tidal elevation offset was applied, and current velocity was set to zero throughout the modelling domain. Although tidal currents within Cook Strait may locally exceed several metres per second, the objective of the present assessment was to investigate first-order propagation behaviour under representative baseline conditions rather than simulate specific tidal phases or transient oceanographic states.

Use of a homogeneous sound-speed field provides a conservative and reproducible framework for comparing the relative influence of source depth and frequency content across all modelled scenarios. **Table 22** summarises the water-column parameters adopted in the model.

Parameter	Value
Compressional sound speed	1,580 m/s
Temperature	10°C
Salinity	35 ppt
pH	8.0
Current speed	0 m/s
Current direction	90°

Table 22: Water-column parameters used in the transmission-loss model. *Source:* OSC (2026).

B.1.3. Seabed Properties

The seabed was represented using a single acoustically homogeneous sediment layer extending throughout the modelling domain. This simplification was adopted to minimise uncertainties associated with poorly constrained regional sediment distributions and to allow the influence of bathymetric geometry to be examined independently of complex spatial variations in sediment composition. Consequently, the seabed layer was defined as a silty sand to mixed-sediment environment and parameterised using acoustic properties associated with

unconsolidated marine sand within the dBSea material database. The sediment layer extended from the local seabed surface to infinite depth and was referenced directly to the bathymetric profile at each model location. A sediment density of 1,595 kg m³ was specified together with a frequency-dependent attenuation coefficient of 0.4 dB per wavelength. These values are representative of moderately attenuating unconsolidated marine sediments and provide a realistic approximation of acoustic energy losses associated with seabed interaction within the frequency range considered.

Because the selected propagation scenarios encompass both shallow shelf environments and deep offshore basins, repeated interactions between the acoustic field and the seabed were expected to constitute one of the dominant transmission-loss mechanisms within portions of the modelling domain. Consequently, although sediment properties were uniform spatially, influence of the seabed on propagation can vary substantially between scenarios, as a function of water depth and local bathymetric geometry. **Table 23** summarises the seabed parameters adopted in the model:

Parameter	Value
Sediment type	Silty sand/mixed sediment
Material classification	Sand
Layer reference	Local seabed
Layer thickness	Infinite
Density	1,595 kg m ³
Attenuation	0.4 dB/wavelength

Table 23: Seabed properties used in the transmission-loss model.
Source: OSC (2026).

The environmental configuration described provided a controlled modelling framework in which the principal drivers of propagation variability are source depth, frequency content, and regional bathymetric structure. This approach allowed physical mechanisms responsible for the observed transmission-loss patterns to be identified more clearly than would be possible within a highly parameterised oceanographic model.

B.2. Results

The transmission-loss simulations revealed pronounced differences in propagation behaviour between the shallow- and deep-water source scenarios, reflecting the strong influence exerted by regional bathymetry on acoustic transmission throughout Cook Strait. Results demonstrated that source depth not only governed overall propagation range but also modified the directional distribution of acoustic energy, the interaction between the propagating wavefront and the seabed, and the degree of spatial variability observed throughout the modelling domain. The following sections examine these processes progressively, beginning with the regional propagation patterns, followed by analyses of directional variability, propagation cross-sections and receiver-specific predictions.

Unless otherwise stated, SEL_{cum} values presented in **Sections B.2.1-B.2.4** correspond to the standardised 3,600-s assessment period described in **Section B.1** and are used to characterise relative spatial and directional propagation behaviour between scenarios

B.2.1. Regional propagation patterns

The spatial distributions of SEL_{cum} predicted for the four modelled scenarios provided the first indication of how source depth, frequency content, and regional bathymetry collectively governed underwater sound propagation throughout Cook Strait. Rather than exhibiting simple radial spreading from source locations, the predicted acoustic fields displayed highly heterogeneous propagation patterns that closely reflected the complex physiographic structure of the study area. Differences in continental shelf width, basin geometry, submarine slopes, and major bathymetric transitions exerted a dominant control on the redistribution of acoustic energy, producing propagation footprints that varied substantially between scenarios despite use of identical environmental properties and propagation algorithms, differing only in source location and water depth (**Figure 42**). A clear distinction emerged between the shallow-water and deep-water source configurations. Whereas the shallow source generated an acoustic field largely confined to the continental shelf and adjacent shallow marine environments, the deep-water source produced a considerably broader regional footprint extending across much of the offshore basin east of Cook Strait (**Figure 42**). These contrasting behaviours primarily reflected the fundamentally different propagation environments experienced by the acoustic wavefront immediately after emission. In shallow water, repeated interaction with both the seabed and the sea surface resulted in rapid cumulative attenuation and limited the effective propagation range. In contrast, the deep-water configuration allowed a much larger proportion of the acoustic energy to remain within the water column over extended distances before interacting with major bathymetric features, thereby maintaining higher standardised modelled levels across substantially larger areas.

