MARINE MAMMAL IMPACT ASSESSMENT (MMIA) FOR THE BROTHERS VOLCANO SEISMIC STRUCTURE (BRASS) SURVEY

Prepared on behalf of

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LIST OF ACRONYMS/ABBREVIATIONS

2D	Two-Dimensional
3D	Three-Dimensional
AAIW	Antarctic Intermediate Water
ADD	Acoustic Deterrent Device
ADDO	Acoustic Deterrent Device Operator
AOI	Area of Interest
BMBF	Federal Ministry of Education and Research
BPA	Benthic Protected Area
BRASS	Brothers Volcano Seismic Structure
BRT	Boosted Regression Tree
ca	*Circa* or approximately
Chl-*a*	Chlorophyll ɑ
CTD	Conductivity Temperature Depth
CO_2	Carbon dioxide
CPZ	Cable Protection Zones
C	Celsius
dB	DeciBel
DIC	Dissolved Inorganic Carbon
DOC	Department of Conservation
EAUC	East Auckland Current
EEZ	Exclusive Economic Zone
e.g.	*exampli gracia* or for example
EIA	Environmental Impact Assessment
E&P	Exploration & Production
EPA	Environmental Protection Authority
EPSG	European Petroleum Survey Group
FEM	Finite Element Method
GEBCO	General Bathymetric Chart of the Oceans
GPS	Global Positioning System
Hz	Hertz
IBA	Important Bird Areas
IR	Infra-Red
ISWSR	Incoming Short-Wave Solar Radiation
IUCN	International Union for Conservation of Nature
IWC	International Whaling Commission
JIP	Joint Industry Programme
LCDW	Lower Circumpolar Deep Water
MMIA	Marine Mammal Impact Assessment
MMO	Marine Mammal Observer

MPA	Marine Protected Area
m	metres
NBSAP	National Biodiversity Strategy and Action Plan
NIS	Non-Indigenous Species
NIWA	National Institute of Water and Atmosphere
NZBS	New Zealand Biodiversity Strategy
NZMEC	New Zealand Marine Environmental Classification
NZTCS	New Zealand Threat Classification System
Oil & Gas	Oil and Gas
OBS	Ocean-Bottom Seismometers
OSC	Ocean Science Consulting Limited
OSC NZ	Ocean Science Consulting NZ (Asia-Pacific) Limited
PAM(O)	Passive Acoustic Monitoring (Operator)
PE	Parabolic Equation
PEPANZ	Petroleum Exploration and Production Association of New Zealand
PPE	Personal Protective Equipment
PPT	Part Per Thousand
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
SAC	Seamount Area Closures
SEL	Sound Exposure Level
SL	Sound Level
SONAR	SOund Navigation And Ranging
SPL	Sound Pressure Level
$SPL_{p\text{-}peak}$	Peak-to-Peak Sound Pressure Level
SST	Sea Surface Temperatures
STLM	Sound Transmission Loss Modelling
Sv	Sievert
TTS	Temporary Threshold Shift
UCDW	Upper Circumpolar Deep Water
URN	Underwater Radiated Noise
WGS	World Geodetic System
ZOI	Zone of Influence
µPa	microPascal
°	Degrees

DEFINITIONS

CUI	Cubic inch (in^3), common measurement of volume used in seismic research, 1 CUI = 0.016387064 l
Iwi	Largest social groups in Māori society, often translated as tribe
hapū	A subtribe or clan which functions as a political unit within Māori society
Level 1 survey	An operational acoustic source capacity of >427 CUI (in^3)

Level 2 survey	An operational acoustic source capacity of 151–426 CUI (in^3)
Level 3 survey	An operational acoustic source capacity of <150 CUI (in^3)
Māori	Indigenous Polynesian people of New Zealand
Taiapure	an estuarine or littoral coastal area which is traditionally important to hapū or iwi
Takutai moana	The marine and coastal area starting from the mean high-tide mark and ending 12 nautical miles out to sea
Tangata whenua	A specific group of people with historical claim to a certain district (or Māori people as a whole)
Whānau	Extended family group which is formed of several generations and forms the political version below hapū

SUMMARY

This Marine Mammal Impact Assessment (MMIA) has been prepared for the Brothers Volcano Seismic Structure (BRASS) Survey, which will be conducted in the Kermadec Arc offshore region, New Zealand. The BRASS survey, scheduled for May 2025, has been commissioned by GEOMAR Helmholtz Centre for Ocean Research Kiel and will be carried out using the *RV Sonne*, a German research vessel. Ocean Science Consulting Limited (OSC) has been contracted to prepare the MMIA and to provide Marine Mammal Observers (MMOs) and Passive Acoustic Monitoring (PAM) operators. The survey aims to investigate the geological structure of Brothers Volcano through Three-Dimensional (3D) seismic imaging, which is essential for understanding submarine caldera collapses and associated volcanic hazards. This research will support scientific advancements in climate modelling, mineral resource assessment, and geohazard mitigation.

The assessment evaluates potential impacts of the seismic survey on marine mammals, in accordance with the '2013 Code of Conduct for minimising acoustic disturbance to marine mammals from seismic survey operations' (DOC, 2013), issued by New Zealand's Department of Conservation (DOC). This assessment ensures compliance with the 2013 Code of Conduct and the Marine Mammals Protection Act 1978.

The mitigation measures outlined in the 2013 Code of Conduct aim to minimise both the physical and behavioural risks posed to marine mammals. These measures will be implemented during the BRASS survey through the following strict protocols. These mitigation measures have been considered in this assessment, and are as follows:

- At least two qualified MMOs and two PAMOs must be onboard at all times;
- Before any acoustic source activation, a 30-minute visual and acoustic pre-start observation is required to ensure no marine mammals are present. If detected, seismic operations will be delayed until the area is clear;
- The 'soft-start' or 'ramp-up' procedure will gradually increase sound levels over 20–40 minutes, allowing marine mammals to detect and move away before full operational intensity is reached;
- If a shutdown occurs and the pause lasts less than 10 minutes without marine mammal detections, the source may be reactivated at full power;
- Strict shutdown protocols will require immediate cessation of seismic activity if marine mammals enter predefined mitigation zones, with stricter thresholds for species of concern, particularly those with calves; and,
- Additional requirements apply for initial activation of the seismic sources in new survey locations at night or in poor visibility.

By integrating both visual and acoustic detection, these mitigation strategies aim to minimise harm while allowing seismic surveys to proceed in a controlled and environmentally responsible manner.

For the impact assessment, a scoping exercise was undertaken to identify key ecological receptors and potential impact pathways associated with the BRASS seismic survey and vessel transit route. A total of 32 marine mammal species were identified as potentially at risk, including baleen whales, sperm whales, and beaked

whales. Along the transit route, Bryde's whales, killer whales, common dolphins, and bottlenose dolphins were identified as being at greater risk. The associated risks were identified as:

Risks from vessel activity in the operational area and along the transit route:

- Vessel collision;
- Increased underwater noise from vessel operations; and,
- Temporary habitat displacement.

Risks from seismic noise exposure in the operational area:

- Physical injury and auditory damage;
- Behavioural disturbance and habitat displacement; and,
- Indirect effects on prey species.

To evaluate residual risk across marine mammal species, a risk matrix approach was applied to quantify the likelihood and severity of impacts after mitigation. Factors considered include:

- Likelihood of exposure: based on species distribution and movement patterns;
- Severity of impact: evaluated by species sensitivity to seismic noise and vessel interactions;
- Population exposure; and,
- Conservation valuation.

The impact assessment evaluated the effects of vessel activity and seismic operations on marine mammals and other marine organisms, identifying key risks such as:

- Vessel collision;
- Behavioural disturbance and habitat displacement;
- Masking from both seismic and vessel noise;
- Physical injury including both temporary and permanent auditory damage;
- Indirect effects on prey species;
- In-combination and cumulative effects; and,
- Unplanned events from vessel collision/sinking and loss of equipment.

The mitigation measures prescribed in the 2013 Code of Conduct were found to effectively minimise these risks. While Bryde's whales in the Hauraki Gulf were identified as moderately vulnerable to vessel collisions, mitigation strategies including speed restrictions and MMOs will reduce this risk. Behavioural disturbances were considered low due to the survey's short duration and slow vessel speed.

Seismic operations pose potential risks of physical injury, auditory damage, and prey reduction; however, exclusion zones, a soft-start procedure, and PAM will ensure minimal impact, particularly for deep-diving species such as beaked whale and sperm whale. Although seismic noise can temporarily reduce zooplankton and fish densities, long-term ecological consequences are unlikely due to the limited survey period. Other marine receptors, including invertebrates, fish, sharks, rays, marine reptiles, and seabirds, exhibit some sensitivity to seismic noise; however, residual risks were deemed minor given the absence of critical habitats in the operational area and the transient nature of disturbances.

Cumulative effects were also assessed, with no significant in-combination risks identified due to the remote location and lack of concurrent seismic activity. Overall, the offshore setting, adherence to mitigation protocols, and short survey duration will ensure negligible to minor residual risks across all species, with no anticipated population-level impacts.

As the survey will be conducted in an Area of Ecological Importance (AEI), Sound Transmission Loss (STL) modelling was conducted to evaluate the propagation of the seismic pulse and effectiveness of prescribed exclusion zone. The methodology consists of three primary modelling components:

- Array Signature Modelling: The acoustic source array for the BRASS survey consists of a 5,420 Cubic Inches (CUI; in^3) G.Gun source array with 12 sources paired into six clusters, operating at a towing depth of 12 m and an operating pressure of 3,000 Pounds per Square Inch (PSI). Notional signatures were generated using Nucleus+ Designer software, which incorporates non-linear interactions between airgun elements;
- Short-Range Transmission Loss Modelling: Predictions of received Sound Exposure Levels (SELs) within a range of 2,000 m from the source were conducted to assess compliance with the 2013 Code of Conduct mitigation zones. Finite Element Method (FEM) was used to solve the Helmholtz equation for complex wave interactions at close distances; and,
- Long-Range Transmission Loss Modelling: A Parabolic Equation (PE) method was used to estimate noise propagation over distances ranging from tens to hundreds of kilometres, incorporating seasonal sound speed profiles, bathymetric variations, and sediment properties.

The results of the STL are summarised as follows:

- Array Source Characteristics: The Peak-to-Peak Sound Pressure Level ($SPL_{p\text{-}peak}$) was 262.4 dB re 1 μPa @ 1m, with an Root-Mean-Square (RMS) SPL of 231.0 dB re 1 μPa @ 1m and an SEL of 230.5 dB re $\mu Pa^2 \cdot s$ @ 1m.
- SEL @ 200m was estimated to be 181.5 dB re $\mu Pa^2 \cdot s$, under the threshold of 186 dB re $\mu Pa^2 \cdot s$, specified by the code.
- SEL @ 1km and 1.5km were estimated to be 170.3 and 168.7 dB re $\mu Pa^2 \cdot s$, respectively, both under the threshold of 171 dB re $\mu Pa^2 \cdot s$, specified by the code.

The BRASS survey is critical for advancing geological research on submarine caldera collapses, providing valuable insights into volcanic hazards and climate interactions; however, seismic operations have the potential to disturb marine mammal populations. The rigorous implementation of mitigation strategies will minimise acoustic disturbance, ensuring that the survey proceeds in an environmentally responsible and sustainable manner while contributing to New Zealand's ongoing marine conservation efforts.

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 the regulations and protections of countries worldwide. Many marine mammal species are still threatened or endangered and face threats from climate change, habitat degradation, and by-catch or entanglement from commercial fishing operations. An additional threat to these animals is noise from anthropogenic sources.

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; NMFS, 2018; Southall *et al.*, 2019). 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). 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 in extreme cases may cause (5) 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 Maui'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's (DOC's) 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 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 (see **section 1.3**). 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, sound transmission loss modelling is conducted to evaluate whether the mitigation zone distance prescribed in the code are sufficient for the seismic air gun being used and to identify long range propagation and its overlap with critical habitat. Additional requirements under the 2013 Code of Conduct include a consultation (see **Section 4**) and a Marine Mammal Mitigation Plan (see **APPENDIX A – MITIGATION PROTOCOL**).

This MMIA has been prepared for the BRothers Volcano Seismic Structure (BRASS) survey, planned in the Kermadec Arc offshore region, New Zealand (an Area of Ecological Importance for marine mammals, as identified by the DOC). This survey will occur over 24 days, in May 2025. The seismic survey, which will take place over three days, will be carried out on Three-Dimensional (3D) seismic data collected using airguns and Ocean-Bottom Seismometers (OBSs), as well as geological samples using a Remote Operated Vehicle (ROV), for ground truthing. This survey will be conducted using the research vessel *RV Sonne*, owned and operated by Federal Republic of Germany, represented by the Federal Ministry of Education and Research (BMBF). Impacts potentially associated with both planned activities and unplanned events of the BRASS seismic survey have been identified, described, and evaluated across marine mammal species and other ecological receptor groups.

1.1. BRASS survey aims

The aim of the BRASS seismic survey is to image the underground structure of the Brothers Volcano in the Kermadec Arc, a caldera collapse, which is an important geological process that shapes many of Earth's volcanoes. Caldera collapses are associated with volcanism, which can pose significant threats to society and promote climate change through the injection of sulphur dioxide (SO_2) into the atmosphere. To understand this process, 3D investigation of geological structures is required. This survey will provide unprecedented insight into the geological processes involved in submarine caldera collapse, facilitate hazard assessment, as well as mineral resource assessment of similar volcanoes. It will also inform improved climate models and contribute directly to protecting climate as a common good (Berndt *et al.*, 2019).

Records of marine mammals in the operational area are sparse, with only a few direct marine mammal species observations made during seabird counts and official expeditions, most having been made incidentally and during incidental captures (Berkenbusch *et al.*, 2013; Duffy *et al.*, 2015; Richard and Berkenbusch, 2024). Distribution models constructed are mainly based on known habitat preferences, rather than observations and are thus considered here with caution (Stephenson et al., 2020). One extreme example of this principle is beaked whales, a typically cryptic group of marine mammals with very little known about them. Other than Gray's beaked whale (*Mesoplodon grayi*) (Dalebout *et al.*, 2004), no living beaked whales have been spotted in the operational area (Thompson *et al.*, 2013); however, since they are thought to inhabit deep canyons much like the Brother's Volcano, their presence in the area is possible. Other marine mammals that have been spotted in the area are New Zealand fur seals (*Arctocephalus forsteri*), common dolphins (*Delphinus delphis*), bottlenose dolphins (*Tursiops truncatus*), minke whales (*B. acutorostrata* & *B. acutorostrata ssp.*), humpback whales (*Megaptera novaeangliae*), sperm whales (*Physeter macrocephalus*), sei whales (*Balaenoptera borealis*), killer whales (*Orcinus orca*), pilot whales (*Globicephala sp.*), and beaked whales. Further information on marine mammals is provided in **section 5.3.5.**

The survey vessel will also pass through the Hauraki Gulf, which has considerable marine mammal activity and is an important foraging ground for many marine mammals, including, Bryde's whale (*B. edeni)*, Sei whale (*B. borealis*), fin whale (*B. physalus*), bottlenose dolphin (*T. truncatus*), and common dolphin (*D. delphis*).

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).

1.2. BRASS survey requirements

This MMIA, which is a requirement of the planning process for the BRASS survey, will be made available to all personnel involved in observational capacities. The MMIA will be submitted to the Director-General at the earliest opportunity, but no less than one month before the survey begins, as required.

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	**6.2 Results**
Identify persons, organisations, or *tangata whenua* with specific interests or expertise relevant to the potential impacts on the environment	**4 CONSULTATION & ENGAGEMENT ACTIVITIES** and **APPENDIX C – STAKEHOLDER ENGAGMENT**
Describe any consultation undertaken with persons described above and specify those who	**4 CONSULTATION & ENGAGEMENT ACTIVITIES**

have provided written submissions on the proposed activities	and **APPENDIX C – STAKEHOLDER ENGAGMENT**
Include copies of any written submissions from the consultation process	**APPENDIX C – STAKEHOLDER ENGAGMENT**
Specify any possible alternative methods for undertaking the activities to avoid, remedy or mitigate any adverse effects	**2.5 Survey design considerations**
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 (2025).

1.3. 2013 DOC Code of Conduct

Developed by the New Zealand Government's DOC, and in effect since 29 November 2013, the '2013 Code of Conduct for minimising acoustic disturbance to marine mammals from seismic survey operations' (DOC, 2013) replaced the '2012 Code of Conduct for minimising acoustic disturbance to marine mammals from seismic survey operations' and must be read in conjunction with the '2012 Code of Conduct: reference document' (DOC, 2012b; DOC, 2012a). The main purpose is to mitigate the impact to marine mammals from seismic surveys.

The 2013 Code of Conduct applies to all marine seismic survey operations in New Zealand continental waters, from the coast to the outer edge of the 200 nautical mile EEZ, including the continental shelf. The 2013 Code of Conduct is mandatory in these areas; however, is voluntary in territorial waters and outside the EEZ. 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.

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, see **section 1.3** and **APPENDIX A – MITIGATION PROTOCOL** for more details. 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; in^3). These tend to be large-scale geophysical investigations (often oil & gas);
- *Level 2*: 151–426 CUI (in^3). Lower scale investigations (often scientific); and,
- *Level 3*: <150 CUI (in^3). 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.

1.4. Rationale

Ocean Science Consulting Limited (OSC) was contracted by GEOMAR to conduct a MMIA for the BRASS seismic survey, planned in the Kermadec Arc offshore region, New Zealand. The purpose of this MMIA is to identify, quantify, and evaluate potential impacts to marine mammals in the operational area from the BRASS survey, as required under the New Zealand DOC's 2013 Code of Conduct (DOC, 2013). This assessment also includes information on the physical environment and other marine life, *e.g.* fish, marine reptiles, and seabirds, *etc*., in the survey area. Potential environmental impact effects are provided in **section 6**.

The aim of this MMIA is to provide a comprehensive evaluation of potential impacts of the BRASS seismic survey on marine mammals in the Kermadec Arc offshore region, New Zealand. This MMIA is crucial for several reasons:

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 survey aims to image the underground structure of the Brothers Volcano, which is essential for understanding geological processes like caldera collapse; however, use of seismic equipment can disturb marine mammals. This assessment identifies, quantifies, and evaluates these potential impacts to mitigate any adverse effects;
3. Scientific insight: findings from this survey will provide unprecedented insight into the geological processes involved in submarine caldera collapse, facilitate hazard assessment, and contribute to improved climate models. This knowledge is vital for both scientific advancement and environmental conservation;
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 organizations, 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. This proactive approach ensures that the survey can be conducted responsibly and sustainably.

This assessment serves as a critical tool for balancing the scientific objectives of the BRASS seismic survey with the need to protect marine mammals and their habitats. It underscores the importance of conducting such activities in an environmentally responsible manner, adhering to regulatory requirements, and contributing to the broader understanding of marine ecosystems.

2. PROJECT ACTIVITIES DESCRIPTION

This section provides information on the activities that will be undertaken during the project.