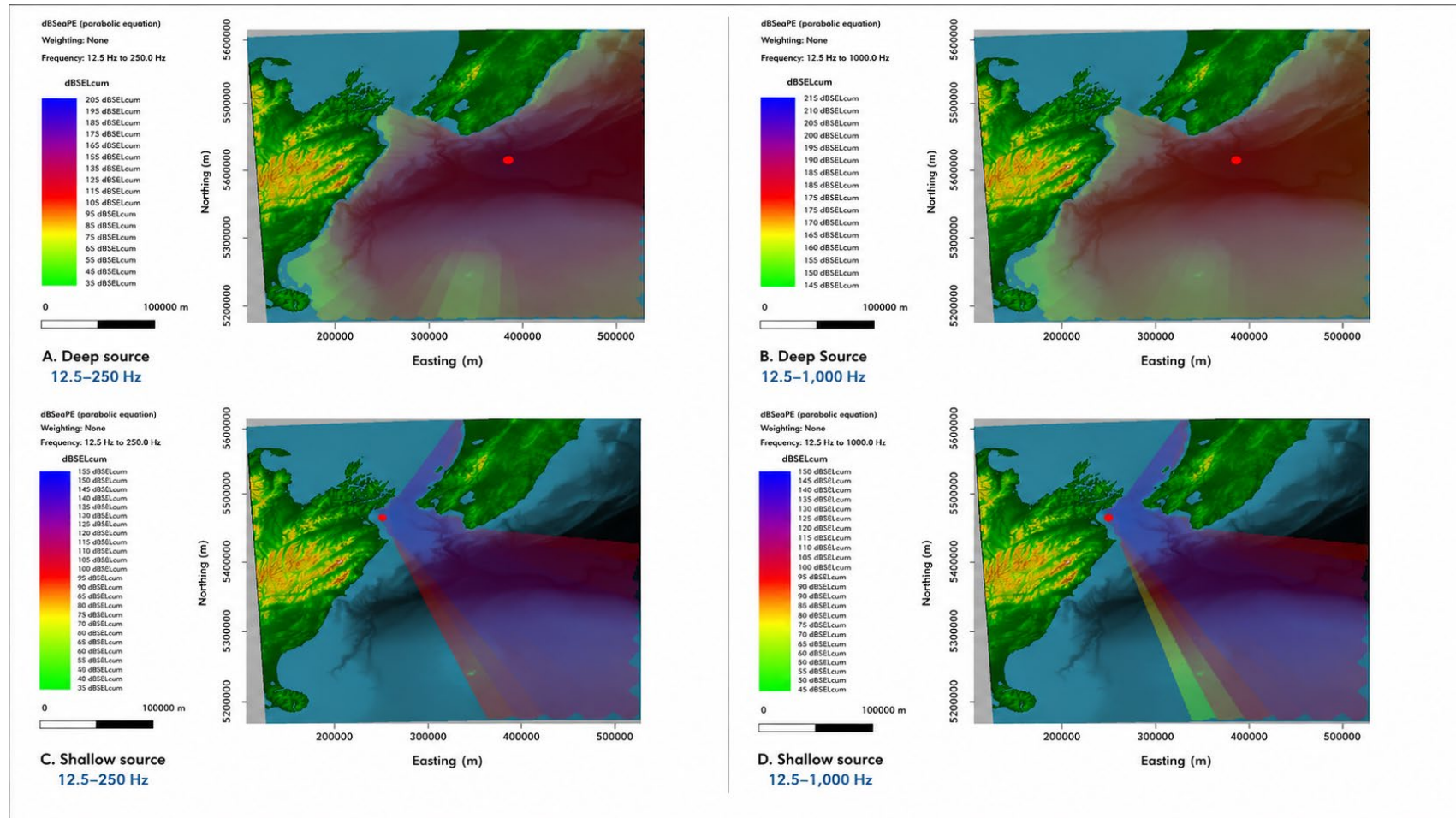


Figure 42: Standardised cumulative Sound Exposure Level (SEL_{cum}) propagation maps for the four transmission-loss modelling scenarios in Cook Strait, New Zealand, calculated using a common 3,600-s assessment period for comparative propagation analysis. Upper panels show the deep-water source, whereas lower panels show the shallow-water source. Values represent comparative model outputs and not operational cumulative exposure from the planned impulsive seismic sequence. *Source:* OSC (2026).

The influence of source depth was evident particularly in the overall geometry of the predicted propagation fields. The shallow-water simulations revealed relatively rapid contraction of the high-exposure region following emission, with acoustic energy becoming increasingly constrained by local bathymetric relief and the irregular geometry of the continental shelf. Several areas exhibited abrupt changes in predicted exposure over comparatively short spatial scales, indicating strong modulation of transmission loss by seabed morphology. Such behaviour is consistent with environments in which repeated bottom interaction becomes the dominant mechanism controlling acoustic attenuation.

Conversely, the deep-water simulations exhibited a significantly more extensive propagation footprint characterised by smoother regional gradients and greater continuity of elevated SEL_{cum} values over long distances. Rather than being rapidly attenuated, acoustic energy remained distributed throughout the deep offshore basin where the larger water-column thickness reduced the frequency of bottom interactions and allows propagation to occur under conditions that more closely approximate deep-ocean transmission. Nevertheless, the predicted sound field remains distinctly anisotropic, demonstrating that even within deep water the surrounding bathymetric framework continued to influence the redistribution of acoustic energy and the efficiency of propagation along different azimuths.

Comparison of the two frequency ranges further demonstrated the increasing influence of frequency dependent attenuation on regional sound transmission. For both source depths, extension of the upper modelling limit from 250 Hz to 1 kHz resulted in a progressive reduction in the spatial extent of elevated SEL_{cum} values. This effect was most pronounced within the shallow-water scenario, where higher-frequency components experienced more frequent interactions with the seabed and therefore accumulate greater transmission loss. By comparison, the deep-water source exhibited a comparatively smaller reduction in overall propagation extent, reflecting the reduced importance of bottom interaction during the initial stages of long-range propagation.

Perhaps the most important observation arising from **Figure 42** is that the predicted acoustic field is far from isotropic. Instead of expanding uniformly from the source, acoustic energy followed preferential propagation corridors that appear associated closely with the large-scale morphology of Cook Strait and the adjacent offshore basins. Likewise, several sectors exhibited comparatively rapid attenuation, suggesting presence of bathymetrically controlled shadowing effects or regions where repeated interactions with steep seabed gradients accelerated energy loss. These directional differences provided the first indication that regional bathymetry constitutes one of the principal controls on underwater sound propagation within the study area and motivate the more detailed directional analyses presented in the following section.

B.2.2. Directional propagation characteristics

The regional propagation maps presented in **Figure 42** indicate that sound transmission within Cook Strait is not spatially uniform. To examine this behaviour, **Figure 43** presents the corresponding radial model outputs in polar coordinates, in which SEL_{cum} is represented as a function of propagation azimuth and radial distance from the source. This representation allows directional variations in predicted acoustic levels to be visualised independently of geographical position, facilitating direct comparison between source depths and modelled frequency ranges.

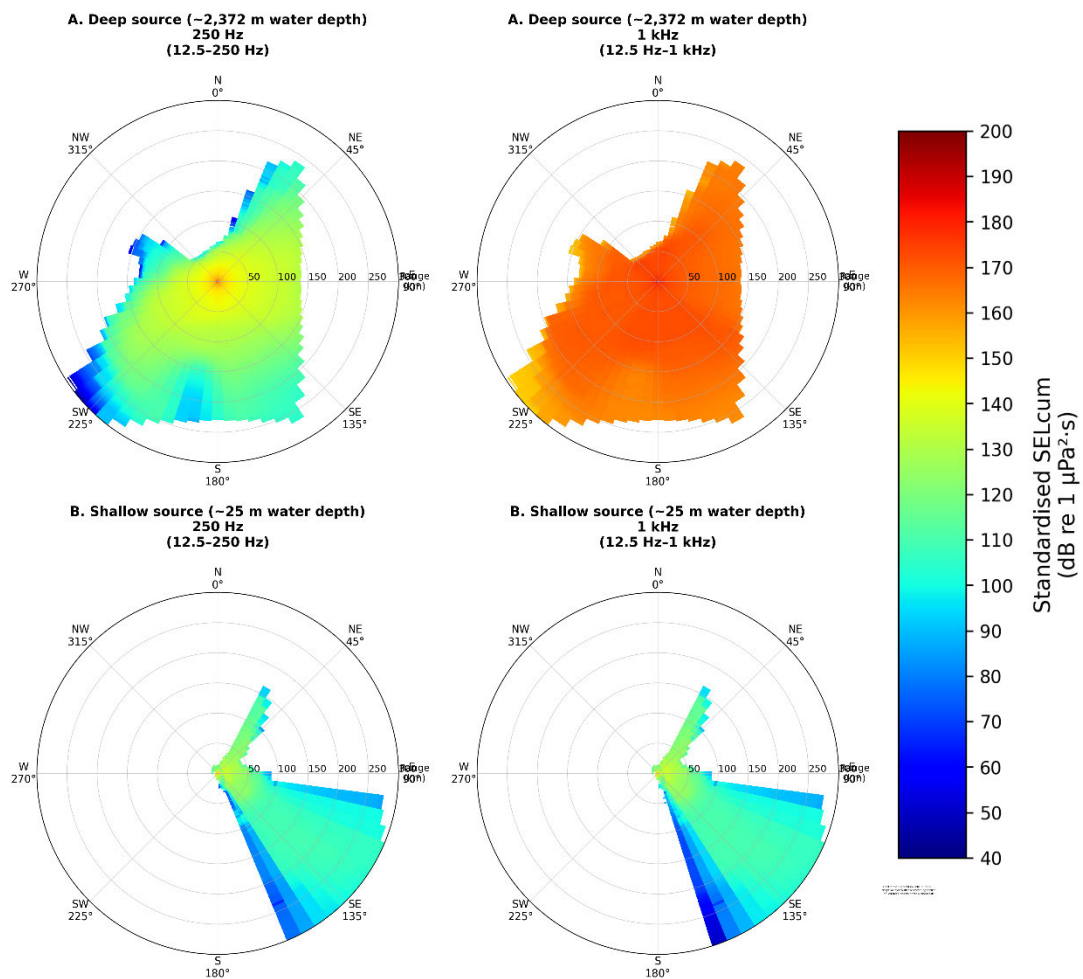


Figure 43: Polar representation of standardised cumulative Sound Exposure Level (SEL_{cum}) as a function of propagation direction and radial distance for the shallow- and deep-water source scenarios across the two modelled frequency ranges. Values are plotted directly from the discrete dBSea radial model outputs without spatial interpolation or smoothing; unfilled areas indicate locations for which no radial model data were available. The plots use the common 3,600-s assessment period applied to the comparative propagation analyses and should not be interpreted as operational cumulative exposure from the planned impulsive seismic sequence. *Source:* OSC (2026)

The polar representations demonstrate that the predicted acoustic field is characterised by substantial directional variability under all four modelling scenarios. Rather than exhibiting radially uniform distributions, the modelled SEL_{cum} fields show pronounced directional elongation and contraction, indicating that acoustic levels decrease at different rates with distance depending on propagation azimuth. These directional differences are evident for both source locations and frequency ranges, although their magnitude and spatial distribution differ between scenarios.

The deep-water source scenarios exhibit comparatively broad regions of elevated SEL_{cum} , with relatively high levels persisting over substantially greater radial distances along several propagation directions. Nevertheless, the acoustic field remains distinctly asymmetric, with some azimuths maintaining higher levels over considerably greater distances than others. Conversely, the shallow-water scenarios show a substantially more restricted distribution of elevated SEL_{cum} and generally more rapid reductions in level with radial distance. This contrast indicates a strong influence of source environment and regional bathymetry on the directional propagation patterns represented by the model.

Comparison between the two modelled frequency ranges shows that extending the upper frequency limit from 250 Hz to 1 kHz increases the predicted broadband SEL_{cum} because the latter scenario incorporates the additional modelled frequency bands between 315 Hz and 1 kHz. This increase is particularly pronounced for the deep-water source, where elevated broadband SEL_{cum} persists over comparatively large radial distances along several azimuths. The corresponding change is less pronounced for the shallow-water source, demonstrating that the effect of extending the modelled bandwidth depends strongly on the propagation environment rather than on frequency range alone. Despite these differences in absolute broadband levels, the principal directional structure of the acoustic field remains broadly comparable between frequency scenarios, indicating persistence of the major propagation pathways identified by the model.

The polar representation further demonstrates that directional variability occurs across the full range of modelled azimuths rather than being confined to a small number of discrete directions. Adjacent radials generally show progressive changes in predicted SEL_{cum} , although some sectors exhibit comparatively abrupt changes over relatively small angular intervals. Importantly, the corrected representation plots the discrete dBSea radial outputs directly and does not spatially interpolate between modelled values; consequently, these directional patterns reflect the underlying model results rather than interpolation-derived features.

B.2.3. Mean propagation behaviour

Although polar representations presented in **Figure 43** illustrated the full directional variability of the predicted acoustic field, comparison between scenarios were facilitated by examining the mean attenuation behaviour calculated across all simulated propagation azimuths. **Figure 44** summarised the average directional decay in SEL_{cum} as a function of radial distance from the source for the shallow- and deep-water source configurations. Shaded envelopes represented the directional variability observed at each distance, expressed as one standard deviation around the mean predicted SEL_{cum} .

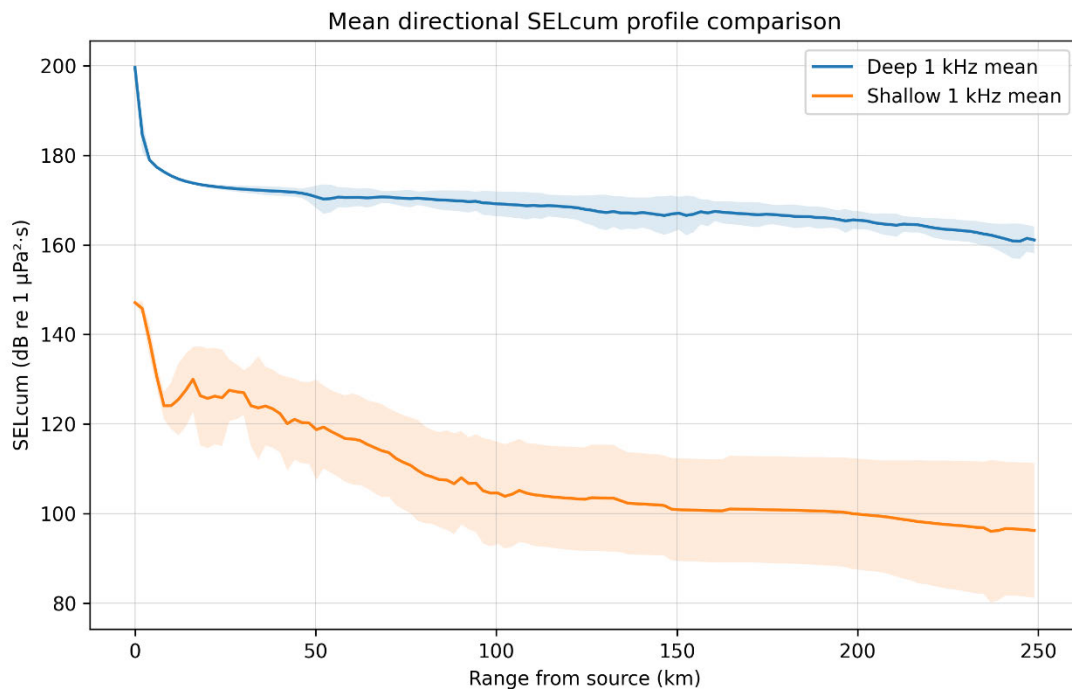


Figure 44: Comparison of mean directional standardised cumulative Sound Exposure Level (SEL_{cum}) decay with distance for the shallow- and deep-water source scenarios, calculated using a common 3,600-s assessment period for comparative propagation analysis. Shaded envelopes indicate the corresponding directional variability (± 1 standard deviation). *Source:* OSC (2026).

The mean attenuation profiles (**Figure 44**) indicated consistent differences between the two source configurations throughout the modelled distance range. For both frequency bands, the deep-water source maintains higher mean SEL_{cum} values over substantially greater distances than the corresponding shallow-water source. Divergence between the two source configurations becomes progressively more evident with increasing propagation range, resulting in increasingly distinct attenuation trajectories beyond the near-source region.

Figure 44 highlights the marked contrast in mean propagation behaviour between the shallow- and deep-water source configurations. The deep-water scenario maintained substantially higher mean SEL_{cum} values over the entire propagation range, with only a gradual reduction in cumulative exposure as distance increases. In contrast, the shallow-water source exhibited a much more rapid decrease in mean SEL_{cum} during the first tens of kilometres, followed by comparatively low levels over the remainder of the modelled domain. The associated variability envelope further indicated that directional differences are proportionally larger for the shallow-water scenario, whereas the deep-water source produces a more spatially consistent propagation field despite the pronounced bathymetric complexity of the study area.