2.1. Timing & location

The survey will be undertaken from the *RV Sonne* over a period of 24 days in the Kermadec Arc offshore region, New Zealand, in the area bounded by 178 degrees east to 180 degrees east, and 34 degrees south to 35.5 degrees south (**Figure 1**), between 5 May 2025 to 29 May 2025.

OSC will also provide Marine Mammal Observers (MMOs) and Passive Acoustic Monitoring Operators (PAMOs) to who will be responsible for monitoring, mitigation, and collection of information (where available) on marine mammals and any other species of interest in the region. MMOs/PAMOs have broad power to implement the 2013 Code of Conduct, including stopping activities during the survey if required. Further information on mitigation requirements and MMO/PAMO protocols are provided in **APPENDIX A – MITIGATION PROTOCOL**.

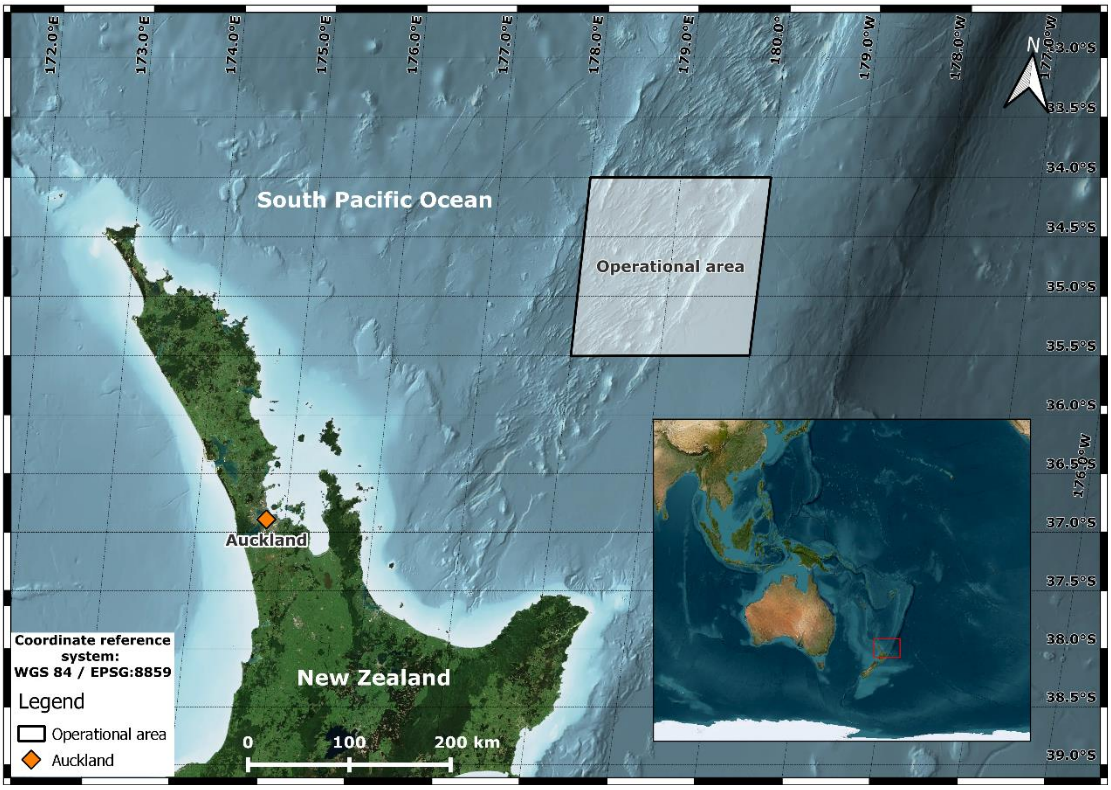

Figure 1: BRASS survey operational area. Coordinate reference system: WGS 84/Equal Earth Asia-Pacific (EPSG:8859). *Source*: OSC (2025).

2.1.1. Navigational safety

The vessel will transit from the Port of Aukland through the Hauraki Gulf to the operational area. The transit is expected to take 1 day.

The Hauraki Gulf Transit Protocol for commercial shipping (Port of Auckland, 2024), provides recommended approaches to the port, as well as advice for reducing the risk of death to whales. Requirements to comply with the Transit Protocol include:

- Reducing vessel speed (from 15 to 10 knots);
- Having a dedicated observer watching for Bryde's whales during daylight hours; and,
- Report any whale sightings so that other vessels can be aware and avoid the whale.

This protocol will be followed during transit through the Hauraki Gulf.

2.2. Marine seismic survey

The BRASS seismic survey aims to investigate the geological structure of the Brothers Volcano, a submarine caldera in the Kermadec Arc. Caldera collapse is a fundamental geological process that plays a critical role in shaping many of Earth's volcanoes. This process is closely linked to volcanic activity, which can pose significant hazards to human societies and contribute to climate change. A detailed 3D seismic imaging of the Brothers Volcano will provide unprecedented insights into the mechanisms of submarine caldera collapse, improve hazard assessments, and support mineral resource evaluations of similar underwater volcanoes. Furthermore, this research will contribute to refining climate models and enhancing global efforts to protect the climate as a common good (Berndt et al., 2019).

2.3. Seismic survey materials

The cruise will begin with a one-day transit to the study area (**Figure 2**). Upon arrival, a regional Two-Dimensional (2D) seismic and bathymetry survey will take place, estimated to last three days (**Figure 3**). Line spacing for this survey will be chosen on-site. The seismic source used for the survey will be a 12-GI gun seismic source, 5,420 CUI (in^3) array (*Level 1*, within the scope of this assessment; see **APPENDIX B – SOUND TRANSMISSION LOSS MODELLING** for a full description of the seismic source). OBSs will be deployed to the south-west and north-east of Brothers, based on the results of the 2D survey. These deployments will include 12 broadband (2–1,000 Hz) OBS around Brothers Volcano, and 12 regular (8–500 Hz) OBS along the reference lines (**Figure 3**). This is estimated to last one day. After completion of the OBS deployment, a 7x17 km 3D seismic volume will be collected, estimated to last 16 working days. The smaller airgun array than the 2D survey will be used, paired with a P-Cable system. The P-Cable system consists of 14–16 mini-streamers that are towed on a cross-wire that is spread perpendicular to the vessel's steaming direction by two paravanes (**Figure 4**). The P-Cable system will use an operational source capacity of <150 CUI (in^3), *i.e.* *Level 3*, which falls outside the scope of this assessment. At the end of the P-Cable survey, the OBSs will be recovered utilising their acoustic releases. After completion of all seismic surveys, video-guided surveys and geological sampling will be carried out using a HyBis system, a ROV. The ROV is planned to perform eight dives, providing imagery and collecting volcanic and hydrothermal material samples. The ROV activities are also outside the scope of this assessment. The cruise will then end with a one-day transit back to Auckland.

Task	Number/Distance	Estimated time
CTD / Sound velocity profiles and calibration	2 x 2 h (beginning and end of cruise)	**4 h**
Deployment of 2D seismic system	1 time	1h
2D seismic surveying for target selection	360 km @ 4.5 kn	43 h
Recovery of 2D seismic system	1 time	1 h
Total 2D seismic		**45 h**
Deployment of OBS	20 times x 0.5 h	10 h
Transfer between OBS	75 km @ 10 kn	4 h
OBS shooting	520 km @ 4.5 kn	62 h
Collection of OBS	20 times x 1 h	20 h
Total OBS		**96 h**
Deployment of 3D seismic system	2 times 4 hours	8 h
Cube 1: 3D seismic sail lines	109 x 17 km @ 3.5 kn	283 h
Turns	109 x 0.5 hrs	55 h
P-Cable service	1 time	10 h
Recovery of 3D seismic system	2 times 2 hours	4 h
Total P-Cable		**359 h**
HyBis dives including transits	**12 dives x 6 hours**	**72 h**
Transit from Auckland to Brothers V and back		**48 h**
Total		**24 (576 h) + 2 days**

Figure 2: Project timetable. *Source*: GEOMAR (2019).

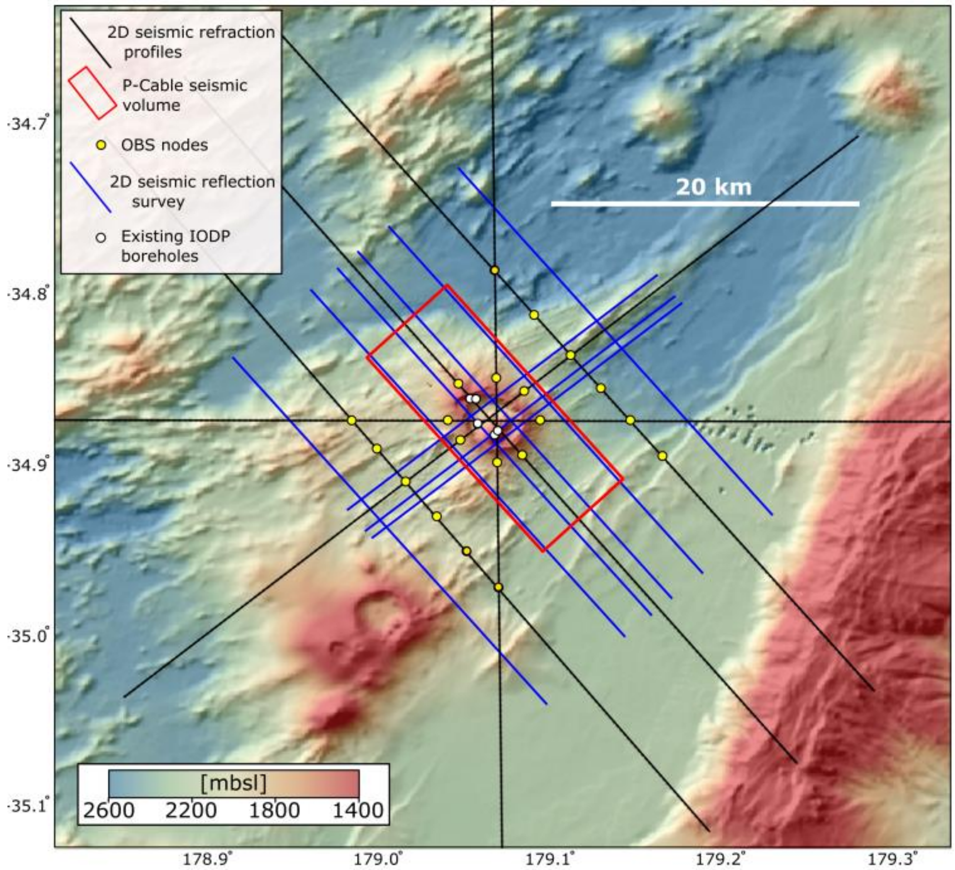

Figure 3: Estimated locations of the Ocean-Bottom Seismometer deployments and seismic surveys. *Source*: GEOMAR (2019).

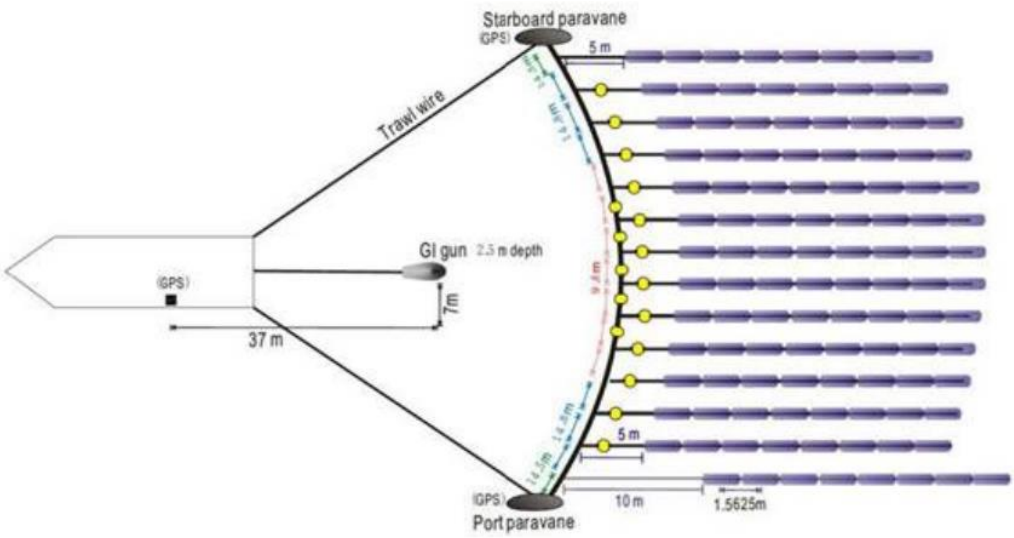

Figure 4: Sketch of the P-Cable system with 14 streamers**.** *Source*: GEOMAR (2019).

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 5**). Vessel specifications are found in **Table 2**.

Figure 5: Vessel *RV Sonne Source*: David Menzel, GEOMAR (2025).

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
Operating range	7,500 nautical miles
Time at sea	50 days
Crew	Ship: 35, science: 40
Scientific facilities	17 laboratories, 521 square metres

Table 2: Specifications of the *RV Sonne*. *Source*: GEOMAR (2025).

2.5. Survey design considerations

During the planning of the survey, GEOMAR was directed by scientific requirements and did not consider alternatives. Investigation of structural architecture and hydrothermal fluid circulation are required to understand caldera collapse and related hydrothermal processes. The findings of this survey will provide valuable insight into the geological processes involved in submarine caldera collapse and will aid hazard assessment and mineral resource assessment of similar volcanoes.

2.5.1. Sound sources

No alternative sound sources were considered due to the specific scientific demands of the survey. The proposed airgun arrays of have been selected as they provide sufficient seismic energy to meet the survey's objectives, and they are the minimum source volumes which will be able to do this. Large *Level 1* arrays are only being used for a small proportion of the survey compared to the *Level 3* array.

2.5.2. Survey design

Equipment deployment locations will be determined *in-situ* as necessary for accurate data collection. Deviation from optimal deployment parameters would invalidate the data and is therefore impossible to consider.

2.5.3. Vessel

The *RV Sonne* is the only research vessel with the appropriate geophysical equipment and technical expertise onboard which is available to conduct the proposed survey work. It is not expected to disturb the local environment more than any other science vessel.

2.5.4. Timing

It is not possible to adjust the duration or timing of the survey, due to the personnel involved and duration of activities for required data collection. The date of the cruise has been planned in advance to minimise any logistical issues arising from organising an international research programme involving scientists from different institutions and countries. The *Level 1* seismic survey, as part of the cruise, will total approximately three days of airgun shooting time. This is the shortest period over which the data can be collected assuming weather conditions are favourable.

3. LEGISLATIVE FRAMEWORK

In addition to the 2013 Code of Conduct (DOC, 2013), there are other important legislative requirements to consider when completing a seismic survey. This section aims to provide information on legislation relevant to the project.

3.1. Marine Mammals Protection Act 1978

An Act of Parliament passed in New Zealand and administered by the Department of Conservation, the Marine Mammals Protection Act 1978 (Department of Conservation, 1978) protects all seals, sea lions, dolphins, and whales by making it an offence to harass, disturb, injure, or kill marine mammals. The Act also sets out principles for conservation management strategies and plans including the creation of Marine Mammal Sanctuaries, five of which include provisions for the regulation of seismic activities, as well as establishing a requirement for reporting any accidental death or injury.

3.2. Exclusive Economic Zone & Continental Shelf Act 2012

The Exclusive Economic Zone and Continental Shelf Act 2012 (New Zealand Parliamentary Counsel Office, 2012) promotes the sustainable management of natural resources within the EEZ and continental shelf. This involves managing the use, development, and protection of natural resources, such that people can provide for their economic wellbeing while safeguarding the life-supporting capacity of the environment, sustaining the potential of natural resources to meet the reasonable needs of future generations, and mitigating any adverse effects of activities on the environment.

The Act allows for the Minister for the Environment to classify activities within the EEZ and continental shelf as:

- Permitted activities: a permitted activity may be undertaken without a marine consent if it complies with any terms and conditions in the regulations; and, the Environmental Protection Authority (EPA) must be notified before undertaking the activity if required to by regulations.
- Discretionary activities: a discretionary activity is allowed with a marine consent. Applicants must obtain a marine consent from the EPA. The consent application is publicly notified and has a statutory timeframe of 140 working days during which the EPA must assess the marine consent application.
- Prohibited activities: A marine consent cannot be applied or granted for a prohibited activity.
- Non-notified discretionary: activities that can be undertaken in applicants obtain a marine consent from the EPA. The consent application is not publicly notified and has statutory timeframes adding up to 60 working days in which the EPA must assess the marine consent application.

Considerations for classification include the environmental effects of the activity, the importance of protecting rare and vulnerable ecosystems, and the economic benefit of the activity to New Zealand.

Under the Exclusive Economic Zone and Continental Shelf Act 2012 seismic surveying is a permitted activity if it complies with 2013 Code of Conduct. As such, compliance is monitored by the DOC, *via* the use of MMO/PAMOs, and the EPA is responsible for enforcement should a non-compliance occur.

3.3. Maritime Transport Act 1994

The Maritime Transport Act 1994 (New Zealand Parliamentary Counsel Office, 1994) states that harmful substances must not be discharged from a ship into the sea within the EEZ, or into or onto the seabed.

4. CONSULTATION & ENGAGEMENT ACTIVITIES

OSC has undertaken engagement with key stakeholders, *iwi*, and *tangata whenua* that were identified in relation to the seismic activities within the Kermadec Ridge area. All consulted groups are listed in **Table 3**.

Iwi	**Response**
Ngāti Kuri Iwi Trust Board	No response
Te Ohu Kaimoan	No response
Te Hiku / Kaitaia Office	No response
Te Runanga Nui o Te Aupouri Trust	Seeking permission to forward to the Māori they work with
Te Rūnanga-ā-Iwi o Ngāti Kahu	No response
Other groups	
Auckland Council	No response
Department of Conservation	Recommendation of contacts
Department of Conservation – Auckland	Recommendation to contact Ngāti Kuri and Te Aupouri
Department of Conservation – National Office	Given personal email to forward initial contact to
Dr Karen Stockin	No response
Dr Rochelle Constantine	No response
Environmental Protection Authority	No comment to provide
NZ Whale and Dolphin Trust	Data requested after survey
Port of Auckland	No response
Project Jonah	No response
Sanford Fisheries	No response
Sealord	No response
Tom Trsnki	No response

Table 3: Groups who were engaged in the consultation phase. *Source*: OSC (2025).

This engagement process involved groups being engaged through the sending of a contact letter and information sheet *via* email and follow up phone calls. The documents, provided in **APPENDIX C – STAKEHOLDER ENGAGMENT**, formed the basis of the engagement process. A register outlining the keys points of the formal engagements is included as a table within **APPENDIX C – STAKEHOLDER ENGAGMENT**.

The primary commitments made by GEOMAR and OSC during the engagement process are summarised as:

- Data will be provided to the NZ Whale and Dolphin Trust after review.