B.2.4. Vertical propagation structure

To further characterise the three-dimensional distribution of the predicted acoustic field, representative vertical propagation cross-sections were extracted from the broadband (12.5 Hz–1 kHz) simulations for both source configurations. The broadband simulations were selected because they provided the most comprehensive representation of the modelled propagation environment, encompassing the full frequency range considered in the principal analyses presented throughout this appendix.

Selected transects were chosen to intersect the operational survey area and to represent principal propagation directions of relevance for each source location. For the shallow-water source, cross-sections were extracted along the eastward (90°) and south-eastward (135°) azimuths, representing the primary offshore propagation directions available from the coastal source location. For the deep-water source, westward (270°) and south-westward (225°) transects were selected to illustrate propagation from the offshore basin towards Cook Strait and the adjacent continental margin within the operational area.

The shallow-water cross-sections in **Figure 45** and **Figure 46** showed that the predicted acoustic field remains confined within the comparatively limited water column available across the continental shelf. Along both transects, the SEL_{cum} contours broadly follow the geometry of the seabed, with the vertical extent and overall shape of the acoustic field varying in response to changes in local bathymetry encountered along each propagation path.

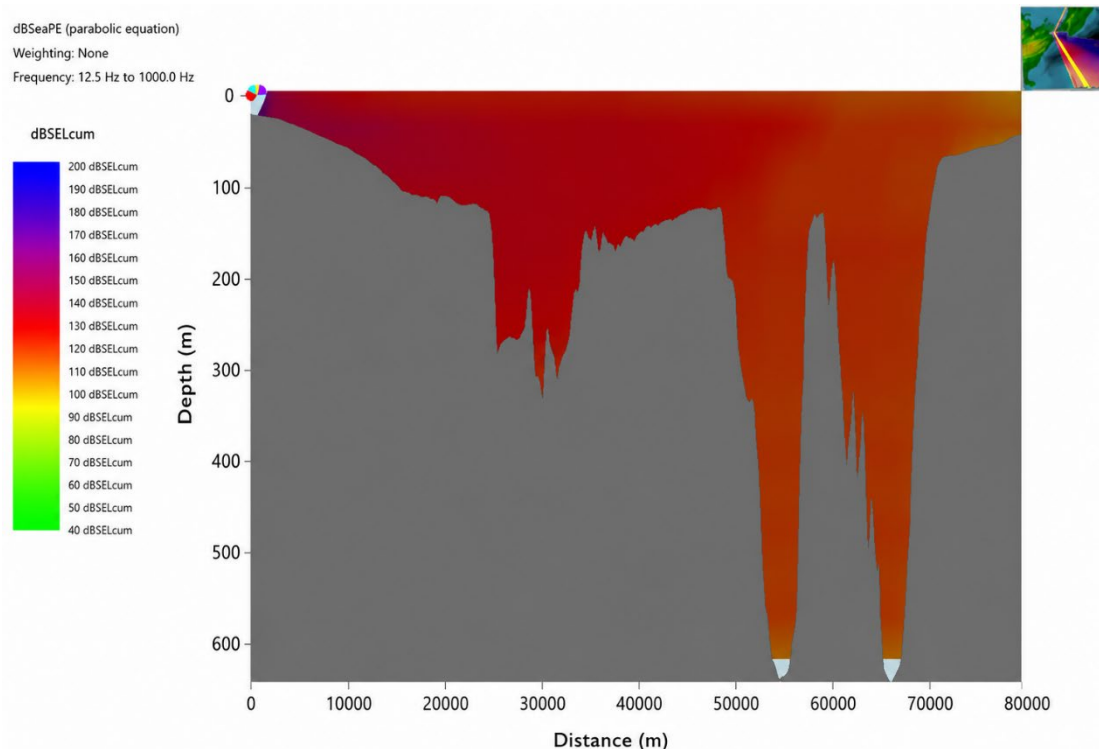


Figure 45: Vertical standardised SEL_{cum} propagation cross-sections for the shallow-water source along the eastward (90°) propagation transect, derived from the broadband (12.5 Hz–1 kHz) simulation using a common 3,600-s assessment period for comparative

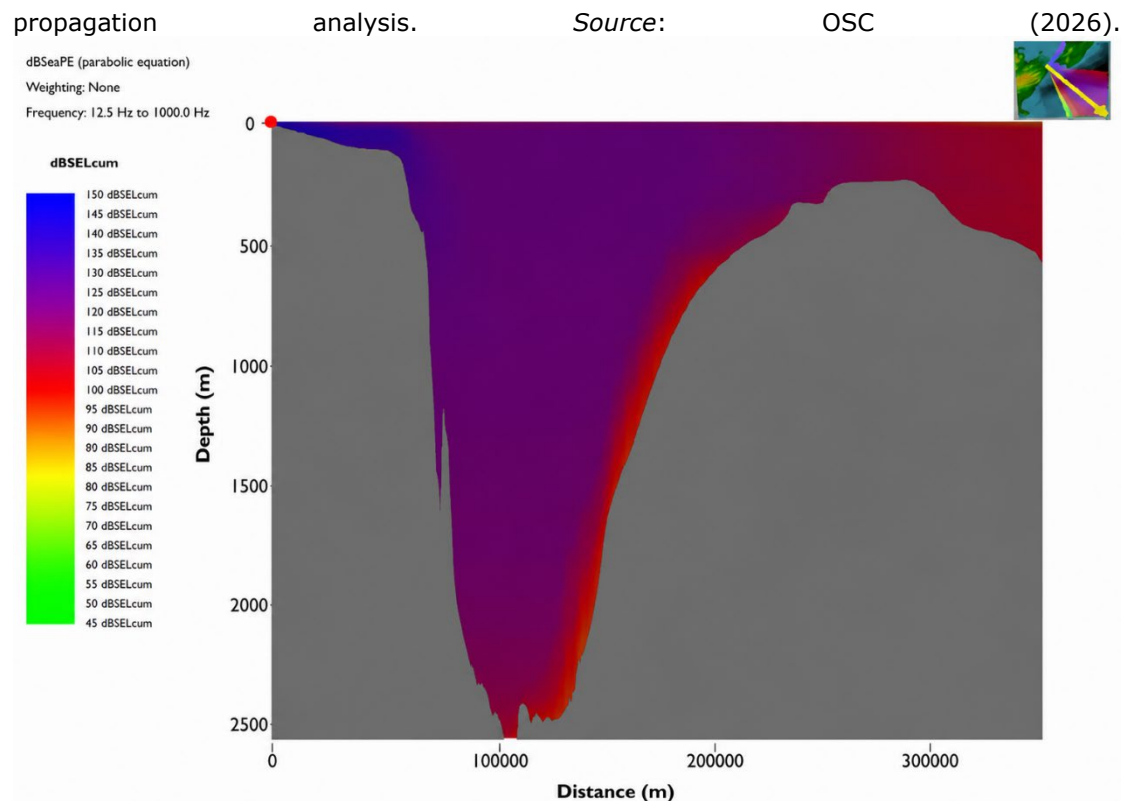


Figure 46: Vertical standardised SEL_{cum} propagation cross-sections for the shallow-water source along the south-eastward (135°) propagation transect, derived from the broadband (12.5 Hz–1 kHz) simulation using a common 3,600-s assessment period for comparative propagation analysis. *Source:* OSC (2026).