5. DESCRIPTION OF OPERATIONAL AREA

A review of the existing environment is provided for the operational area of the Kermadec Arc. For marine mammals and other biological features, the transit route through the Hauraki Gulf has also been considered.

5.1. Physical environment

The general area of the Kermadec Arc is characterised by prominent seamounts surrounded by a hydrothermal vent habitat (Menini and Van Dover, 2019). The southern Kermadec Arc is noteworthy for its extensive sulphide deposits (Wysoczanski *et al*., 2012), with sediment comprised primarily of volcanic gravel and mud with polymetallic crusts (Bostock *et al*., 2019). The Brothers Volcano is a unique caldera in the region with four active hydrothermal systems, two high-temperature sulphide-depositing sites on its northwestern and western walls, and gas-rich sites that fill most of the southern area (Embley *et al.*, 2010).

5.1.1. Bathymetry

The Kermadec Arc is a tectonically active zone north of New Zealand's North Island. The area has highly varied seafloor morphology, shaped by subduction, volcanic activity, and tectonic processes, featuring multiple submarine volcanoes. The Kermadec Trench is a deep trough east of the arc, reaching maximum depths of 10,000 m. To the west lies the Havre Trough, a back-arc basin characterised by rifting and extensional features (Ballance *et al.*, 1999). Many of the arc's seamounts exhibit active hydrothermal vents, contributing to unique ecosystems (Rowden *et al.*, 2003; Rowden *et al.*, 2005; Tracey *et al.*, 2011). The study area varies in depth from about 1,000 m to about 3,500 m (**Figure 6**). Prominent features in this area include the Brothers and Healy seamounts (Davey, 1980; Rowden *et al.*, 2003).

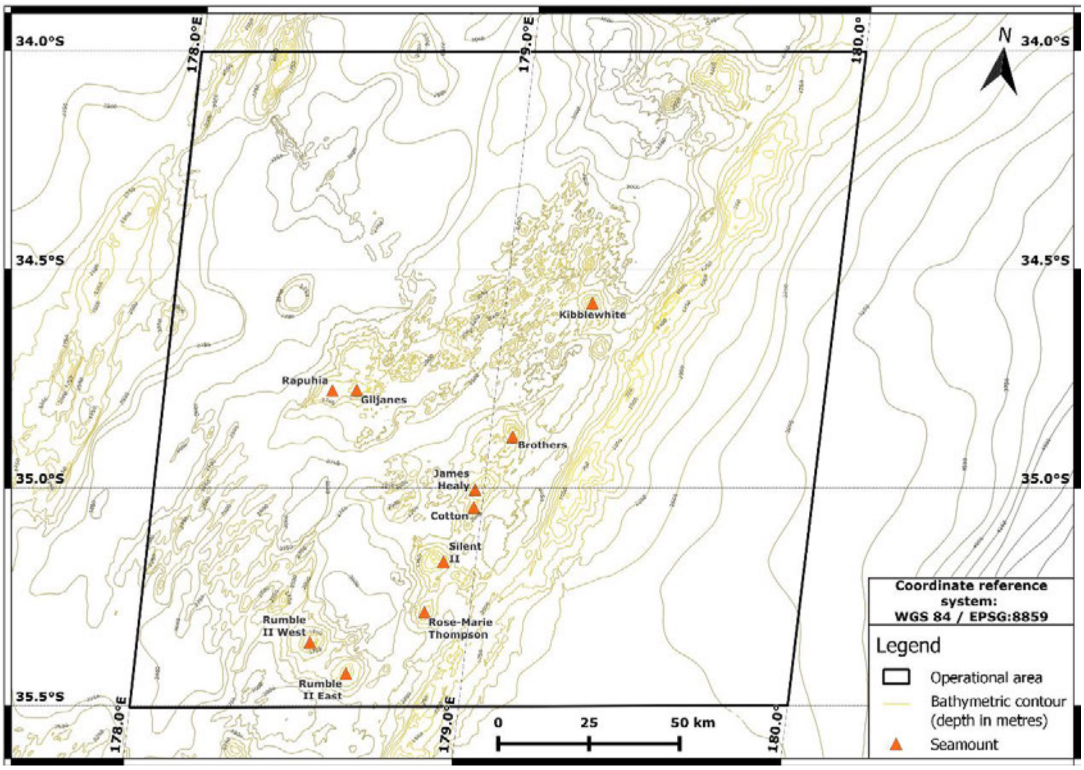

Figure 6: Bathymetric contours in operational area with notable seamount features, including the Brothers caldera. Coordinate reference system: WGS 84/Equal Earth Asia-Pacific (EPSG:8859). *Source*: National Institute of Water and Atmosphere (NIWA, 2016).

5.1.2. Ambient noise

The ocean soundscape is composed of sound from natural origins related to geological processes, marine life (biophonic), and of manmade origin. Sound is the primary way that many marine species gather information and understand their environment, and it is a valuable tool for us to study their behaviour. There has been a substantial increase in anthropogenic noise in the oceans since the Industrial Revolution, and assessing the human impact on marine mammals is an emerging topic aiming to leave a healthy ocean for future generations (Bayrakci and Klingelhoefer, 2023).

There are a paucity of data on ambient noise levels in the operational area. Given the tectonic and volcanic activity in the area, very low frequencies are likely dominated by earthquake and hydrothermal-vent noise (Metz *et al.*, 2016; Pipatprathanporn and Simons, 2022; Smith and Barclay, 2024).

Contributing to the soundscape of the Hauraki Gulf is a combination of natural and anthropogenic sources, including biological contributions from whale calls and dolphin echolocation (Putland *et al.*, 2017). During a recent study in the area, the Root Mean Square (RMS) sound pressure level of ambient noise (50–24,000 Hz) ranged from 90 to 110 dB re 1 µPa and vessel noise was shown to raise ambient sound levels, particularly in frequencies that overlap with these biophonic sources (Putland *et al.*, 2017).

5.2. Physical oceanography

Physical oceanography is the study of the physical conditions and processes within the ocean. It encompasses a wide range of topics, including ocean circulation, waves, tides, temperature, salinity, and the topic aims to understand how these physical factors influence the ocean's behaviour and its role in the Earth's climate system. For example, ocean circulation involves studying large-scale currents transport heat and nutrients around the globe. Waves and tides are also crucial topics, as they affect navigation, coastal management, and the prediction of natural disasters. Additionally, physical oceanography explores how temperature and salinity vary with depth and location, which can impact marine life and climate patterns. Overall, physical oceanography provides essential insights into the dynamic nature of the ocean and its influence on global climate and ecosystems.

5.2.1. Ocean circulation

Water circulation in the operational area is mainly driven by subtropical water, affecting several currents at different depths. Surface currents are created by the Tasman Front, which flows into the East Auckland Current (EAUC), to the southeast. The EAUC is highly variable and can extend to depths of 2,000 m. The area also includes two quasi-permanent deep eddies embedded in the EAUC: the North Cape Eddy, centred northeast of North Cape; and the East Cape Eddy, centred north of East Cape. Water transport in the EAUC is *ca.* 9 Sv (Stevens *et al.*, 2021).

At intermediate depths current circulation is dominated by Antarctic Intermediate Water (AAIW), formed by the subduction of surface waters to depths of between 500 m and 1,300 m, flowing south from the southeast Pacific Ocean to the east coast of New Zealand. Deep waters flow northward as they transition from Lower Circumpolar Deep Water (LCDW) to Upper Circumpolar Deep Water (UCDW). UCDW, found between 1,450 and 2,500 m, has a low oxygen, high nutrient signature (Chiswell *et al.*, 2015).

5.2.2. Water density

Surface water in the operational area is characterised by warm Sea Surface Temperatures (SST) and saline conditions caused by subtropical water arriving *via* the EAUC, with temperatures around 15° C and salinity higher than 34.5 Parts Per Thousand (PPT) (Chiswell *et al.*, 2015). These values are highly variable with temperature having a *ca.* 3° C amplitude in an annual cycle. Short-term temperature anomalies caused by lingering water currents also contribute to temperature variability in the area (Lavelle *et al.*, 2008). At intermediate depths 500 m to 1,300 m) the water is a mix of low salinity, highly oxygenated AAIW coming from the South Pacific and more saline AAIW formed in the Tasman Sea (Chiswell *et al.*, 2015).

5.2.3. Waves & tides

Northern New Zealand generally has calm waves as it is sheltered from large swells originating in the Southern Ocean, but the area has been hit by extratropical cyclones in the past (Leslie *et al.*, 2005; Godoi *et al.*, 2017). The lunar tide propagates in a counterclockwise sense around New Zealand with a pronounced increase in amplitude near land. The tides are also strongly affected by the complicated topography around New Zealand. In particular, there is an oceanic plate convergence and associated structures that pass along the islands and trend south-west-north-east. There is little variation in the spring-neap tides on the east coast of New Zealand (Walters *et al.*, 2001). In the Hauraki Gulf tides have been shown to be mainly influenced by lunar gravity, approximating a standing wave within the gulf (Stevens *et al.*, 2021).

5.2.4. Ocean mixing

In the coastal area of North Island, vertical nutrient supply across the water column is primarily driven by subsurface tides during summer, contributing significantly to primary productivity in the upper layer of the water column (Sharples *et al*., 2001). Episodic wind-driven upwelling events driving deep water onto the shelf have also been suggested to contribute substantially to nutrient supply in the coastal area (Sharples and Greig, 1998). This effect is maintained even through strong stratification during austral summer (Sharples and Zeldis, 2021). The inner part of the Hauraki Gulf is salinity-stratified for up to four months during the austral late winter and early spring (Stevens *et al.*, 2021).

The Hauraki Gulf and surrounding areas are among the most studied in the region, but there is a relative paucity of data in the BRASS operational area in terms of empirical oceanographic measurement data, such as Conductivity Temperature Depth (CTD) profiling (Stevens *et al.*, 2021). Nonetheless, hydrothermal vents have been shown to influence upwelled deep waters in the Southern Ocean, stimulating phytoplankton blooms (Ardyna *et al*., 2019). These process might be expected to operate here as well; however a recent study showed that the hydrothermal signature of macronutrients over the Brothers caldera is negligible on a basin scale, without excluding possible influences on smaller-scale local nutrient distributions (Kleint *et al*., 2022).

5.2.5. Ocean-atmosphere interactions

The ocean around New Zealand is undersaturated with respect to the atmosphere, making it is a sink for atmospheric CO_2 on seasonal and interannual timescales. However, current understanding of the broader carbonate system is limited, with few repeat measurements of dissolved inorganic carbon (DIC) and alkalinity in the BRASS operational area (Nodder *et al.*, 2025). Additionally, during the austral summer of 2017/2018 a general lack of vertical mixing due to exceptional low winds caused a large scale ocean-atmosphere heatwave in the waters north of North Island (Salinger *et al.*, 2019). Such events are expected to increase in frequency due to long term ocean warming, leading to decreased primary production in the area (Chiswell and Sutton, 2020).

5.3. 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 is comprised of mainly Class 63 and 22 habitat (**Figure 7**) (Snelder *et al.*, 2005). Class 63 habitat waters have a mean depth of 754 m, with moderate annual Incoming Short-Wave Solar Radiation (ISWSR), average chlorophyll ɑ (Chl-*a.*) concentrations, and winter SST of 12.1° C; while Class 22 habitat is found in deeper waters, with a mean depth of 1,879 m, Chl-*a.* reaching low average concentrations, and winter SST of 16.3° C (Snelder *et al.*, 2005).

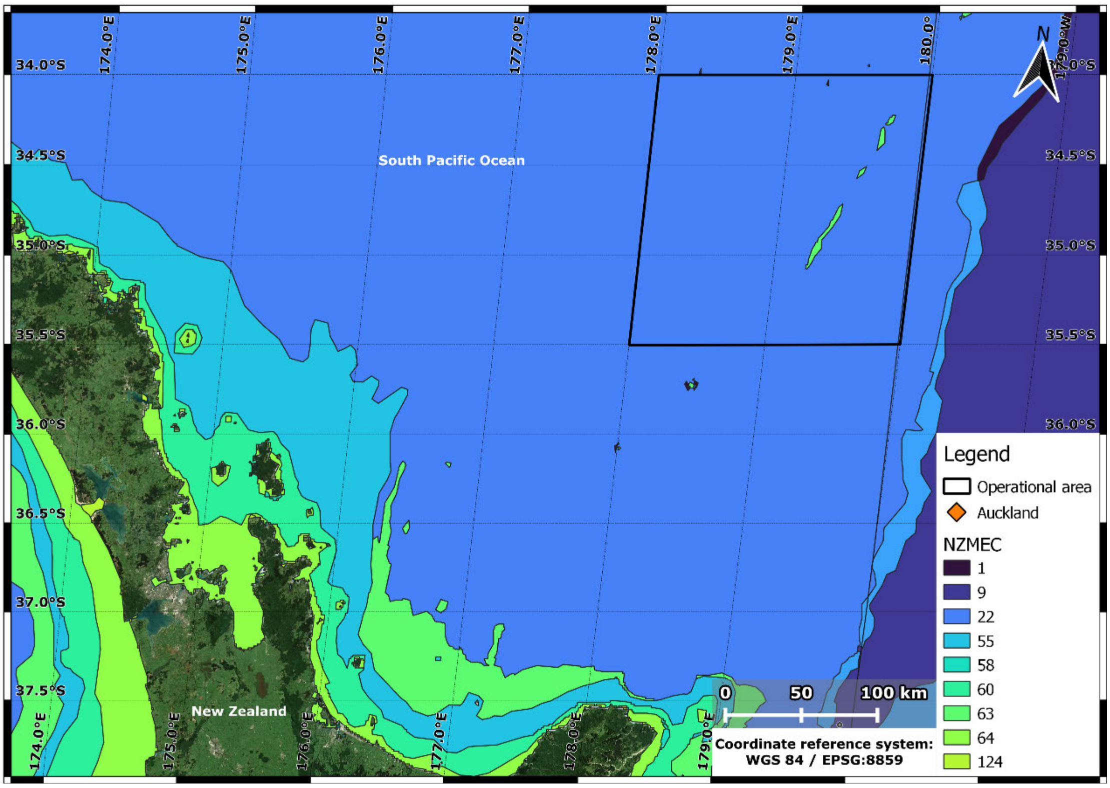

Figure 7: Bioregions as defined by the NZMEC system. Coordinate reference system: WGS 84/Equal Earth Asia-Pacific (EPSG:8859). *Source*: OSC (2025), modified from Snelder *et al.* (2005).

5.3.1. Plankton

Phytoplankton blooms in the area occur between May and October, which is typical timing for austral spring and autumn peak-primary production respectively (Murphy *et al.*, 2001). The region is dominated by dinoflagellates and green algae, the bulk of which is constituted of *Mamiellophyceae*. This protist composition is different to other areas in New Zealand, probably due to the region's salinity (Gutiérrez-Rodríguez *et al.*, 2022).

5.3.2. Invertebrates

Benthic habitat in the Kermadec Arc is characterised by unique cold water corals in all depths, the distribution of which has been linked to seamount presence (Tracey *et al.*, 2011). These corals provide refuge to other species, like sea snails and brittle stars, forming unique habitats that are vulnerable to anthropogenic disturbance, mainly dredging (Zeng *et al.*, 2017; DOC, 2024a). The Brothers Volcano specifically has been shown to have low biodiversity, with communities sampled mainly comprising of vent shrimp, tubed polychaete worms, and echiuran worms (Boschen *et al.*, 2015). These communities are often unique to the caldera as it is the only volcanically active underwater volcano in the region. Unique endemic species like stalked barnacles and squat lobsters have been identified in the caldera, highlighting its ecological importance (Buckeridge, 2000; Cubelio *et al.*, 2007). Other benthic invertebrate families represented among samples of 14 sites in the area are *Dentaliidae*, *Carditidae*, *Pectinidae*, *Serpulidae*, *Veneridae*, and *Limidae* (Snelder *et al.*, 2005).

5.3.3. Fish

The biodiversity of fish species in the general region of the Kermadec Trench has been shown to be low, mainly dominated by large numbers of snailfish (Fujii *et al.*, 2010; Linley *et al.*, 2016). Such hadal liparids are generally benthic, but their larval stage has been shown to possibly be pelagic (Gerringer *et al.*, 2018). Snailfish larvae might rise to depths above 1,000 m, followed by a return to the hadal environment as they grow, which might make them more vulnerable to anthropogenic noise.

Demersal fish species characteristic of Class 63 and 22 habitats, and likely to be found in the area, include Baxter's lantern dogfish (*Etmopterus baxteri*), orange roughy (*Hoplostethus atlanticus*), and hoki (*Macruronus novaezelandiae*) (Snelder *et al.*, 2005).

Bathydermersal chondrichthyes are expected to be present in the area, mainly squaliform sharks, *e.g.* dogfish, lanternsharks, and bramble sharks (Duffy and Ahyong, 2015). Pelagic sharks and rays, like great white shark (Duffy *et al.*, 2012), oceanic manta rays (*Mobula birostris*) (Marshall *et al.*, 2022a; Marshall *et al.*, 2022b), and spinetail devil rays (Marshall *et al.*, 2022b; Marshall *et al.*, 2022a) could also be encountered.

Protected grouper species

Giant grouper (*Epinephelus lanceolatus*) and spotted black grouper (*Epinephelus daemelii*), vulnerable species due to late age at maturity, protogynous hermaphroditism, territoriality, and limited shallow reef habitat, are both protected in New Zealand. Declines in spotted black grouper abundance due to fishing pressure were reported as early as 1916. Although nearly fully protected, incidental bycatch still occurs. They prefer intertidal habitat (juveniles) to 50 m, with adults preferring <25–50 m; however, they have been reportedly caught at 100–300 m (Francis *et al.*, 2015). Giant grouper tend to be found in depths of <50 m, but have been found up to 100 m (Megarajan, 2017; Pollard *et al.*, 2018).

Neither species of grouper are expected to be found in the operational area; however, they may be found in coastal areas of the Hauraki Gulf, where the vessel transit will occur.

5.4.3. Marine reptiles

All seven sea turtle species are globally threatened by global warming, rising sea levels, and by-catch mortality (Poloczanska *et al.*, 2009). While New Zealand is not home to sea turtle rookeries, five species of sea turtles have been recorded in the region (Gill, 1997). The three main species are leatherback (*Dermochelys coriacea*), green (*Chelonia mydas*), and loggerhead (*Caretta caretta*), which have been spotted close to the operational area while migrating (Boyle *et al.*, 2009; Godoy *et al.*, 2016).

5.3.4. Seabirds

Twenty-eight seabird species breed within the northern New Zealand region. Of these, five species breed nowhere else in the world: black petrel (*Procellaria parkinsoni*), Pycroft's petrel (*Pterodroma pycrofti*), Buller's shearwater (*Ardenna (Puffinus) bulleri*), New Zealand storm petrel (*Fregetta maoriana*) and New Zealand fairy tern (*Sternula nereis davisae*) (Whitehead *et al.*, 2019). 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 8**. **Table 4** details seabirds that might be encountered foraging in the area.

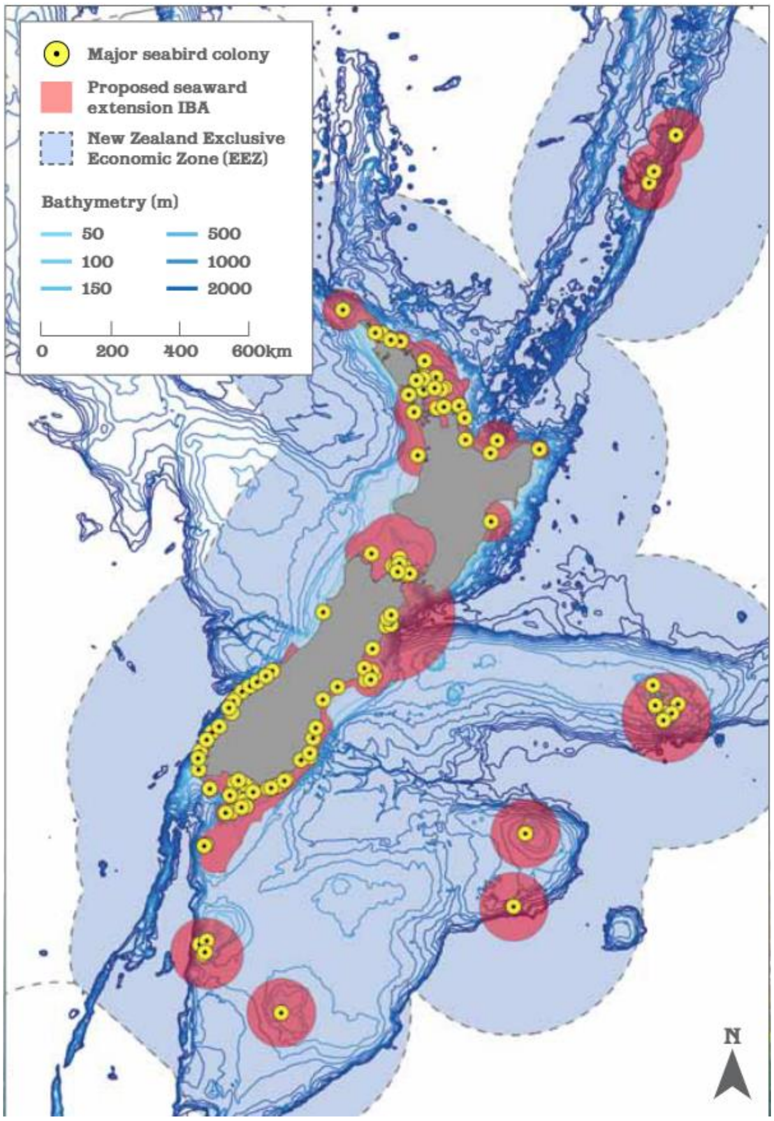

Figure 8: Major seabird colonies in New Zealand. *Source*: Abraham *et al.* (2014).

Species	Conservation status (IUCN and NZTCS)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Antipodean albatross (*Diomedea antipodensis antipodensis*)	**Threatened** Nationally critical												
Black petrel (*Procellaria parkinsoni*)	**Threatened** Nationally vulnerable												
Black-browed albatross (*Thalassarche melanophris*)	Non-resident Coloniser												
Buller's shearwater (*Puffinus bulleri*)	**At-risk** Declining												
Campbell albatross (*Thalassarche impavida*)	**At-risk** Naturally uncommon												
Chatham albatross (*Thalassarche eremita*)	**At-risk** Naturally uncommon												
Flesh-footed shearwater (*Puffinus carneipes*)	**At-risk** Relict												
Fluttering shearwater (*Puffinus gavia*)	**At-risk** Relict												
Gibson's albatross (*Diomedea antipodensis gibsoni*)	**Threatened** Nationally critical												
Grey-faced petrel (*Pterodroma macroptera gouldi*)	**Not threatened**												
Hutton's shearwater (*Puffinus huttoni*)	**Threatened** Nationally vulnerable												

Light-mantled sooty albatross (*Phoebetria palpebrata*)	**Threatened** Nationally vulnerable
Mottled petrel (*Pterodroma inexpectata*)	**At-risk** Relict
Northern giant petrel (*Macronectes halli*)	**At-risk** Recovering
Northern royal albatross (*Diomedea sanfordi*)	**Threatened** Nationally vulnerable
Salvin's albatross (*Thalassarche salvini*)	**Threatened** Nationally critical
Sooty shearwater (*Puffinus griseus*)	**At-risk** Declining
Southern royal albatross (*Diomedea epomophora epomophora*)	**Threatened** Nationally vulnerable
Westland petrel (*Procellaria westlandica*)	**At-risk** Nationally uncommon
White-capped albatross (*Thalassarche cauta steadi*)	**At-risk** Declining
White-chinned petrel (*Procellaria aequinoctialis steadi*)	**Not threatened**

Table 4: Seabirds with IUCN and NZ conservation status and breeding season, that might be encountered foraging in the operational area. *Source*: Robertson *et al.* (2003); Robertson *et al.* (2021).

5.3.5. Marine mammals

Marine mammals likely to be found in the operational area of Kermadec Arc or transit route through Hauraki Gulf are detailed here.

5.3.5.1. Baleen whales (mysticetes)

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).

Blue whale & pygmy blue whale (*Balaenoptera musculus* & *B. musculus brevicauda*)

The blue whale is a cosmopolitan species, found in all oceans. They feed almost exclusively on euphausiids (krill). 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, 2018a).

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 regularly use waters around southern New Zealand (Branch *et al.*, 2007a; Branch *et al.*, 2007b; Cooke, 2018a; Warren *et al.*, 2021). Pygmy blue whales can be found in New Zealand throughout the year, mainly in the Taranaki Bight and coastal areas of the North Island (Goetz *et al.*, 2021). This native population has been shown to be genetically distinct (Barlow *et al.*, 2018; Barlow *et al.*, 2023). The status of pygmy blue whales under the New Zealand Threat Classification System (NZTCS) changed from migrant to data deficient in 2019, due to year-round presence but lack of data (Baker *et al.*, 2019).

Bryde's whale (*B. edeni*)

Bryde's whales can be found throughout the year in the Hauraki Gulf (**Figure 9**). They survive on more limited resources than most baleen whales due to their preferred temperate habitat, and diet of both zooplankton and schooling fish. There has been a shift in their diet, from primarily fish to primarily zooplankton, thought to reflect changes in prey availability. Bryde's whales of the Hauraki Gulf were observed foraging alone except for mother-calf pairs that fed together, with the mother assisting her calf. Tagged whales fed only during the day, passing most of the night in a low energy resting state (Wiseman, 2008; Izadi *et al.*, 2022). There is genetic evidence that Bryde's whale populations are connected throughout their range, with whales migrating from Hauraki Gulf for part of the year (Wiseman, 2008). Emigration has been shown to be significant, with estimates suggesting a quarter of the total population visit the gulf each year following seasonal upwelling patterns (Tezanos-Pinto *et al.*, 2017; Hamilton *et al.*, 2024).

Bryde's whale is assessed by the IUCN as one species, even though its taxonomy is not fully resolved. There are several subpopulations or subspecies that should be assessed separately and may warrant threatened categories; however, Bryde's whale is globally classified as a species of least concern (Cooke and Brownell Jr., 2018). It is classified as nationally critical by the NZTCS due to the small size of the local population and known threats; however, due to active management measures, mortality from vessel strikes is rare (Baker *et al.*, 2019).

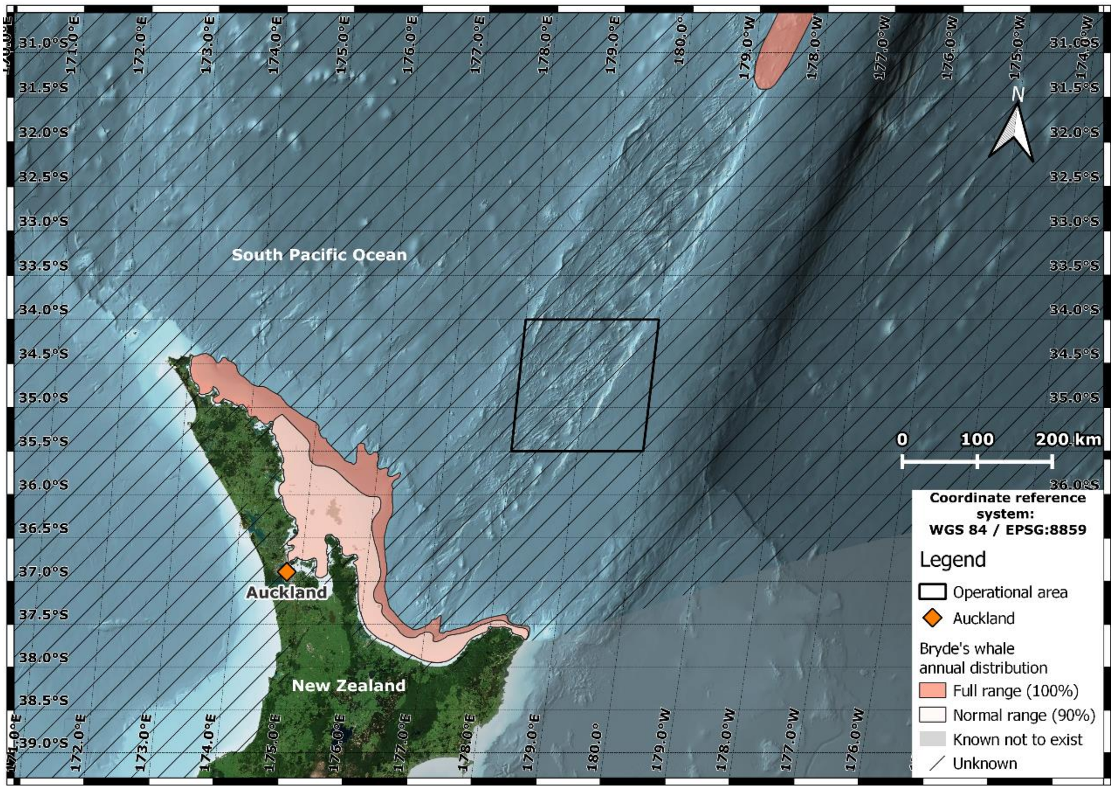

Figure 9: Bryde's whale annual distribution in operational area. WGS 84/Equal Earth Asia-Pacific (EPSG:8859). *Source*: OSC (2025), modified from MPI (2025a).

<u>Fin whale (*B. physalus*)</u>
Fin whale 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. The global population size is uncertain but thought to be recovering (Cooke, 2018c).

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). They can also be found in the offshore part of the Hauraki Gulf, with peak densities from June to September (McDonald, 2006). Its classification under the NZTCS changed from migrant to data deficient in 2019 due to year-round presence but lack of data (Baker *et al.*, 2019).

<u>Humpback whale (*Megaptera novaeangliae*)</u>
The humpback whale 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. Their diet consists mainly of krill, with some populations also possibly preying on

small fish(Cooke, 2018b). 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. The majority of reported sightings are from the east coast of New Zealand, with almost half from Kaikoura and the Cook Strait (Constantine *et al.*, 2007). Individuals and groups with site-fidelity to the New Caledonia and Tonga breeding grounds are likely to pass northwards along the eastern coastline of the North Island and the northern tip of New Zealand, a migration path supported by genetic evidence (Franklin *et al.*, 2014; Duffy *et al.*, 2015; Steel *et al.*, 2018). The Kermadec Islands north of the operational area have been identified as an important area along this route, as most groups within the Oceania subpopulation seem to pass by it despite travelling between different wintering and breeding grounds (Riekkola *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).

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 migrant as there is no endemic population (Baker *et al.*, 2019).

Minke whale & dwarf minke whale (*B. acutorostrata* & *B. acutorostrata ssp.*)
The minke whale is a cosmopolitan species found in all oceans. They occur in both coastal and offshore waters and prey on a variety of species. Dwarf minke whale feeding habits are poorly known. Minke whales are known to aggregate in the Great Barrier Reef in Australia during the winter, but the global population's winter distribution is highly dispersed. Minke whale abundance in the Southern Hemisphere has not been estimated, as sightings do not distinguish it from the more numerous Antarctic minke whale (*B. bonaerensis*), with which it is partially sympatric, but not in the operational area. Minke whale have not been subject to significant exploitation in the southern hemisphere and is listed as least concern (Cooke, 2018e).

Minke whales are potentially found in the operational area, as a migratory connection between New Zealand, Tonga, and the Antarctic has been suggested (Pastene *et al.*, 2010). Their NZTCS changed from not threatened to data deficient in 2019 due to a potentially resident population in New Zealand's subantarctic waters, but insufficient data on population abundance (Baker *et al.*, 2019).

Pygmy right whale (*Caperea marginata*)
The pygmy right whale is rarely sighted and there is no estimate on global population size. They 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, 2018d).

Pygmy right whales are known to inhabit Australian mid-latitude waters year-round (Dedden *et al.*, 2023). 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; however, extensive strandings have been recorded in the Hauraki Gulf (Matsuoka *et al.*, 2005; Kemper *et al.*, 2013). It is classified as data deficient under the NZTCS (Baker *et al.*, 2019).

Sei whale (*B. borealis*)
The sei whale is a cosmopolitan species, with a mainly offshore distribution. They primarily feed on krill and copepods but have also been reported preying on fish. They can be hard to differentiate from Bryde's whales. The IUCN has classified fin 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, 2018f).

The Southern Hemisphere lacks reliable abundance information for sei whale populations (Berkenbusch *et al.*, 2013; Austin, 2021); however, but they can be found in the Hauraki Gulf and have been spotted near the operational area (Duffy *et al.*, 2015). Their NZTCS changed from migrant to data deficient, although there is much uncertainty around residency, abundance, and trends (Baker *et al.*, 2019).

5.3.5.2. Toothed whales & dolphins (Odontocetes)

Odontocetes (toothed whales and dolphins) are widely distributed 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 Maui'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 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, depredation, vessel strikes, plastics, and oil spills (Feyrer *et al.*, 2024)

Andrew's beaked whale (*Mesoplodon bowdoini*)
Data on Andrew's beaked whale is extremely deficient, with little information on distribution or abundance. It is assumed this species to inhabits deep waters and

feeds on cephalopods. The IUCN classifies it as data deficient (Pitman and Brownell Jr., 2020b).

Strandings in the north part of the North Island suggest a possible presence operational area (Thompson *et al.*, 2013). The NZTCS classifies them as data deficient (Baker *et al.*, 2019).

<u>Arnoux's beaked whale (*Berardius arnuxii*)</u>
The Arnoux's beaked whale 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. The IUCN classifies it as least concern despite little 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 strandings in the north part of the North Island suggest possible presence in the area (Thompson *et al.*, 2013). Their status under the NZTCS changed from migrant to data deficient in 2019 (Baker *et al.*, 2019).

<u>Bottlenose dolphin (*Tursiops truncatus*)</u>
The bottlenose dolphin is among the most common cetacean species worldwide. Global abundance has been estimated at 750,000 individuals but is likely much higher. Bottlenose dolphins exhibit complex social behaviours partly facilitated by the variety of vocalisation they can produce (Lusseau, 2007; Patiño-Pérez *et al.*, 2024). They can be found in inshore, coastal, shelf, and oceanic waters, with the ones in coastal waters being the most vulnerable to anthropogenic disturbance (Wells *et al.*, 2019). Coastal and pelagic populations exploit different enough niches to be split into two ecotypes (Zaeschmar *et al.*, 2020). They generally feed on 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).

The Hauraki Gulf has been identified as a hotspot for bottlenose dolphins in New Zealand, with around 200 dolphins recorded in the area throughout the year (**Figure 10**). They undertake a general seasonal movement between shallow waters in the winter and deeper waters during the summer, with sightings peaking during the autumn in the inner Hauraki Gulf (Dwyer *et al.*, 2014). Bottlenose dolphins have also been spotted in the operational area, probably belonging to the pelagic ecotype (Richard and Berkenbusch, 2024). Under the NZTCS, bottlenose dolphins are classified as nationally endangered, largely due to the small number of individuals in different coastal subpopulations (Baker *et al.*, 2019).

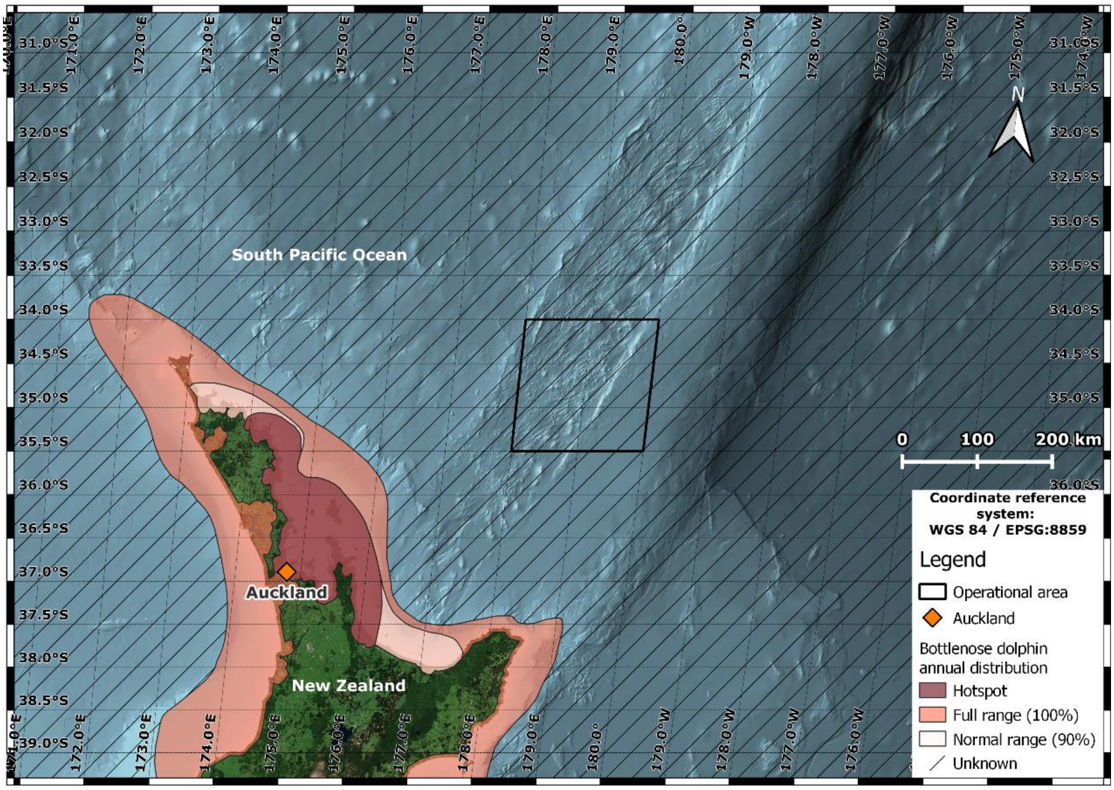

Figure 10: Bottlenose dolphin annual distribution in operational area. *Source*: OSC (2025), modified from MPI (2025a).