The deep-water cross-sections in **Figure 47** and **Figure 48** exhibited a substantially larger vertical propagation domain associated with the greater water depths surrounding the offshore source location. Elevated SEL_{cum} contours occupied a larger proportion of the water column over extended ranges, while the overall geometry of the predicted acoustic field continued to reflect the large-scale bathymetric structure encountered along the selected transects between the offshore basin and the continental margin. Comparison of the two source configurations demonstrated clear differences in the spatial extent of the predicted acoustic field. Whereas the shallow-water scenario was characterised by propagation within a relatively restricted water column, the deep-water scenario displayed a considerably larger propagation volume extending through much greater water depths. In both cases, the vertical distribution of SEL_{cum} closely followed the underlying seabed morphology represented within the numerical model.

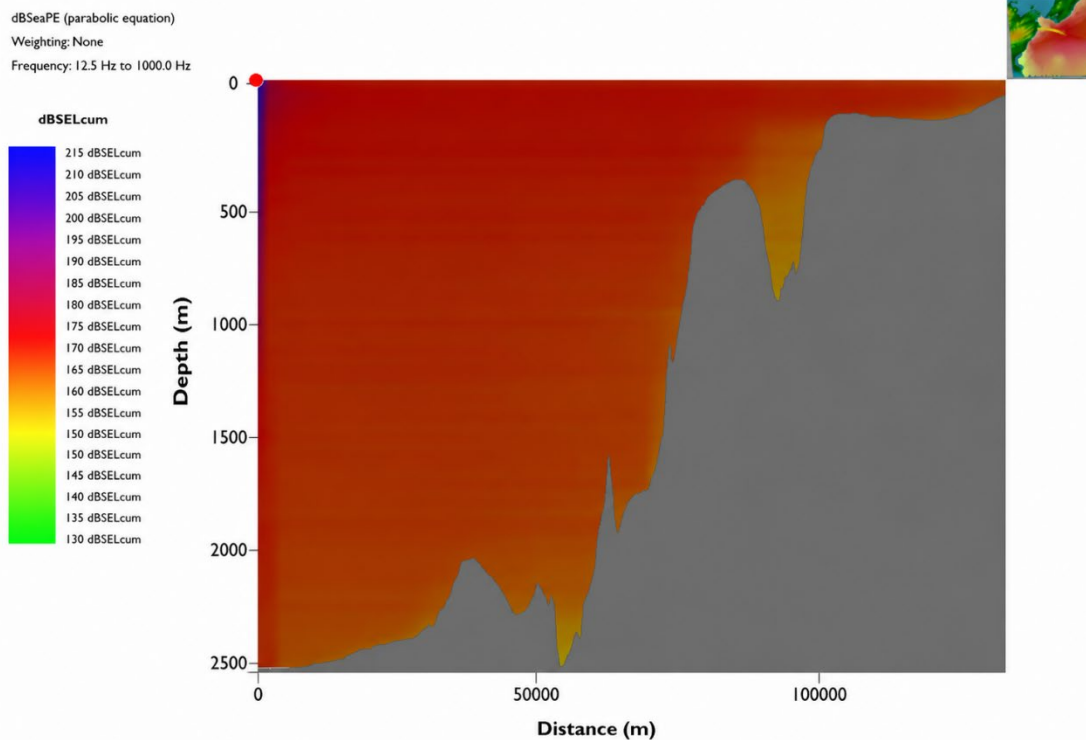


Figure 47: Vertical standardised SEL_{cum} propagation cross-sections for the shallow-water source along the westward (270°) propagation transect, derived from the broadband (12.5 Hz–1 kHz) simulation using a common 3,600-s assessment period for comparative propagation analysis. Source: OSC (2026).

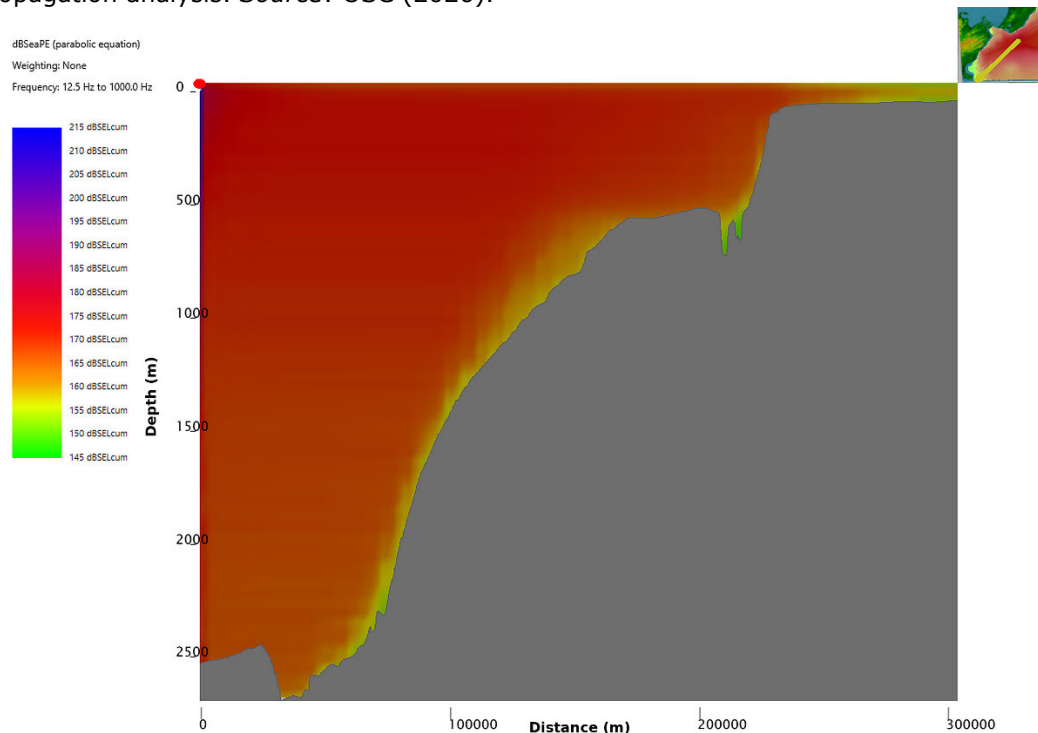


Figure 48: Vertical standardised SEL_{cum} propagation cross-sections for the shallow-water source along the south-westward (225°) propagation transect, derived from the broadband (12.5 Hz–1 kHz) simulation using a common 3,600-s assessment period for comparative propagation analysis. Source: OSC (2026).

Receiver-specific received SEL at mitigation-zone boundaries

To complement the spatial propagation analyses and evaluate received sound levels at the mitigation-zone boundaries specified under the 2013 Code, representative received SELs were evaluated at virtual receiver locations positioned 200 m, 1 km and 1.5 km from each source. These distances correspond to the locations at which received sound levels are relevant to evaluation of the prescribed mitigation zones.

The standardised 3,600-s SEL_{cum} outputs used for the comparative spatial analyses in **Sections B.2.1-B.2.4** are not directly applicable to this comparison because the planned seismic source will operate as a sequence of discrete impulsive shots at approximately 10–15-s intervals rather than as a continuously active source throughout the assessment period. Receiver-specific levels were therefore evaluated from the existing propagation solutions using the corresponding 1-s reference exposure (Count = 1). Received levels were referenced to a representative broadband source SEL of 230.5 dB re 1 $\mu Pa^2 \cdot s$ at 1 m, consistent with the 5,420-in³ G-Gun array specified for the survey. The spectral distribution used in the propagation modelling represents a simplified low-frequency source spectrum for screening purposes and should not be interpreted as a measured or detailed source-signature or directivity model of the operational array (**Figure 49**).

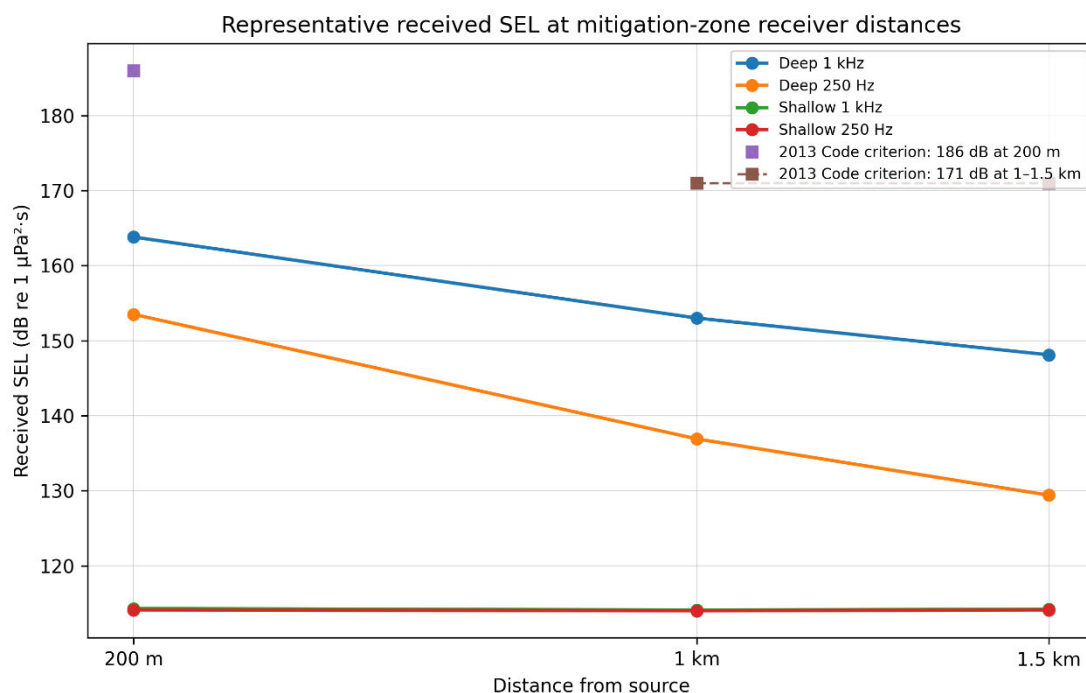


Figure 49: Representative broadband received Sound Exposure Level (SEL; 12.5 Hz–1 kHz) at virtual receiver distances from source for the shallow- and deep-water propagation scenarios. Receiver levels are presented as 1-s reference exposures (Count = 1) and referenced to a representative broadband source SEL of 230.5 dB re 1 $\mu Pa^2 \cdot s$ at 1 m for the 5,420-in³ G-Gun array. The 2013 Code received-SEL criteria of 186 dB re 1 $\mu Pa^2 \cdot s$ at 200 m and 171 dB re 1 $\mu Pa^2 \cdot s$ at 1 km and 1.5 km are shown for comparison. *Source:* OSC (2026).

Figure 49 shows that representative received SEL values decreased progressively with increasing distance from both source locations. The rate of decrease varied with propagation range, with relatively rapid reductions occurring close to the source followed by a slightly more gradual decline at greater distances. Across the

entire modelled range, received SEL values associated with the deep-water source remained consistently higher than those obtained for the shallow-water source. Separation between the two receiver profiles was maintained throughout the propagation domain, indicating persistent differences in propagation behaviour between the two representative source environments over the distances considered. The receiver-based results were consistent with the broader spatial patterns presented in the preceding sections and provide a quantitative comparison of representative received SEL at the specified receiver distances. Importantly, received levels at 200 m, 1 km and 1.5 km remained below the corresponding 2013 Code criteria in all modelled scenarios.

B.3. Discussion

The modelling results consistently demonstrated that bathymetric variability exerted the primary control on regional acoustic propagation throughout the Cook Strait study area. Rather than exhibiting radially symmetric transmission, the predicted SEL_{cum} fields showed pronounced directional dependence, with substantial variations in propagation range occurring over relatively small changes in azimuth. This behaviour was observed consistently for both source configurations and across investigated frequency ranges, indicating that the surrounding seabed morphology governed the spatial redistribution of acoustic energy to a much greater extent than would be expected under simplified range-independent conditions.

Directional envelopes and horizontal-propagation maps revealed that acoustic energy propagated preferentially along specific sectors while experiencing comparatively rapid attenuation in others. These directional differences coincided closely with major geomorphological transitions surrounding the operational area, including the continental shelf, steep shelf-breaks, submarine canyon systems, and adjacent deep basins. Rather than acting as a uniform propagation environment, the Cook Strait presented a highly heterogeneous acoustic waveguide in which local bathymetric gradients, continuously modify propagation paths, bottom interactions, and the cumulative transmission loss experienced by the acoustic field.

The vertical propagation cross-sections further illustrated the influence of seabed relief on sound transmission. Depending on propagation direction, acoustic energy may remain confined within relatively deep-water columns over extended distances or encounter rapidly shoaling bathymetry that increases bottom interaction and accelerates energy loss. Consequently, propagation characteristics differed substantially between azimuths, even for identical source parameters, emphasising that local bathymetry should be regarded as a first-order control on regional sound propagation.

These observations are consistent with the broader geological setting of Cook Strait, which represents one of the world's most complex marine environments owing to the transition between the Hikurangi subduction margin and the Marlborough strike-slip fault system. The region is characterised by abrupt bathymetric gradients, structurally controlled ridges, submarine canyons and deep sedimentary basins, all of which contributed to strong spatial heterogeneity in acoustic propagation conditions. Although the modelling was designed to evaluate underwater sound transmission rather than geological processes, the close correspondence between the predicted acoustic field and the regional physiography demonstrates the importance of representing realistic bathymetry within numerical propagation models for this area.

B.3.1. Effect of source location and water depth on propagation behaviour

The comparison between the shallow- and deep-water source configurations demonstrated that source depth exerted a fundamental influence on the predicted regional propagation characteristics throughout Cook Strait. Although both scenarios were modelled using identical environmental parameters, source spectra and numerical propagation methodology, the resulting acoustic fields differed markedly in their horizontal extent, directional variability, and vertical structure, indicating that the surrounding water-column geometry strongly influenced the evolution of the propagating sound field.

The shallow-water source consistently produced a comparatively restricted acoustic footprint characterised by relatively rapid attenuation with increasing distance from the source. The propagation maps showed that elevated standardised SEL_{cum} values remained confined largely to the continental shelf environment, while the receiver profiles demonstrated a correspondingly steeper reduction in modelled sound levels over range. The vertical cross-sections further illustrated that propagation occurred within a comparatively limited water column, with the predicted acoustic field remaining closely associated with the local seabed morphology throughout the modelled transects.

By contrast, the deep-water source generated a substantially broader regional acoustic footprint, maintaining elevated standardised SEL_{cum} values over considerably greater propagation distances. This behaviour is consistently reflected in the plan-view propagation maps, the directional envelopes, the mean attenuation curves and the receiver-specific predictions. The vertical cross-sections similarly demonstrated that the predicted acoustic field occupies a much larger proportion of the available water column before encountering major bathymetric transitions.