<u>Common dolphin (*Delphinus delphis*)</u>

Common dolphin are widely distributed in all oceans, from coastal to offshore waters. Estimates put the global population at around six million, but it is probably higher. They are very social animals that live in large groups. They primarily prey on pelagic fish. The IUCN classifies them as least concern (Braulik *et al.*, 2021)

In New Zealand common dolphins can be found in the Hauraki Gulf (**Figure 11**) and mainly use the area for foraging (Stockin *et al.*, 2009); however, they may be shifting to offshore feeding due to depleted fish stocks in the Hauraki Gulf, forcing these dolphin to forage further offshore. (Peters *et al.*, 2020). Their density within the gulf follows similar patterns to bottlenose dolphin, with higher densities in the inner part of the gulf during the winter (Dwyer *et al.*, 2016; Hupman *et al.*, 2018). The population within the gulf seems to be distinct, with little migration between other parts of their range (Stephenson *et al.*, 2020). The NZTCS classifies them as not threatened (Baker *et al.*, 2019).

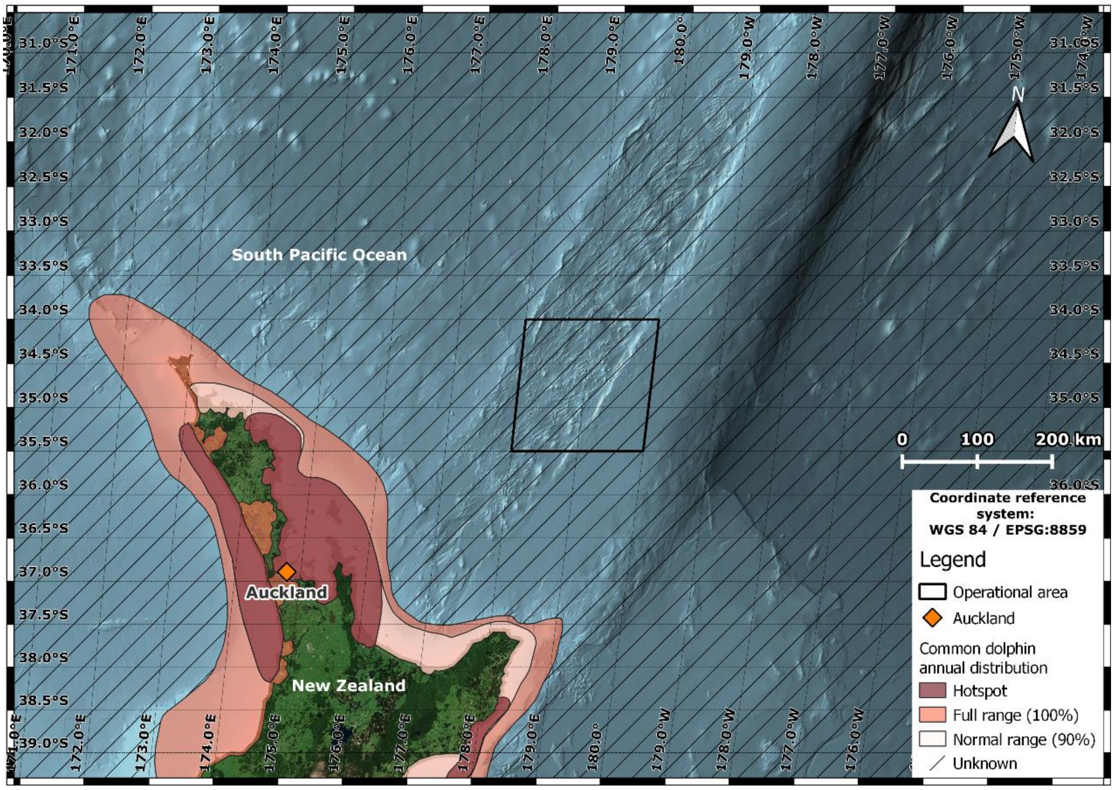

Figure 11: Common dolphin annual distribution in the operational area. *Source*: OSC (2025), modified from MPI (2025a).

<u>Dense beaked whale/Blainville's beaked whale (*M. densirostris*)</u>

Dense beaked whale sightings are rare due difficulty in identification unless the head is observed. Knowledge of the distribution of this species has been inferred almost entirely from stranding records. In the eastern Pacific, strandings and sighting records range from 37.3°N to 41.5°S (Baker and Van Helden, 1999; MacLeod *et al.*, 2005). It is generally assumed that they inhabit very deep waters, as most beaked whales are assumed to and the majority of observations have occurred in deep waters (Allen *et al.*, 2011). They are assumed to prey on fish and cephalopods. The IUCN classifies them as least concern despite limited information, due to being considered common in parts of its distribution (Pitman and Brownell Jr., 2020d).

The operational area is within the southernmost distribution limit of the dense beaked whale; however, strandings in the north part of the North Island suggest possible presence in the area (Baker and Van Helden, 1999; MacLeod *et al.*, 2005). The NZTCS classifies them as data deficient (Baker *et al.*, 2019).

<u>Dwarf sperm whale (*Kogia sima*)</u>

The dwarf sperm whale is an oceanic species found in tropical waters around the world. Accurate population assessments don't exist for this species as it is difficult to detect; however, as no major threats are known to occur across the majority of its range, it is likely to be more common than is suggested from the results of sighting surveys. The IUCN classifies them as least concern (Kiszka and Braulik, 2020b).

The operational area is within the southernmost distribution limit of dwarf sperm whale. Its status under the NZTCS changed from vagrant to data deficient in 2019; however, it is uncertain how they use New Zealand waters (Baker *et al.*, 2019).

False killer whale (*Pseudorca crassidens*)
False killer whales have a wide distribution range across the world but are globally uncommon. They are most common in offshore tropical waters where they mainly prey on large pelagic fish. The IUCN classifies them as near threatened due to low abundance and susceptibility to anthropogenic disturbance (Baird, 2018).

Abundance estimates for false killer whales off New Zealand put the local population to 111 based on sightings between 2005–2012. Long term resightings suggest the likelihood of a small local population off the north side of North Island, probably exploiting warm waters and prey species closer to shore (Zaeschmar, 2014). The low encounter rate in coastal areas suggests that the distribution of false killer whales is likely concentrated offshore, further supported by genetic evidence of ongoing connections with wider Pacific populations (Zaeschmar *et al.*, 2014; Tezanos-Pinto *et al.*, 2024). False killer whale status under the NZTCS changed in 2019 from not threatened to naturally uncommon, as local populations are small and not thought to be impacted by anthropogenic activity in the area (Baker *et al.*, 2019).

Ginkgo-toothed beaked whale (*M. ginkgodens*)
There is no information on global population abundance for the ginkgo-toothed beaked whale, but stranding records suggest a wide distribution range in deep waters in the Pacific (Pitman and Brownell Jr., 2020a). This species is almost impossible to identify with certainty at sea and there have been as yet no confirmed sightings (MacLeod *et al.*, 2005). The IUCN classifies ginkgo-toothed beaked whales as data deficient.

The only evidence of presence in New Zealand comes from strandings concentrated around the Taranaki area (Baker and Van Helden, 1999; Thompson *et al.*, 2013). Its NZTCS status changed from vagrant to data deficient in 2019 (Baker *et al.*, 2019).

Goose-beaked whale (*Ziphius cavirostris*)
Goose-beaked whales have the most extensive range of any beaked whale species, they are widely distributed in offshore waters of all oceans. It inhabits steep slope habitat, preferring submarine canyons and escarpments. 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).

Strandings in the north part of the North Island suggest possible presence in operational area (Thompson *et al.*, 2013). The NZTCS classifies them as data deficient (Baker *et al.*, 2019).

Gray's beaked whale (*M. grayi*)
Gray's beaked whales have a circumpolar range in the southern hemisphere. The vast majority of information for this species comes from stranding records, particularly in New Zealand. They are thought to inhabit deep waters and prey on fish and cephalopods (Pitman and Taylor, 2020a). 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, 2020a).

Direct evidence of Gray's beaked whale presence in the area consists of a single observation of a pair of free-swimming individuals in Mahurangi Harbour, near Warkworth, on the North Island in June 2001 (Dalebout *et al.*, 2004). Other evidence comes from strandings in the north part of the North Island (Peters *et al.*, 2022). The NZTCS classifies it as not threatened (Baker *et al.*, 2019).

Hector's beaked whale (*M. hectori*)

Hector's beaked whales can be found in cool-temperate waters of the Southern Hemisphere. The vast majority of information for the species comes from stranding records. It is thought to inhabit deep waters and prey on cephalopods and fish. The IUCN classifies it as data deficient (Pitman and Brownell Jr., 2020c).

Strandings in the north part of the North Island suggest possible presence in operational area (Thompson *et al.*, 2013). The NZTCS classifies it as data deficient (Baker *et al.*, 2019).

Killer whale (*Orcinus orca*)

Killer whales are widely distributed and abundant globally, in coastal and offshore areas, with only some regional populations showing decline. They 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 genetically distinct from Australian populations (Reeves *et al.*, 2022). They are resident to the Hauraki Gulf (**Figure 12**), with encounters higher in spring and winter (Hupman *et al.*, 2015). 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). There is evidence of possible niche differentiation within local killer whale populations (Visser, 2007). The four ecotypes in the region are treated by the NZTCS as forms of *O. orca*, but are classified separately. The coastal population is classed as nationally critical due to small population size (Baker *et al.*, 2019).

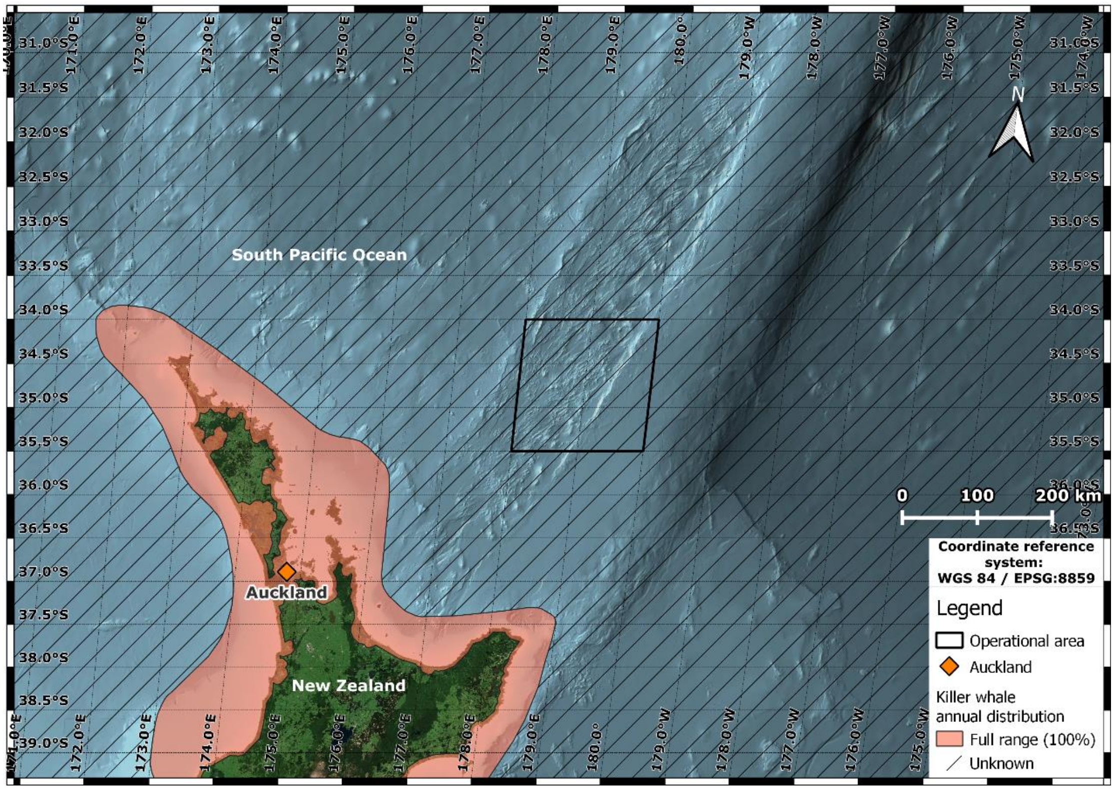

Figure 12: Killer whale annual distribution in operational area. *Source*: OSC (2025), modified from MPI (2025a).

<u>Long-finned pilot whale (*Globicephala melas*)</u>
Long-finned pilot whales are widely distributed in temperate and subpolar waters, except for the north Pacific. There are no population estimates for this species as it is hard to distinguish from short-finned pilot whales (*G. macrorhynchus*). They generally prefer waters along continental shelf edges and primarily prey on small and medium sized fish. Long-finned pilot whales in New Zealand feed primarily on cephalopods, predominantly 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.*, 2018b).

Live sightings are rare, with most data on the species coming from strandings. 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. 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). The NZTCS classifies them as not threatened (Baker *et al.*, 2019).

<u>Pygmy sperm whale (*K. breviceps*)</u>
There is very limited information on the distribution, abundance, behaviour, or population structure of pygmy sperm whales globally. 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, 2020a). Their diet consists primarily of cephalopods (Beatson, 2007). 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, so the IUCN classifies them as least concern (Kiszka and Braulik, 2020a).

Evidence of presence in northern New Zealand comes from stranding records (Beatson, 2007). They are generally thought to be found in deep waters, so they might be encountered in the operational area. Their NZTCS status was changed from not threatened to data deficient due to previous assessments deemed overly optimistic (Baker *et al.*, 2019).

<u>Risso's dolphin (*Grampus griseus*)</u>
Risso's dolphin are widely distributed, with their range spanning between at least 64°N and 46°S. Although they occur in all habitats from coastal to oceanic, they show a strong range-wide preference for mid-temperate waters of the continental shelf and slope between 30° and 45° latitude (Jefferson *et al.*, 2014; Kiszka and Braulik, 2018). Their diet consists primarily of cephalopods (Baird, 2009). Their population is not thought to be declining, with the IUCN classifying them as least concern (Kiszka and Braulik, 2018). Their status under the NZTCS changed from vagrant to data deficient in 2019, as they are thought to be a native species despite lack of data (Baker *et al.*, 2019).

<u>Shepherd's beaked whale (*Tasmacetus shepherdi*)</u>
Shepherd's beaked whales have a circumpolar distribution in the southern hemisphere. The vast majority of information for the species comes from stranding records. 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). The IUCN classifies it as data deficient (Braulik, 2018a).

Strandings in the north part of the North Island suggest possible presence in operational area (Pitman *et al.*, 2006). The NZTCS classifies it as data deficient (Baker *et al.*, 2019).

<u>Short-finned pilot whale (*G. macrorhynchus*)</u>
Widely distributed in tropical and temperate waters globally, short-finned pilot whales are typically found in deep waters over the outer continental shelf or continental slope and are generally nomadic. They primarily feed on cephalopods. The IUCN classifies them as least concern despite lack of data, due to their wide distribution, lack of threats, and absence of evidence for population decline (Minton *et al.*, 2018a).

The operational area is within their southernmost limit (Minton *et al.*, 2018a). Their status under the NZTCS changed from migrant to data deficient in 2019, as it is thought to be a native species despite lack of data (Baker *et al.*, 2019).

<u>Southern bottlenose whale (*Hyperoodon planifrons*)</u>
Southern bottlenose whales have a circumpolar distribution in the Southern Hemisphere. This species is thought to inhabit deep waters and prey on cephalopods (Lowry and Brownell Jr., 2020). The IUCN classifies them as least concern as they are not thought to be under any threat.

The operational area is within their northernmost part of their distribution (Lowry and Brownell Jr., 2020). The only evidence of southern bottlenose whale presence off the North Island comes from strandings (MacLeod *et al.*, 2005). The NZTCS classifies them as data deficient (Baker *et al.*, 2019).

<u>Southern right whale dolphin (*Lissodelphis peronii*)</u>
Southern right whale dolphins have a circumpolar distribution in the Southern Hemisphere, usually found in offshore waters. They prey on fish and cephalopods. The IUCN classifies them as least concern, despite lack of data, due to their wide distribution and lack of threats (Braulik, 2018b).

In New Zealand, there has been one massive sighting of southern right whale dolphins east of Kaikoura (Visser *et al.*, 2004). There are DOC records of strandings on the North Island, which suggests they could be present in the operational area. Their status under the NZTCS changed from vagrant to data deficient in 2019, as it is thought to be a native species despite lack of data (Baker *et al.*, 2019).

<u>Spade-toothed whale (*M. traversii*)</u>
Only data available for the spade-toothed whale is five strandings, four of which were in New Zealand, with the IUCN classifying it as data deficient (Pitman and Taylor, 2020b).

As the strandings occurred in the north part of the North Island, it is possibly present in the operational area (Thompson *et al.*, 2013). The NZTCS classifies it as data deficient (Baker *et al.*, 2019).

<u>Sperm whale (*Physeter macrocephalus*)</u>
The largest of the odontocetes is the sperm whale, 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). The IUCN classified them as vulnerable, due to historical population declines attributed to commercial whaling and uncertain population abundance trends (Taylor *et al.*, 2019).

Historical strandings of sperm whales suggest they are present off the North Island (Palmer *et al.*, 2022); however, most studies in New Zealand have been carried out near Kaikoura, where acoustic studies suggest increased foraging activity and sperm whale presence throughout the year (Giorli and Goetz, 2019; Giorli and Goetz, 2020). A pod of 17 sperm whales were spotted near the Kermadec Islands during an expedition in 2004, suggesting they could be in the operations area (Duffy *et al.*, 2015). Their status under the NZTCS changed from not threatened to data deficient in 2019, as there are not enough data to estimate population abundance in New Zealand waters (Baker *et al.*, 2019).

<u>Striped dolphin (*Stenella coeruleoalba*)</u>
The striped dolphin is a widely distributed species, found in tropical to warm-temperate waters. The global population is estimated to be over two million. They inhabit deep waters, with studies mainly focused in the Mediterranean and Mexican coasts. They prey on a variety of species, including cod and squid. The IUCN classifies the global population as least concern; however, the Mediterranean subpopulation is classified as vulnerable due to population decline (Braulik, 2019).

Strandings in the north part of the North Island suggest possible presence in area of interest (Peters *et al.*, 2022). The NZTCS classifies them as data deficient (Baker *et al.*, 2019).

5.3.5.3. *Seals & sea lions (Pinnipeds)*

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 operation area is the New Zealand fur seal (*Arctocephalus forsteri*). Threats to pinnipeds include entanglement, noise pollution, injuries from vessel collision, and loss of breeding grounds due to climate change and land development (Kovacs *et al.*, 2012; Schoeman *et al.*, 2020; Roberts and Hendriks, 2022).

<u>New Zealand fur seal</u>
New Zealand fur seals are active during both day and night, and possess acute vision and good hearing under water (Nowak, 2003). 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 (Chilvers and Goldsworthy, 2015).

New Zealand fur seals can be found foraging across New Zealand, but mostly around the South Island, as the North Island has fewer colonies, see **Figure 13** (Davis, 2006; Bouma *et al.*, 2008; Richard and Berkenbusch, 2024). They are classified as not threatened under the NZTCS (Baker *et al.*, 2019).

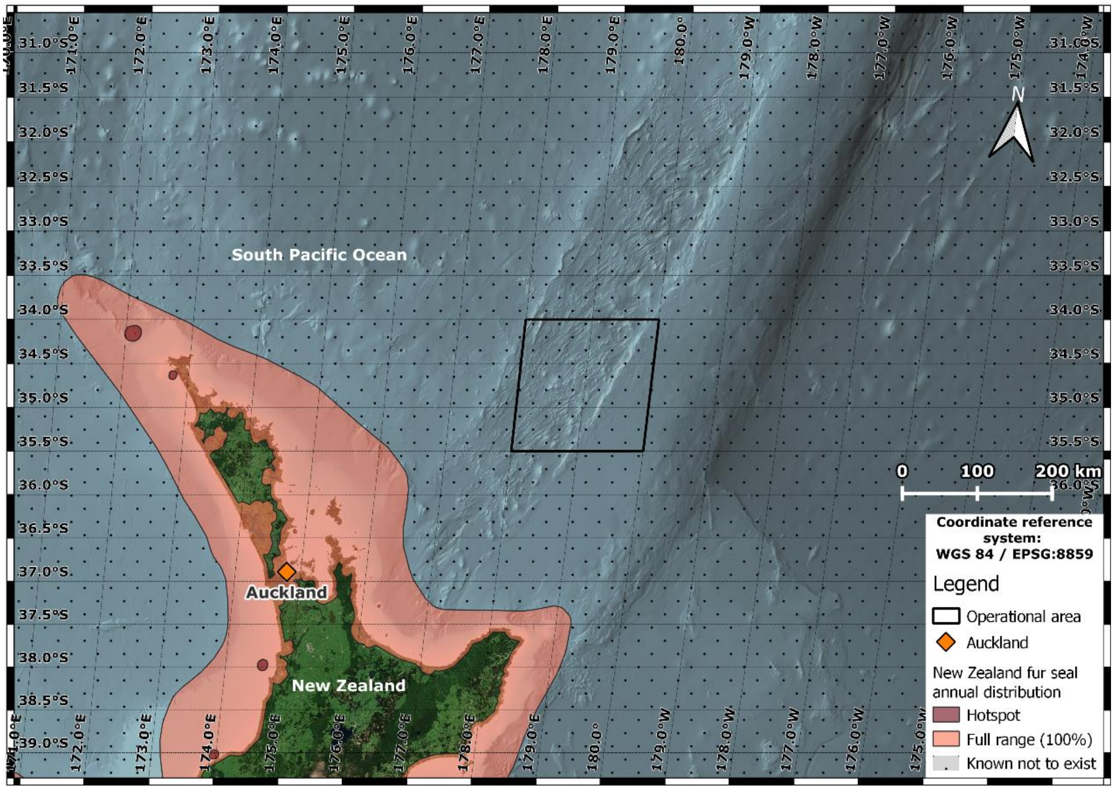

Figure 13: New Zealand fur seal annual distribution in operational area. *Source*: OSC (2025), modified from MPI (2025a).

5.4. Coastal environment & marine conservation

5.4.1. Coastal environment

The Hauraki Gulf can be divided into two major environmental types, estuarine and marine, based on biological and physical differences. The entire gulf is shallower than 200 m in depth, with the majority being around 50 m deep. Currents in the gulf are mostly slow with some high current areas between islands (Jackson and Lundquist, 2016). The sediment is a mix of mud and sand with some rocky areas.

Most estuarine vegetation in the gulf occurs intertidally within estuaries. Estuarine vegetation is comprised of mostly mangroves (*Avicennia marina*), as well as some saltmarsh and seagrass (*Zostera muelleri*) (Jackson and Lundquist, 2016). The Hauraki Gulf has historically been an important spawning and nursery ground for red snapper (Parsons *et al.*, 2014). It hosts relatively small permanent populations of marine mammals, mostly bottlenose dolphins, common dolphins, Bryde's whales and killer whales. This has led to a small scale and tightly regulated cetacean tourism industry in the area (Fumagalli *et al.*, 2021). It is also an important bird area for seabirds, being home to multiple large seabird colonies. Seabirds breeding and foraging in the area include all endemic species mentioned in **section 5.3.4** (Abraham *et al.*, 2014).

5.4.2. 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. New Zealand's territorial sea includes 44 such reserves, four of which are situated in coastal areas near the operational area (**Figure 14**).

Type 2 MPAs are established under other legislations and may allow some extractive activities while meeting standards of protection. The Marine Mammals Protection Act 1978 allows for the establishment of marine mammal sanctuaries to protect species as well as the ability to impose fishing-related mortality limits. In most cases fishing and seismic surveys can be undertaken; however, there are restrictions about how they can be conducted. New Zealand has eight marine mammal sanctuaries, none of which are in the seismic operational area (**Figure 14**).

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, areas for the protection of submarine cables, and protected areas created by special legislation. In areas declared as Cable Protection Zones (CPZ), anchoring and most types of fishing is prohibited (**Figure 14**).

BPAs are designed to protect the seabed from the impacts of bottom fishing and dredging activities. New Zealand has 17 BPAs and 18 Seamount Area Closures (SACs) in its EEZ and continental shelf, covering 1.1 million km², or approximately a third of the total EEZ. Within BPAs, bottom trawling, dredging, and fishing within 100 m of the seabed is prohibited. Within SACs, all forms of trawling are prohibited. Two BPAs fall within the operational area, Kermadec and Tectonic Reach, with the Tectonic Reach BPA also including two SACs with hydrothermal vents at the Brothers Volcano (Seamount Closure 6B2-a) and at the Rumble III Volcano (Seamount Closure 6B2-b), see **Figure 14** (Menini and Van Dover, 2019).

The Hauraki Gulf Marine Park was established in 2000 under the Hauraki Gulf Marine Park Act, to achieve integrated management of the area across land and sea. The Act lists a number of objectives including ecological, social, cultural, and economic goals. Although there is the possibility for tension between these interests, the requirement to sustain the life-supporting capacity of the marine environment means that the goal is not to simply allocate the Gulf's resources between competing users. The park is not a protected area; however, new protection areas within the park have been proposed under the Hauraki Gulf/Tīkapa Moana Marine Protection Bill, which is currently in second reading (New Zealand Parliament, 2024). The two new types of protection areas would be high protection areas and seafloor protection areas, mainly offering protections against fishing, waste discharge, and abiotic material removal, see **Figure 15** (DOC, 2024b).

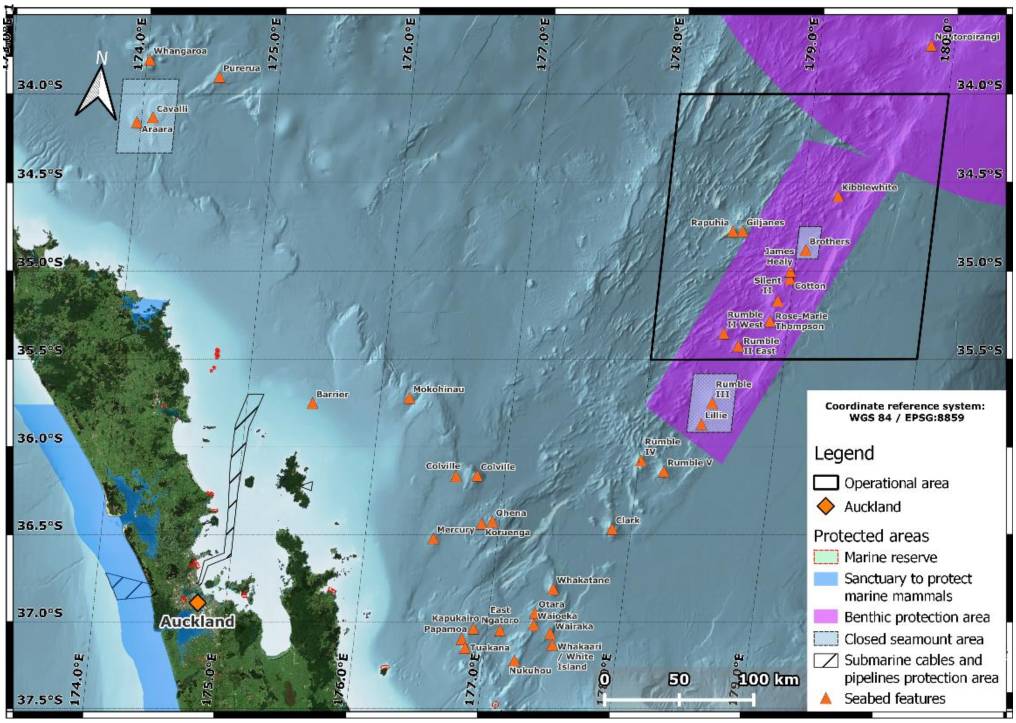

Figure 14: Current marine protected areas near operational area. WGS 84/Equal Earth Asia-Pacific (EPSG:8859). *Source*: OSC (2025).

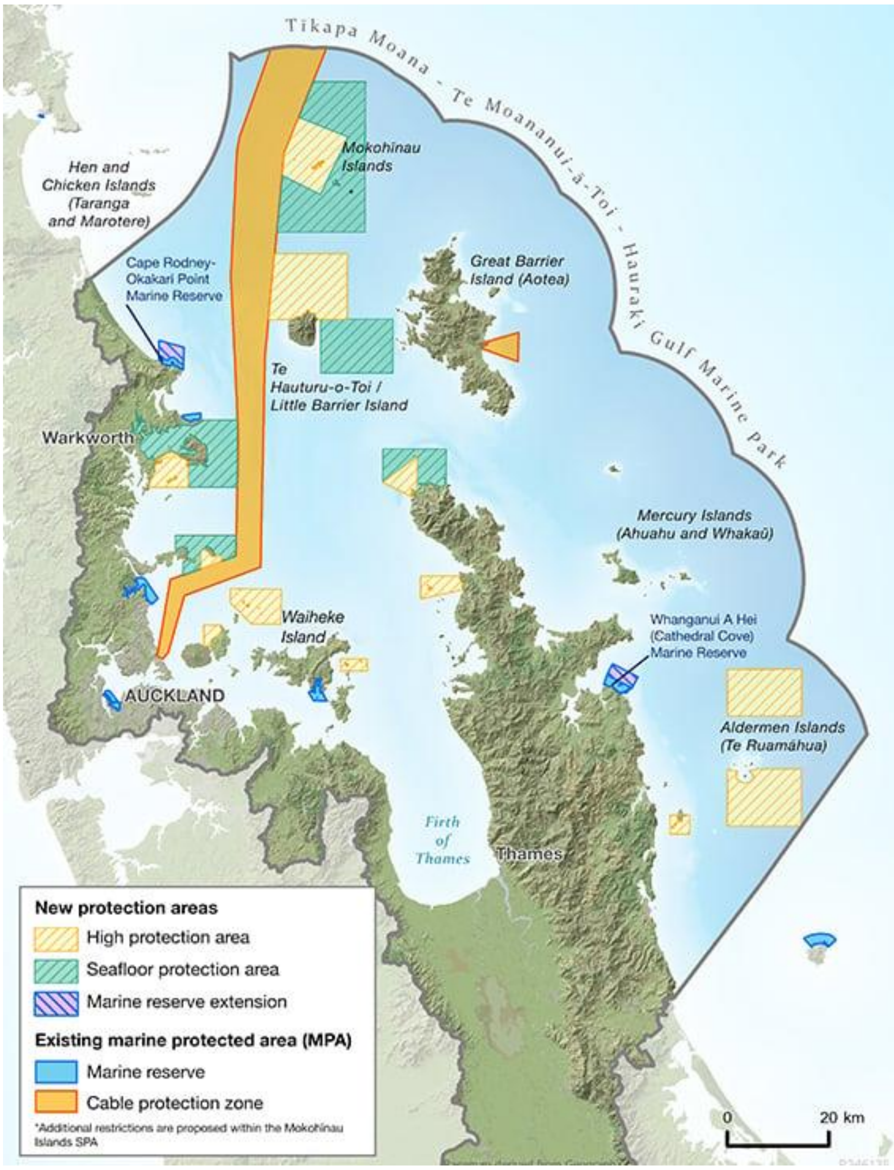

Figure 15: Proposed protection areas in the Hauraki gulf. *Source*: DOC (2025).

5.5. Cultural environment

The Kermadec region is of cultural significance to a number of *iwi* as a historical stop-over point on their journey across the Pacific to New Zealand. The islands in the region and the marine area around them are currently uninhabited and serve as nature reserves to a variety of protected flora and fauna (Ministry for the Environment, 2016). The wider Kermadec region was considered as a candidate for one of the world's largest ocean sanctuaries, but plans on implementation were halted in 2024 due to, *inter alia*, concerns over *iwi* fishing rights (McCormack, 2021; New Zealand Government, 2024).

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, 18 such titles have been granted, all in coastal areas not in the operational area (**Figure 16**).

The fishing rights of Māori are protected through special reserves with additional rules regarding fishing (**Figure 16**). Mātaitai reserves are areas closed to commercial fishing, that may have bylaws affecting recreational and customary fishing. A *taiapure* is an estuarine or littoral coastal area which is traditionally important to *hapū* or *iwi*. A *taiapure*, 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).

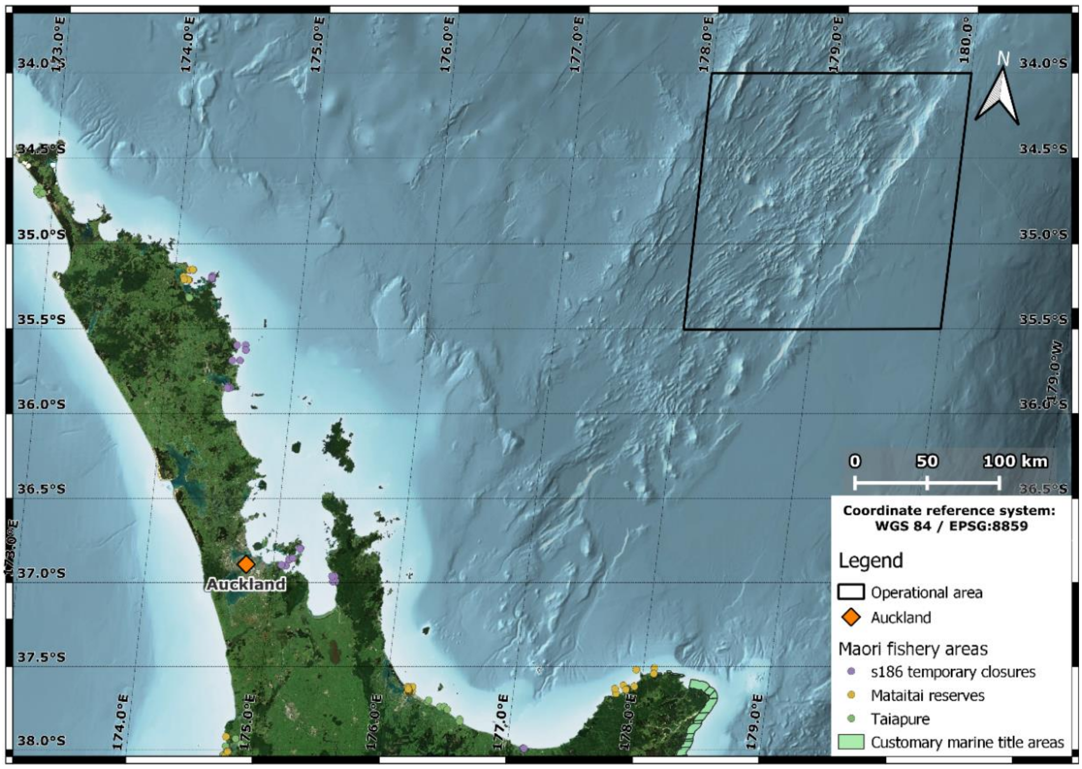

Figure 16: Māori customary fishing areas. WGS 84/Equal Earth Asia-Pacific (EPSG:8859). *Source*: OSC (2025).

5.6. Socio-economic environment

5.6.1. Commercial fisheries

The region is important for commercial fishing. With multiple ports and an international airport, Auckland provides prime exporting opportunities for commercial fish and shellfish species caught in the region and elsewhere. Popular landing sites are at Mangonui, Whangarei, Leigh, Auckland, and Tauranga. Main species are snapper (*Pagrus auratus*), John dory (*Zeus fabe*), and terakihi (*Nemadactylus macropterus*). In east Northland and the Hauraki Gulf, fisheries mostly use long-line and Danish seine/trawl, while in the Bay of Plenty, fishing for these species is mostly done by trawl. Other fisheries include purse seining for mackerels, kahawai (*Arripis trutta*), and skipjack tuna (*Katsuwonus pelamis*), as well as surface long-lining for tunas and swordfish, and lining for bluenose (*Hyperoglyphe antarctica*) and hapuku (*Polyprion oxygeneios*)/bass (MPI, 2025b; MPI, 2025c). There is also a small fishery of arrow squid (*Nototodarus* sp.) in the area (Smith *et al.*, 1987).

The operational area includes two BPAs, Kermadec and Tectonic Reach. The Tectonic Reach BPA includes two seamount closures where all trawling within 100 m of the seabed is prohibited (MPI, 2025d). The area is not a priority for commercial fisheries (Baird *et al.*, 2011; MPI, 2024)

5.6.2. Recreational fishing

The North Island is a popular area for recreational fishing, largely due to the number of large population centres. The vast majority of catch is snapper and terakihi using fishing rods, and diving for shellfish like pipi (*Paphies australis*) and kina (*Evechinus chloroticus*). Most recreational fishing activity takes place from trailer motorboats or larger boats, and off land (Heinemann and Gray, 2024).

5.6.3. Commercial shipping

The North Island is home to the two busiest ports in New Zealand, Tauranga in the Bay of Plenty and Auckland in the Hauraki Gulf, encompassing around 67% of container trade (MOT, 2024). Increased vessel traffic can result in more frequent vessel strike events with marine mammals, especially during whale migration periods (Mayaud *et al.*, 2022). Such vessel strike injuries have been observed in Bryde's whales in the region (Behrens and Constantine, 2008). The Hauraki Gulf Transit Protocol was put into place to mitigate the risks of vessel strikes to marine mammals in the area (see **section 2.1.1**). Other effects include habitat exclusion and behavioural shifts due to vessel noise (Meissner *et al.*, 2015), as well as sound masking (Pine *et al.*, 2021).