These contrasting propagation characteristics are consistent with fundamental principles of underwater acoustics. In relatively shallow environments, repeated interaction between the propagating wavefront, the seabed and the sea surface increases the cumulative transmission loss and limits long-range propagation. Conversely, greater water depths provide a substantially larger propagation domain, allowing acoustic energy to travel over longer distances before repeated boundary interactions become dominant. Similar differences between shallow- and deep-water propagation have long been recognised in underwater acoustics and are incorporated into modern numerical propagation models (Urlick, 1983; Ainslie, 2010; Jensen *et al.*, 2011).

It is important to recognise that the differences identified in this study arose solely from changes in source location within the regional bathymetric framework. No changes were introduced to the source spectrum, environmental properties or propagation algorithm between the paired simulations. Consequently, the observed differences in modelled propagation behaviour can be attributed directly to the interaction between source depth and the highly heterogeneous bathymetric environment represented within the numerical model. This finding highlights the importance of selecting representative source locations when undertaking environmental sound propagation assessments for offshore geophysical surveys, particularly in regions characterised by strong bathymetric variability such as Cook Strait.

B.3.2. Influence of frequency bandwidth on regional propagation

The comparison between the two broadband simulations demonstrates that extending the upper modelling frequency from 250 Hz to 1 kHz modifies the standardised modelled sound field throughout the study area while preserving the principal spatial characteristics of the propagation field. Although the higher-frequency simulations generally exhibit reduced spatial extents of elevated standardised SEL_{cum} values, the overall distribution of preferential propagation pathways and regions of comparatively rapid attenuation remains remarkably consistent between the two frequency ranges.

This behaviour is evident in both the regional propagation maps and the directional propagation envelopes. The principal sectors of enhanced propagation identified in the 12.5–250 Hz simulations remain recognisable when the upper frequency limit is increased to 1 kHz, despite the overall contraction of the predicted acoustic footprint. Likewise, sectors exhibiting comparatively rapid attenuation maintain broadly similar spatial positions across both frequency ranges.

The preservation of these regional propagation patterns indicates that the large-scale bathymetric framework exerts a stronger influence on the geometry of the acoustic field than the relatively modest extension of the upper frequency limit considered in the study. While increasing frequency content modifies the magnitude and spatial extent of cumulative acoustic exposure, it does not fundamentally alter the principal propagation pathways predicted within the Cook Strait environment.

From a physical perspective, this behaviour is consistent with established underwater acoustic theory. Higher-frequency sound components generally experience greater attenuation owing to increased absorption within the water column and enhanced interaction with environmental boundaries, whereas lower-frequency components propagate more efficiently over long distances (Urick, 1983; Ainslie, 2010; Jensen *et al.*, 2011). Consequently, inclusion of frequencies up to 1 kHz is expected to increase the overall transmission loss relative to simulations restricted to 250 Hz. The modelling demonstrates that these frequency-dependent effects primarily influence the spatial extent of the predicted acoustic field rather than its overall directional organisation.

It should also be recognised that the upper frequency limit adopted for the principal analyses was selected primarily to provide a conservative representation of the broadband acoustic energy potentially associated with the proposed seismic source. Although the dominant energy of large airgun arrays is concentrated below a few hundred hertz, measurable acoustic energy extends into higher frequencies and contributes to the cumulative sound exposure experienced within the marine environment (Richardson *et al.*, 1995; Ainslie, 2010). The 12.5 Hz–1 kHz simulations therefore provide an appropriate basis for evaluating regional transmission-loss behaviour while maintaining consistency with contemporary approaches to environmental underwater noise assessment.

B.3.3. Implications for regional seismic surveys

The principal objective of the transmission-loss modelling presented in the appendix was to characterise the regional propagation of underwater sound associated with the proposed seismic survey operations within Cook Strait. Although the modelling was intentionally based on representative source configurations rather than reproducing the detailed acoustic signature of a specific airgun array, the results provide valuable insight into the principal environmental controls governing sound propagation throughout the survey area.

One of the most significant findings of the study is that substantial differences in modelled acoustic propagation arose solely from changes in source location within the same regional environment. Under identical environmental parameters, propagation methodology and source spectral characteristics, the shallow- and deep-water scenarios produced markedly different acoustic footprints, directional propagation patterns and receiver-specific modelled levels. These differences emphasise that source location, local water depth and regional bathymetry should be considered together when evaluating the potential spatial extent of underwater sound generated during offshore geophysical operations.

The modelling further demonstrates that Cook Strait cannot be regarded as a single acoustically homogeneous environment. Instead, the region comprises a succession of continental shelf areas, steep bathymetric gradients, deep offshore basins and structurally complex seabed features that collectively produce substantial spatial variability in predicted sound transmission. This observation is consistent with the geological framework of the SUBTRANS programme, which targets one of the world's most complex transitions between active subduction and strike-slip tectonics and consequently encompasses a correspondingly diverse submarine landscape. Within such settings, site-specific numerical propagation modelling provides a considerably more realistic representation of regional acoustic transmission than simplified range-independent approaches.

The comparison between 12.5–250 Hz and 12.5–1 kHz simulations likewise illustrates the value of evaluating multiple broadband frequency ranges during environmental assessments. Although the principal propagation pathways remain broadly consistent between the two modelling bands, extending the upper frequency limit modifies the predicted broadband sound field and provides a more comprehensive representation of broadband sound transmission throughout the study area. Such comparisons improve confidence that the principal propagation characteristics are robust and are not artefacts of a particular frequency selection.

Receiver-specific evaluation at the mitigation-zone boundaries provides a complementary screening assessment to the regional propagation analyses. When expressed using the 1-s reference exposure appropriate to the receiver-specific comparison, the highest representative received SELs occurred under the deep-water broadband scenario but remained below the corresponding 2013 Code criteria at 200 m, 1 km and 1.5 km. This distinction between the standardised 3,600-s SEL_{cum} fields used to compare regional propagation behaviour and the receiver-specific SEL values used for comparison with the Code criteria is important when interpreting the modelling outputs.

From an environmental assessment perspective, the modelling undertaken here should therefore be viewed primarily as a regional characterisation of sound transmission behaviour rather than as a prediction of operational acoustic exposure under a single survey configuration. The representative source scenarios adopted

in this study were specifically intended to examine the influence of contrasting propagation environments within the study area, thereby providing a physically consistent framework for interpreting how regional bathymetry and source location influence the distribution of underwater sound.

B.4. Conclusions

The transmission-loss modelling undertaken for the Cook Strait region provides a regional assessment of the principal factors controlling underwater sound propagation within the SUBTRANS study area. Based on the numerical simulations and subsequent analyses presented throughout this appendix, the following principal conclusions can be drawn.

B.4.1. Regional bathymetry & dominant control on acoustic propagation

The standardised SEL_{cum} distributions consistently demonstrate that propagation throughout Cook Strait is strongly influenced by highly heterogeneous seabed morphology. Directional variability observed in the propagation maps, polar envelopes and vertical cross-sections indicates that regional bathymetric features exert a first-order influence on the spatial redistribution of acoustic energy.

B.4.2. Source location and water depth influence regional propagation behaviour

Despite otherwise consistent environmental and representative source parameters, the shallow- and deep-water source locations generated markedly different acoustic footprints, propagation ranges and receiver-level profiles. The modelling demonstrated that source location, local water depth and their interaction with regional bathymetry are therefore important considerations when evaluating underwater sound propagation within complex offshore environments.

B.4.3. Principal propagation pathways in investigated frequency ranges

Comparison between the 12.5–250 Hz and 12.5–1 kHz simulations showed that extending the upper modelling frequency modified the standardised modelled sound field while preserving its overall spatial organisation. The principal directional propagation patterns therefore remained robust across the broadband frequency ranges considered in this assessment.