A notable event in the area is the 2011 wreck of the *MV Rena* at Astrolabe Reef off the northeast coast of New Zealand, which resulted in an oil spill (Schiel *et al.*, 2016). It was New Zealand's worst ever maritime environmental disaster, with over 2,000 bird carcasses representing 49 species recovered, though this was most likely an underestimation (Hunter *et al.*, 2019). The wider local ecosystem is now considered mostly recovered (Battershill *et al.*, 2016).

5.6.4. Recreational vessels

The Hauraki Gulf is also a hotspot of recreational vessel activity. Frequent vessel activity have 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 in the area, resulting in behavioural changes and habitat exclusion (Meissner *et al.*, 2015; 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).

5.6.5. Oil & Gas activities

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

5.6.6. Deep-sea mining

The operational area is a potential target for deep-sea mining activity due to major sulphide deposits found in the Kermadec Arc (Wysoczanski *et al.*, 2012); however, it is within the Kermadec Arc Mineral Reservation and permits for minerals are not granted in the area (NZPM, 2025). 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).

6. POTENTIAL ENVIRONMENTAL EFFECTS & MITIGATION METHODS

Impacts potentially associated with both planned activities and unplanned events of the BRASS seismic survey have been identified, described, and evaluated across marine mammal species and other ecological receptor groups.

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 1.3**).

6.1. Environmental Impact Assessment methodology

The EIA methodology employed for the impact assessment included the following stages with further details proved within this section:

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.
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.

6.1.2. Mitigation

Mitigation protocols and procedures that are already prescribed by the 2013 Code of Conduct (see **section 1.3**) and included in the survey protocols were identified and described. These mitigation activities were then accounted for during the assessment process resulting in the identification of residual risk for each activity across receptors.

6.1.3. Evaluating residual risks across receptors

The following section outlines the approach taken to assess residual risk of marine mammals, considering risk at the individual level and accounting for species distribution 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 5** for definitions.

Score	Likelihood	Severity
4	Highly likely: The event is almost certain to occur.	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	Likely: The event is expected to occur in most circumstances.	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	Possible: The event could occur, though not expected.	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	Unlikely: The event is not anticipated but could happen under rare circumstances.	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	Impossible: The event will not occur under any scenario.	None: No measurable impacts, either behavioural or physical. Complete absence of ecological or individual-level consequences.

Table 5: Likelihood and severity score. Scores used to quantify risk to marine mammals from seismic and vessel activities. *Source*: OSC (2025).

6.1.3.2. Population exposure score

The population exposure score for each marine mammal receptor factors into the assessment that animal distributions vary considerably, and that species occurrence within the operational area needs to be accounted for when considering residual risk levels.

Data used for the assessment of population exposure included the results of a modelling study of New Zealand cetacean strandings and sightings records (Stephenson *et al.*, 2020) and where necessary IUCN species distribution information. Stephenson *et al.* (2020) uses a combination of opportunistic sightings and data from dedicated surveys to create spatial models of cetacean distributions in New Zealand's EEZ. These data include historical records and contemporary observations from sources such as citizen science, fisheries bycatch records, and systematic surveys. Environmental predictors, such as sea surface temperature, Chl-*a* concentrations, depth, and bathymetric complexity are used to infer habitat preferences for marine mammal species. Modelling approaches used in the study include Boosted Regression Trees (BRT) and Random Effects Smoothing (RES). BRT is a machine-learning technique that combines regression trees and boosting algorithms to capture complex, non-linear relationships between predictors and species occurrence. RES incorporates random effects into the smoothing process, allowing the model to account for variability caused by uneven survey effort or temporal changes in environmental conditions. RES was used in the study when data was sparse (<20 sightings), as expert opinion can be integrated to fill gaps and stabilise predictions in regions with limited observational.

The predictive power of these models makes them an important resource for both the scoping and population exposure score for the assessment and more appropriate than simply using sightings and strandings records. **Table 6** outlines how the model output values for the survey area were converted into an exposure score. Given that RES models were fitted to species with less than 20 sightings, less confidence was assumed in these estimates and extreme high and low scores where avoided.

Exposure Score	Population Exposure	RES value in operational area	BRT value in operational area
10	High		1
9			0.9-1
8		0.9-1	0.8-0.9
7	Medium	0.8-0.9	0.7-0.8
6		0.6-0.8	0.6-0.7
5		0.5-0.6	0.5-0.6
4	Low	0.3-0.5	0.4-0.5
3		0.1-0.3	0.3-0.4
2			0.2-0.3
1			0.1-0.2
0	None	0	0

Table 6: Population exposure score. The score is based on the interpretation of the model outputs of Stephenson et al., 2020 and is based on two modelling Random Effects Smoothing (RES) and Boosted Regression Tree (BRT). approaches *Source*: OSC (2025).

The RES and BRT result maps were used to see species specific values within the seismic survey operational area, the highest value was used where scores were patchy in that area. For the vessel transit route, scores around the coast of Auckland and the Hauraki Gulf were considered.

The modelling study conducted by Stephenson et al. (2019) did not include all marine mammal species known to occur within New Zealand waters and therefore could not be applied universally across all assessed species. The study was restricted to cetacean species, and as such, modelling outputs were not available for any of the nine pinniped species recorded in the region. In addition, 17 cetacean species were also excluded from the analysis.

Of the nine pinniped species, one was scoped into the current assessment due to its potential presence along the proposed transit route. Of the 17 excluded cetacean species, nine were omitted on the basis that their known distributions did not overlap with either the operational area or the transit route. The remaining six cetacean species were rare but potentially present within the area. For these six species, an exposure value of 4 was assigned, reflecting their low likelihood of occurrence within the operational area.

6.1.3.3. Valuation of receptors

Valuation of receptors accounts for conservation status and population trend for each marine mammal species when calculating residual risk across receptors. Both international (IUCN Red List) and New Zealand conservation status and population trend (Baker *et al.*, 2019) were considered, see **Table 7**.

	Conservation Status		**Population Trend**	
Valuation Score	**NZ**	**IUCN**	**NZ**	**IUCN**
10	Threatened – Nationally Critical	Critically endangered	Decreasing	Decreasing
9				
8	Threatened – Nationally Endangered	Endangered		
7				
6	Threatened - Nationally Vulnerable	Vulnerable		
5	Data Deficient	Data Deficient	Unknown	Unknown
4	At Risk - Recovering	Near Threatened		
3	At Risk - Nationally Uncommon			
2	Not Threatened	Least concern	Stable	Stable
1	Migrant*			
0	Vagrant		Recovering	Increasing

Table 7: Valuation of receptors. Both IUCN and national New Zealand conservation status and population trend are used to determine the valuation score which can increase or reduces the residual risk score, increasing the risk score for threatened species. *Valuation score for migrant species should be increased if migration overlap temporally and spatially with the activity. *Source*: OSC (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 increase residual risk score from a high valuation does 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 was calculated by the following.

First the average of the likelihood and severity score is taken:

$$Risk\ Score = \frac{Likelihood\ Score + Severity\ Score}{2}$$

then it is scaled by the population exposure score:

$$Scaled\ Risk\ Score = \frac{Risk\ Score\ \times Population\ Exposure\ Score}{10}$$

This scaling results in an exposure score of 10, then the score remains the same (as both likelihood and severity assume that the species is present in operational area). Next the score is scaled by the valuation score:

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

Dividing by five has the effect of elevating the residual risk score for species with valuation above 5 (all at risk or threatened species) and reducing the score for species below 5 (species of least concern). The resulting residual risk score is then interpreted as shown in **Table 8**.

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	Non: No effect

Table 8: Residual risk matrix. Residual risk score after taking into account likelihood, severity, exposure and valuation for each marine mammal species. *Source*: OSC (2025).

6.2. Results

The results of the impact assessment are presented in this section.

6.2.1. Scoping

The scoping activity identified potential impacts from the seismic survey and potential ecological receptors.

6.2.1.1. Potential impacts

The identified impacts with the survey are presented in **Table 9** and include those associated with increased vessel activity and from the sound generated by the air gun array, additional impacts are also considered from unplanned events (see **Table 10**).

Activity	Potential risk
Increased vessel activity	Collision risk Behavioural Disturbance from vessel presence Displacement from habitat from vessel presence Masking from underwater radiated noise
Seismic noise	Physical injury Auditory damage Behavioural disturbance Auditory masking Prey reduction

Table 9: Potential impacts from increased vessel activity. Scoped risks of the Brother Volcano Seismic Survey *Source*: OSC (2025).

Unplanned event	Potential risk
Oil and chemical spills	Physical injury and habitat degradation
Vessel collision and sinking	Habitat degradation
Equipment loss	Physical interaction and habitat degradation

Table 10: Potential impacts from unplanned events. Scoped risks associated with unplanned events of the Brother Volcano Seismic Survey *Source*: OSC (2025).

6.2.1.2. Operational area

The operational area is the area that is likely to be impacted by the seismic surveys and associated activities and includes the general area around the Brothers Caldera and the Kermadec Arc. This operational area was considered for scoping and determining marine mammal impact likelihood (**Figure 1**).

For vessel (non-seismic) related impacts, the vessel transit route was also considered. This resulted in additional species present along the vessel course, starting from the Port of Aukland and transiting through the Hauraki Gulf, to the survey area being assessed.

6.2.1.3. Marine mammal receptors

Of the 57 marine mammal species recorded in New Zealand (Baker *et al.*, 2019), 30 species were identified as potentially present in the area (**Table 11**). Other species were excluded as they were only found in southern waters of New Zealand and in nearshore habitat away from the potential effects of the seismic survey or vessel transit route. Excluded species of concern are listed in **Table 12**. An additional two species, minke whale and blue whale (the latter being a species of concern), were also assessed resulting in a total of 32 marine mammal species included in the assessment.

Five species, Bryde's whale, killer whale, common dolphin, bottlenose dolphin, and New Zealand fur seal were determined to have increased risk from the vessel transit route compared to the survey area as they occupy habitat in the Hauraki Gulf.

Taxonomic group	Common Name	Binomial Name	Species of Concern	Seismic risk	Vessel risk
Baleen whales	Minke whale	*Balaenoptera acutorostrata*	No	Yes	Yes
	Dwarf minke whale	*B. acutorostrata subsp.*	Yes	Yes	Yes
	Sei whale	*B. borealis*	Yes	Yes	Yes
	Bryde's whale	*B. edeni*	Yes	No	Yes
	Blue whale	*B. musculus*	Yes	Yes	Yes
	Pygmy blue whale	*B. musculus brevicauda*	Yes	Yes	Yes
	Fin whale	*B. physalus*	Yes	Yes	Yes
	Pygmy right whale	*Caperea marginata*	Yes	Yes	Yes
	Humpback whale	*Megaptera novaeangliae*	No	Yes	Yes
Toothed whales	Arnoux's beaked whale	*Berardius arnuxii*	Yes	Yes	Yes
	Common dolphin	*Delphinus delphis*	No	Yes	Increased
	Short-finned pilot whale	*Globicephala macrorhynchus*	Yes	Yes	Yes
	Long-finned pilot whale	*G. melas*	No	Yes	Yes
	Risso's dolphin	*Grampus griseus*	Yes	Yes	Yes
	Southern bottlenose whale	*Hyperoodon planifrons*	Yes	Yes	Yes
	Pygmy sperm whale	*Kogia breviceps*	Yes	Yes	Yes
	Dwarf sperm whale	*K. sima*	Yes	Yes	Yes
	Southern right-whale dolphin	*Lissodelphis peronii*	Yes	Yes	Yes
	Andrew's beaked whale	*Mesoplodon bowdoini*	Yes	Yes	Yes
	Dense-beaked whale	*M. densirostris*	Yes	Yes	Yes
	Ginkgo-toothed whale	*M. ginkgodens*	Yes	Yes	Yes
	Gray's beaked whale	*M. grayi*	No	Yes	Yes
	Hector's beaked whale	*M. hectori*	Yes	Yes	Yes
	Strap-toothed whale	*M. layardii*	Yes	Yes	Yes

	Spade-toothed whale	*M. traversii*	Yes	Yes	Yes
	Killer whale	*Orcinus orca*	Yes	Yes	Increased
	Sperm whale	*Physeter macrocephalus*	Yes	Yes	Yes
	False killer whale	*Pseudorca crassidens*	No	Yes	Yes
	Striped dolphin	*Stenella coeruleoalba*	Yes	Yes	Yes
	Shepherd's beaked whale	*Tasmacetus shepherdi*	Yes	Yes	Yes
	Bottlenose dolphin	*Tursiops truncatus*	Yes	Yes	Increased
	Goose-beaked whale	*Ziphius cavirostris*	Yes	Yes	Yes
Pinniped	New Zealand fur seal	*Arctocephalus forsteri*	No	No	Yes

Table 11: Marine mammal species potentially present in the operational area. These species have been included in the impact assessment for the Brothers Volcano Seismic Survey. *Source*: OSC (2025).

Taxonomic group	Common name	Binomial name
Baleen whales	Antarctic minke whale Southern right whale	*Balaenoptera bonaerensis* *Eubalaena australis*
Toothed whales	Hector's dolphin Maui's dolphin	*Cephalorhynchus hectori* *C. hectori maui*
	Fraser's dolphin	*Lagenodelphis hosei*
	Hourglass dolphin	*Lagenorhynchus cruciger*
	True's beaked whale	*Mesoplodon mirus*
	Pygmy beaked whale	*M. peruvianus*
	Spectacled porpoise	*Phocoena dioptrica*
	Rough-toothed dolphin	*Steno bredanensis*
Pinniped	Southern elephant seal New Zealand sea lion	*Mirounga leonina* *Phocarctos hookeri*

Table 12: Excluded marine mammal species of concern. A list of species that are considered Species of Concern but identified as not present in the Zone of Influence of the Brothers Volcano Seismic Survey. *Source*: OSC (2025).

6.2.1.4. 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.

6.2.1.5. 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 BRASS 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 Marine Mammal Observers (MMOs) and two qualified Passive Acoustic Monitoring Operators (PAMOs) must be on board at all times. 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 ensure that operations do not commence if marine mammals are present in the vicinity, thereby reducing the risk of exposing animals to sudden, high-intensity noise.

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 prevent both physical damage (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 survey location, initial acoustic source activation is further restricted. It is not permitted at night or during poor sighting conditions unless MMOs have conducted effective visual monitoring over a 20-nautical-mile radius for at least two hours, or, alternatively, the PAM system has been operational for two hours. During this time, there must be no sightings or detections of marine mammals in order for operations to begin. This precaution ensures that the environmental context is well understood and that the risk of inadvertently exposing marine mammals to high-intensity sound is kept to a minimum.

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 D - SPECIES OF CONCERN** for full details).

Finally, the integration of both visual monitoring by trained MMOs and acoustic detection via PAM is critical. PAM, in particular, 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). Ship strikes are also a cause for concern for Bryde's whale in the Hauraki Gulf. Constantine *et al.* (2015) found that out of 44 recorded Bryde's whale deaths in the Hauraki Gulf, 85% (17 out of 20 with confirmed causes) were attributed to vessel strike and suggested that this level of mortality rate was likely unsustainable given the species' slow reproductive rate. In the same study, tagging whales demonstrated that the species spent 91% of their time at depths that fall within the maximum draft of vessels transiting the Gulf, making them highly susceptible to strikes.

Constantine *et al.* (2015) also included stakeholder engagement to establish possible mitigation measures, with speed restrictions identified as the most feasible option. A voluntary speed reduction to 10 knots 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 vessel collision occurs it typically result in severe injuries or mortality for pinnipeds.

For the proposed survey, residual risk of vessel collision (**Table 13**) was calculated with a severity score 4 (severe) for all species, as if it occurs, it can cause mortality or trauma. The likelihood was considered unlikely (score 1) for odontocete species and pinnipeds, except for sperm whale where it was considered possible (score 2), as it was with all baleen whales. The likelihood score was considered conservative considering that during surveys the vessel will be motoring at 3.5 knots, further reducing the risk when compared to transiting. The vessel transit route through the Hauraki Gulf increases risk to species found in that area, including the Nationally Critical Bryde's whale (that is evaluated as having a residual risk score of moderate).

Additional mitigation steps to minimise risk to this species have been adopted, based on the study by Constantine *et al.* (2015), with a voluntary speed reduction to 10 knots when in the Huaraki Gulf and the use of MMOs during transit through this area (Port of Auckland, 2024). All other species where either Negligible or Minor.

Species	**Valuation**	**Exposure**	**Likeli hood**	**Severity**	**Risk score**	**Risk score**
Minke whale	3.5	5	2	4	1.05	Negligible
Dwarf minke whale	5	8	2	4	2.4	Minor
Sei whale	4	6	2	4	1.44	Negligible
Bryde's whale	7.5	7	2	4	3.15	Moderate
Blue whale	4	4	2	4	0.96	Negligible
Pygmy blue whale	4	4	2	4	0.96	Negligible
Fin whale	3	6	2	4	1.08	Negligible
Pygmy right whale	5	4	2	4	1.2	Negligible

Humpback whale	1	4	2	4	0.24	Negligible
Arnoux's beaked whale	5	8	1	4	2	Minor
Common dolphin	3.5	7	1	4	1.23	Negligible
short-finned pilot whale	5	6	1	4	1.5	Minor
Long-finned pilot whale	3.5	6	1	4	1.05	Negligible
Risso's dolphin	5	7	1	4	1.75	Minor
Southern bottlenose whale	5	8	1	4	2	Minor
Pygmy sperm whale	5	8	1	4	2	Minor
Dwarf sperm whale	5	4	1	4	1	Negligible
Dusky dolphin	3.5	1	1	4	0.18	Negligible
Southern right-whale dolphin	5	8	1	4	2	Minor
Andrew's beaked whale	5	8	1	4	2	Minor
Dense-beaked whale	5	8	1	4	2	Minor
Ginkgo-toothed whale	5	4	1	4	1	Negligible
Gray's beaked whale	3.5	8	1	4	1.4	Negligible
Hector's beaked whale	5	4	1	4	1	Negligible
Strap-toothed whale	5	4	1	4	1	Negligible
Spade-toothed whale	5	2	1	4	0.5	Negligible
Killer whale	7.5	6	2	4	2.7	Moderate
Sperm whale	5.5	7	2	4	2.31	Minor
False killer whale	4.5	8	1	4	1.8	Minor
Striped dolphin	5	8	1	4	2	Minor
Shepherd's beaked whale	5	8	1	4	2	Minor
Bottlenose dolphin	6.5	5	1	4	1.63	Minor
Goose-beaked whale	5	8	1	4	2	Minor
New Zealand fur seal	3.5	4	0	4	0.56	Negligible

Table 13: Residual risk of vessel collision. Residual risk category is based on the residual risk score than is calculated based on the likelihood, severity, exposure and valuation scores for each species. *Source*: OSC (2025).

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 activity 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, and 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 vessels traffic, altering their swimming behaviour and exhibiting evasive behaviour (Santos-Carvallo *et al.*, 2021) (Szesciorka *et al.*, 2019).