B.4.4. Numerical propagation modelling & complex acoustic environments

The use of a range-dependent PE model enabled representation of the highly variable bathymetry that characterises Cook Strait. The resulting simulations demonstrate the importance of incorporating site-specific environmental conditions into regional underwater sound assessments rather than relying upon simplified propagation assumptions.

B.4.5. Complementary visualisation & interpretation of model behaviour

The combination of plan-view propagation maps, polar directional envelopes, mean directional attenuation profiles, vertical propagation cross-sections and receiver-specific evaluations provides a complementary description of the simulated acoustic field. Together, these outputs facilitate interpretation of regional propagation behaviour from both spatial and quantitative perspectives. The receiver-specific evaluation further showed that representative received SELs at 200 m, 1 km and 1.5 km remained below the corresponding 2013 Code criteria for all modelled scenarios, with the highest levels occurring under the deep-water broadband scenario.

The modelling presented in this appendix provides a technical basis for interpreting the regional propagation environment relevant to the environmental assessment of the proposed SUBTRANS seismic survey. The standardised 3,600-s SEL_{cum} fields were used to characterise relative spatial and directional propagation behaviour and should not be interpreted as predictions of operational cumulative exposure from the planned impulsive seismic sequence. Receiver-specific comparison with the 2013 Code criteria was therefore undertaken separately using representative 1-s received SELs, as described in **Section B.2.5**. Although the simulations employed a simplified representative low-frequency source spectrum rather than a fully characterised G-Gun array signature and directivity model, they identify the principal regional controls governing underwater sound propagation throughout Cook Strait and provide a physically consistent framework for interpreting differences between the representative propagation environments considered.

Future refinement of the modelling could incorporate a fully characterised operational source signature derived from dedicated seismic source modelling or empirical source verification, allowing direct integration of array directivity, source-depth effects and array-specific spectral characteristics into the regional transmission-loss framework developed in the present study.

APPENDIX C - SPECIES OF CONCERN

Species of concern as outlined in Schedule 2 of the 2013 Code of Conduct (DOC, 2013).

Binomial name	Common name
<i>Megaptera novaeangliae</i>	Humpback whale
<i>Balaenoptera borealis</i>	Sei whale
<i>B. edeni</i>	Bryde's whale
<i>B. bonaerensis</i>	Antarctic minke whale
<i>B. acutorostrata subsp.</i>	Dwarf minke whale
<i>B. musculus</i>	Blue whale
<i>B. physalus</i>	Fin whale
<i>B. musculus breviceauda</i>	Pygmy blue whale
<i>Eubalaena australis</i>	Southern right whale
<i>Caperea marginata</i>	Pygmy right whale
<i>Lissodelphis peronii</i>	Southern Right-whale dolphin
<i>Globicephala melas</i>	Long-finned pilot whale
<i>G. macrorhynchus</i>	Short-finned pilot whale
<i>Peponocephala electra</i>	Melon-headed whale
<i>Physeter macrocephalus</i>	Sperm whale
<i>Kogia sima</i>	Dwarf sperm whale
<i>K. breviceps</i>	Pygmy sperm whale
<i>Mesoplodon grayi</i>	Gray's beaked whale
<i>Berardius arnuxii</i>	Arnoux's beaked whale
<i>Ziphius cavirostris</i>	Cuvier's beaked whale
<i>Mesoplodon layardii</i>	Strap-toothed whale
<i>Hyperoodon planifrons</i>	Southern bottlenose whale
<i>M. bowdoini</i>	Andrew's beaked whale
<i>M. mirus</i>	True's beaked whale
<i>M. densirostris</i>	Blainville's beaked whale
<i>M. ginkgodens</i>	Ginkgo-toothed whale
<i>M. hectori</i>	Hector's beaked whale
<i>M. peruvianus</i>	Pygmy/Peruvian beaked whale
<i>Tasmacetus shepherdi</i>	Shepherd's beaked whale
<i>Orcinus orca</i>	Killer whale
<i>Pseudorca crassidens</i>	False killer whale
<i>Feresa attenuata</i>	Pygmy killer whale
<i>Cephalorhynchus hectori</i>	Hector's dolphin
<i>C. h. maui</i>	Māui's dolphin
<i>Phocartos hookeri</i>	New Zealand sea lion
<i>Tursiops truncatus</i>	Bottlenose dolphin

Table 24: Species of concern. Source: DOC (2013).

APPENDIX D – INACCURATE IMAGE GENERATED BY AI

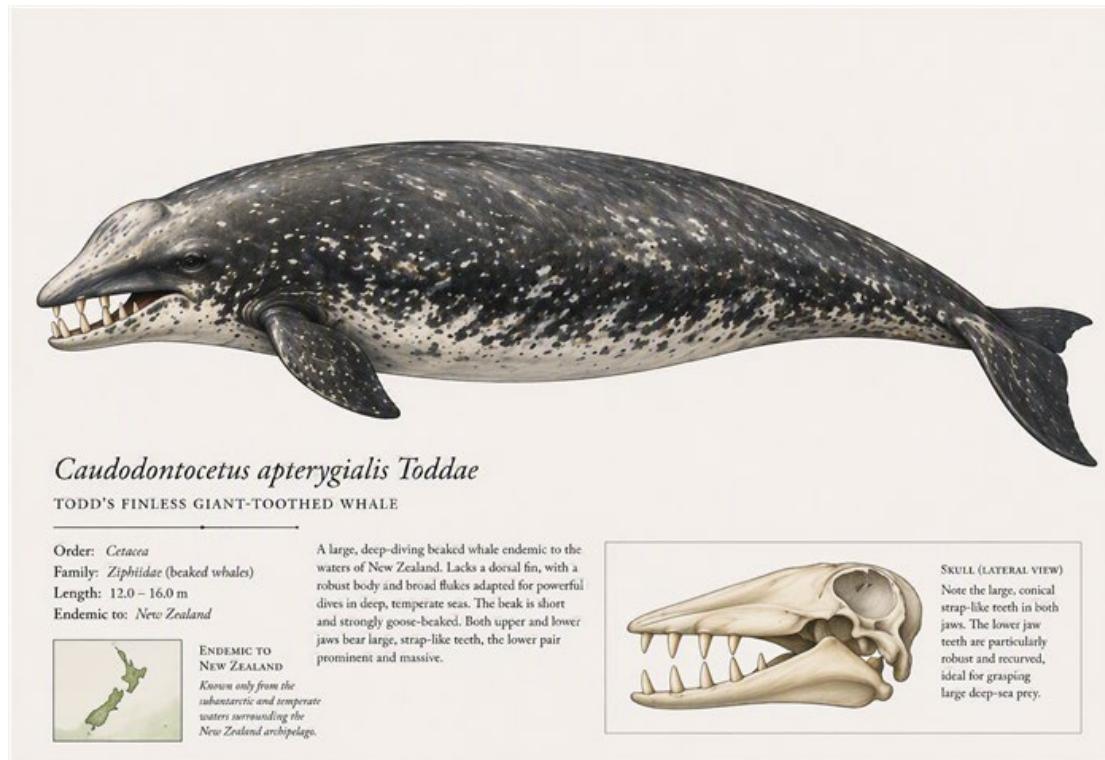


Figure 50: AI-generated image of artificial marine mammal. Source: OSC (2026).