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 impact caused by a single large vessel (**Table 14**) was considered low for all mammal groups as any behavioural effects would be short in duration and unlikely to significantly disrupt important behaviours. This was due to there being only one large vessel, that would be engaging in direct transit and then navigation of transect lines at reduced speed; activities that can be considered low risk to marine mammals. Furthermore, the *Level 1* survey is short (3–5 days) and in oceanic water that is not known to be a critical habitat of any sensitive marine mammal species and near any known haul out areas of pinnipeds. Likelihood was considered possible (score 3), as marine mammal overlapping the vessel route would likely respond to the presence of the vessel, albeit the response would likely be minor and short in duration. No species were identified as having greater than Minor residual risk category.

Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
Minke whale	3.5	5	3	1	0.7	Negligible
Dwarf minke whale	5	8	3	1	1.6	Minor
Sei whale	4	6	3	1	0.96	Negligible
Bryde's whale	7.5	7	3	1	2.1	Minor
Blue whale	4	4	3	1	0.64	Negligible

Pygmy blue whale	4	4	3	1	0.64	Negligible
Fin whale	3	6	3	1	0.72	Negligible
Pygmy right whale	5	4	3	1	0.8	Negligible
Humpback whale	1	4	3	1	0.16	Non
Arnoux's beaked whale	5	8	3	1	1.6	Minor
Common dolphin	3.5	7	3	1	0.98	Negligible
Short-finned pilot whale	5	6	3	1	1.2	Negligible
Long-finned pilot whale	3.5	6	3	1	0.84	Negligible
Risso's dolphin	5	7	3	1	1.4	Negligible
Southern bottlenose whale	5	8	3	1	1.6	Minor
Pygmy sperm whale	5	8	3	1	1.6	Minor
Dwarf Sperm whale	5	4	3	1	0.8	Negligible
Dusky dolphin	3.5	1	3	1	0.14	Non
Southern right-whale dolphin	5	8	3	1	1.6	Minor
Andrew's beaked whale	5	8	3	1	1.6	Minor
Dense-beaked whale	5	8	3	1	1.6	Minor
Ginkgo-toothed whale	5	4	3	1	0.8	Negligible
Gray's beaked whale	3.5	8	3	1	1.12	Negligible
Hector's beaked whale	5	4	3	1	0.8	Negligible
Strap-toothed whale	5	4	3	1	0.8	Negligible
Spade-toothed whale	5	2	3	1	0.4	Negligible
Killer whale	7.5	6	3	1	1.8	Minor
Sperm whale	5.5	7	3	1	1.54	Minor
False killer whale	4.5	8	3	1	1.44	Negligible
Striped dolphin	5	8	3	1	1.6	Minor
Shepherd's beaked whale	5	8	3	1	1.6	Minor
Bottlenose dolphin	6.5	5	3	1	1.3	Negligible
Goose-beaked whale	5	8	3	1	1.6	Minor
New Zealand fur seal	3.5	4	3	1	0.56	Negligible

Table 14: Residual risk of behavioural impact caused by vessel. Residual risk category is based on the residual risk score than is calculated based on the likelihood, severity, exposure and valuation scores for each species. *Source*: OSC (2025).

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 (Pirotta *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 (Pirotta *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 (Pirotta *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 study the risk of displacement (**Table 15**) was considered negligible for all species due to the duration of the survey and as the proposed activity that relies on the vessel moving in a steady direction at slow speeds and for a short period of time. Any displacement caused by the vessel's presence would be short in duration. The timing of the proposed study does not overlap with any known migratory periods (*e.g.* for humpback whales) and therefore displacement from optimal routes and associated increased energetic cost is considered highly improbable. Accordingly, both likelihood and severity were scored low for all species. The resulting residual risk categories across species did not exceed Minor with the majority being Negligible.

Species	**Valuation**	**Exposure**	**Likelihood**	**Severity**	**Risk score**	**Risk Category**
Minke whale	3.5	5	2	1	0.52	Negligible
Dwarf minke whale	5	8	2	1	1.2	Negligible
Sei whale	4	6	2	1	0.72	Negligible
Bryde's whale	7.5	7	2	1	1.58	Minor
Blue whale	4	4	2	1	0.48	Non
Pygmy blue whale	4	4	2	1	0.48	Non
Fin whale	3	6	2	1	0.54	Negligible
Pygmy right whale	5	4	2	1	0.6	Negligible

Humpback whale	1	4	2	1	0.12	Non
Arnoux's beaked whale	5	8	2	1	1.2	Negligible
Common dolphin	3.5	7	2	1	0.74	Negligible
Short-finned pilot whale	5	6	2	1	0.9	Negligible
Long-finned pilot whale	3.5	6	2	1	0.63	Negligible
Risso's dolphin	5	7	2	1	1.05	Negligible
Southern bottlenose whale	5	8	2	1	1.2	Negligible
Pygmy sperm whale	5	8	2	1	1.2	Negligible
Dwarf sperm whale	5	4	2	1	0.6	Negligible
Dusky dolphin	3.5	1	2	1	0.11	Non
Southern right-whale dolphin	5	8	2	1	1.2	Negligible
Andrew's beaked whale	5	8	2	1	1.2	Negligible
Dense-beaked whale	5	8	2	1	1.2	Negligible
Ginkgo-toothed whale	5	4	2	1	0.6	Negligible
Gray's beaked whale	3.5	8	2	1	0.84	Negligible
Hector's beaked whale	5	4	2	1	0.6	Negligible
Strap-toothed whale	5	4	2	1	0.6	Negligible
Spade-toothed whale	5	2	2	1	0.3	Non
Killer whale	7.5	6	2	1	1.35	Negligible
Sperm whale	5.5	7	2	1	1.16	Negligible
False killer whale	4.5	8	2	1	1.08	Negligible
Striped dolphin	5	8	2	1	1.2	Negligible
Shepherd's beaked whale	5	8	2	1	1.2	Negligible
Bottlenose dolphin	6.5	5	2	1	0.98	Negligible
Goose-beaked whale	5	8	2	1	1.2	Negligible
New Zealand fur seal	3.5	4	2	1	0.42	Non

Table 15: Residual risk of displacement from habitat. Residual risk category is based on the residual risk score than is calculated based on the likelihood, severity, exposure and valuation scores for each species. *Source*: OSC (2025).

6.2.2.5. *Masking from underwater radiate noise*

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 study, the severity of risk from Underwater Radiated Noise (URN) generated by the ship was considered minimal (score 1) for all species. Some masking of animal sounds would likely occur but only for a short duration when the vessel was close to the animals. Long term risks from URN on marine mammal species is caused by the cumulative effects of busy shipping routes or heavily used coastal environments. Given the location of the proposed survey the increase in a single ship would be unlikely to have any significant effects. Some effect for species that overlap with the vessel was considered likely so a likelihood score of 3 was deemed appropriate. The resulting residual risks across species did not exceed Minor (**Table 16**).

Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
Minke whale	3.5	5	3	1	0.7	Negligible
Dwarf minke whale	5	8	3	1	1.6	Minor
Sei whale	4	6	3	1	0.96	Negligible
Bryde's whale	7.5	7	3	1	2.1	Minor
Blue whale	4	4	3	1	0.64	Negligible
Pygmy blue whale	4	4	3	1	0.64	Negligible
Fin whale	3	6	3	1	0.72	Negligible
Pygmy right whale	5	4	3	1	0.8	Negligible
Humpback whale	1	4	3	1	0.16	Non
Arnoux's beaked whale	5	8	3	1	1.6	Minor
Common dolphin	3.5	7	3	1	0.98	Negligible
Short-finned pilot whale	5	6	3	1	1.2	Negligible
Long-finned pilot whale	3.5	6	3	1	0.84	Negligible
Risso's dolphin	5	7	3	1	1.4	Negligible
Southern bottlenose whale	5	8	3	1	1.6	Minor
Pygmy sperm whale	5	8	3	1	1.6	Minor
Dwarf sperm whale	5	4	3	1	0.8	Negligible
Dusky dolphin	3.5	1	3	1	0.14	Non
Southern right-whale dolphin	5	8	3	1	1.6	Minor
Andrew's beaked whale	5	8	3	1	1.6	Minor
Dense-beaked whale	5	8	3	1	1.6	Minor
Ginkgo-toothed whale	5	4	3	1	0.8	Negligible
Gray's beaked whale	3.5	8	3	1	1.12	Negligible
Hector's beaked whale	5	4	3	1	0.8	Negligible

Strap-toothed whale	5	4	3	1	0.8	Negligible
Spade-toothed whale	5	2	3	1	0.4	Non
Killer whale	7.5	6	3	1	1.8	Minor
Sperm whale	5.5	7	3	1	1.54	Minor
False killer whale	4.5	8	3	1	1.44	Negligible
Striped dolphin	5	8	3	1	1.6	Minor
Shepherd's beaked whale	5	8	3	1	1.6	Minor
Bottlenose dolphin	6.5	5	3	1	1.3	Negligible
Goose-beaked whale	5	8	3	1	1.6	Minor
New Zealand fur seal	3.5	4	3	1	0.56	Negligible

Table 16: Residual risk of underwater radiated noise from the vessel. Residual risk category is based on the residual risk score than is calculated based on the likelihood, severity, exposure and valuation scores for each species. *Source*: OSC (2025).

6.2.2.6. Seismic noise

Seismic surveys in marine environments present a significant risk to marine mammals, primarily through the generation of intense underwater noise that can disrupt natural behaviors, displace animals from critical habitats, and cause physical harm (Gordon *et al.*, 2003; Heatwole and Cogger, 2013). In some cases, close-range exposure to seismic noise can result in auditory damage and tissue trauma. At greater distances seismic noise can mask important signals and elicit behavioral change.

The *Level 1* activities of the proposed survey required sound transmission loss modelling as requirements under the 2013 Code of Conduct (**APPENDIX B – SOUND TRANSMISSION LOSS MODELLING**). This modeling exercise demonstrates the received Sound Exposure Level (SEL) at varying distances. Under the 2013 Code of Conduct the following SEL thresholds are considered: 171 dB re 1 μPa2s (SEL) at distances corresponding to mitigation distances of 1 km and 1.5 km and 186 dB re 1 μPa^{2}s at 200 m. The report showed that these thresholds were not exceeded at the relevant distance (see **Figure 17**).

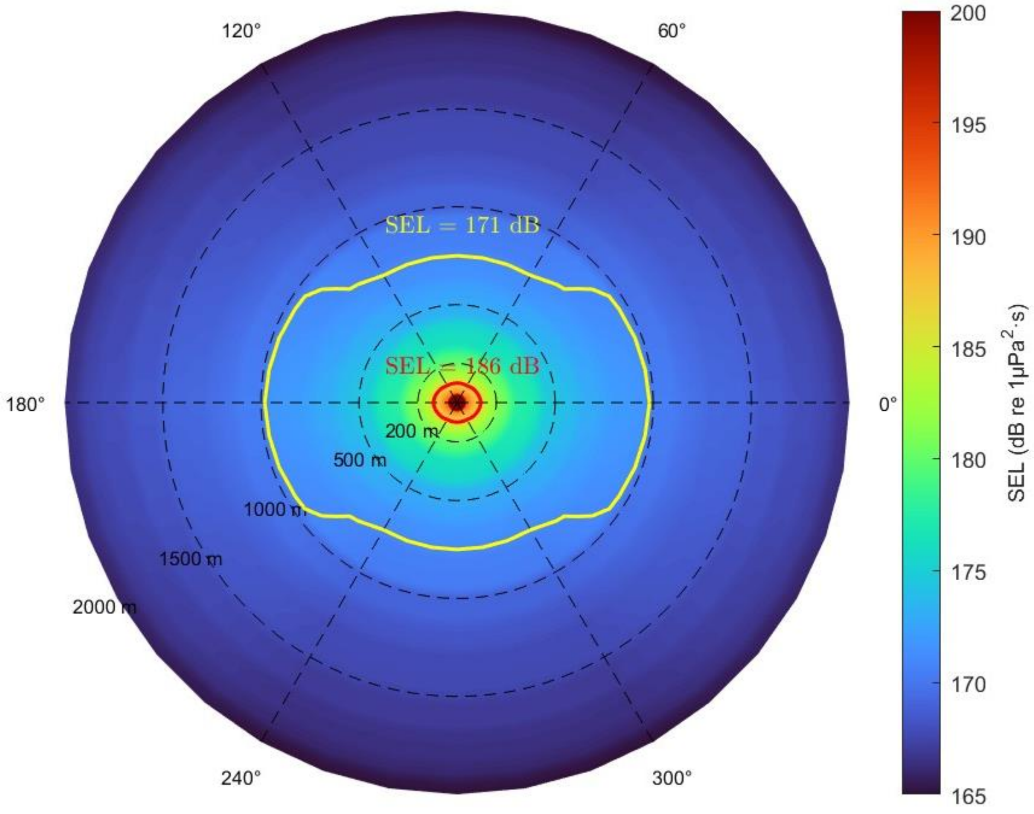

Figure 17: The predicted maximum received SELs across the water column from the proposed 5,420 CUI (in^3) source array as a function of azimuth and range from the centre of the array for source location S. 0 degree azimuth corresponds to the in-line direction. Solid circles represent the mitigation SEL threshold of 186 dB re 1μPa^2·s (red) and 171 dB re 1μPa^2·s (yellow). *Source*: OSC (2025).

6.2.2.7. Physical injury (non-auditory)

Physical injury (other than auditory damage, see below) to marine mammals from seismic survey noise has not been documented (Gordon *et al.*, 2003). Extreme pressure waves from blasting can cause trauma from marine mammals, including damage to the inner ear (Ketten, 1995; Siebert *et al.*, 2022). The onset of pressure waves from air guns have longer rise times than explosives and are therefore less likely to cause such injury. One proposed mechanism for acoustic-induced injury in diving marine mammals involves the growth of gas bubbles in supersaturated tissues, a process known as rectified diffusion, which has been linked to decompression sickness (Ridgway and Howard, 1982). Modelling by (Crum and Mao, 1996) suggested that exposure to 500 Hz sound at a sound pressure level (SPL) of 210 dB re 1μPa could trigger bubble formation significant enough to induce symptoms similar to the 'bends' in marine mammals. However, their analysis indicated that such an effect was unlikely to occur at SPLs below 190 dB re 1μPa. Despite the potential for seismic air gun noise to produce similar physiological effects, this specific risk has not yet been demonstrated.

Given the relatively small area that exceeds the threshold of physical injury (SEL greater than 186 dB re 1 μPa^{2}s occurs at a radius <110 m; see **APPENDIX B – SOUND TRANSMISSION LOSS MODELLING**) and the mitigation that would prevent animals from being in the area or entering the area, a conservative likelihood score of 1 was given to all marine mammal species. Severity was scored 4 due to the potentially lethal impact should an animal be exposed. Given the low likelihood and the mitigation, the residual risk category across species ranged from Non to Minor (**Table 17**).

Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
Minke whale	3.5	5	1	4	0.88	Negligible
Dwarf minke whale	5	8	1	4	2	Minor
Sei whale	4	6	1	4	1.2	Negligible
Bryde's whale	7.5	0	1	4	0	Non
Blue whale	4	4	1	4	0.8	Negligible
Pygmy blue whale	4	4	1	4	0.8	Negligible
Fin whale	3	6	1	4	0.9	Negligible
Pygmy right whale	5	4	1	4	1	Negligible
Humpback whale	1	4	1	4	0.2	Non
Arnoux's beaked whale	5	8	1	4	2	Minor
Common dolphin	3.5	2	1	4	0.35	Non
Short-finned pilot whale	5	6	1	4	1.5	Minor
Long-finned pilot whale	3.5	6	1	4	1.05	Negligible
Risso's dolphin	5	7	1	4	1.75	Minor
Southern bottlenose whale	5	8	1	4	2	Minor
Pygmy sperm whale	5	8	1	4	2	Minor
Dwarf sperm whale	5	4	1	4	1	Negligible
Dusky dolphin	3.5	1	1	4	0.18	Non
Southern right-whale dolphin	5	8	1	4	2	Minor
Andrew's beaked whale	5	8	1	4	2	Minor
Dense-beaked whale	5	8	1	4	2	Minor
Ginkgo-toothed whale	5	4	1	4	1	Negligible
Gray's beaked whale	3.5	8	1	4	1.4	Negligible
Hector's beaked whale	5	4	1	4	1	Negligible

Strap-toothed whale	5	4	1	4	1	Negligible
Spade-toothed whale	5	2	1	4	0.5	Negligible
Killer whale	7.5	4	1	4	1.5	Minor
Sperm whale	5.5	7	1	4	1.93	Minor
False killer whale	4.5	8	1	4	1.8	Minor
Striped dolphin	5	8	1	4	2	Minor
Shepherd's beaked whale	5	8	1	4	2	Minor
Bottlenose dolphin	6.5	5	1	4	1.63	Minor
Goose-beaked whale	5	8	1	4	2	Minor
New Zealand fur seal	3.5	0	1	4	0	Non

Table 17: Residual risk of physical injury from the seismic source. Residual risk category is based on the residual risk score than is calculated based on the likelihood, severity, exposure and valuation scores for each species. *Source*: OSC (2025).

6.2.2.8. Auditory damage

Exposure to intense or prolonged underwater noise can lead to auditory threshold shifts in marine mammals, categorised as either Temporary Threshold Shift (TTS) or Permanent Threshold Shift (PTS). TTS is a temporary reduction in hearing sensitivity caused by noise exposure that exceeds a certain threshold but does not result in permanent damage. Recovery from TTS varies depending on the intensity, duration, and frequency of the noise, with effects lasting from minutes to days (Finneran, 2015). Although reversible, repeated TTS events may lead to cumulative auditory stress, potentially affecting essential behaviours such as communication, navigation, and foraging (Southall *et al.*, 2007). In contrast, PTS represents an irreversible loss of hearing sensitivity due to damage to the cochlear cells caused by prolonged or extreme noise exposure. PTS can significantly impair an individual's ability to detect biologically relevant sounds, thereby affecting survival and reproductive success (Southall *et al.*, 2019). The equivalent energy hypothesis (Kastelein *et al.*, 2024) suggests that the risk of TTS and PTS is determined by the total energy of noise exposure rather than its instantaneous pressure level, implying that extended exposure to lower-level sounds can have similar effects to brief, intense exposures if the overall energy levels are equivalent (Southall *et al.*, 2019). This cumulative effect may impact marine mammals close to seismic surveys.

The 2013 Code of Conduct uses the threshold of 186 dB re 1μPa^2·s SEL for onset of TTS. Sound transmission loss modelling (**APPENDIX B – SOUND TRANSMISSION LOSS MODELLING**) demonstrate that this level is experienced at 110 m from the airgun array (**Table 18**), well within the mitigation zone for reducing risk of auditory injury (200 m).

Source depth (m)	Water depth (m)	Sediment type	Ranges complying with the following SEL thresholds (m)	
			SEL<186dB re 1μPa²·s	SEL<171dB re 1μPa²·s
12	2,000	Clayey silt	110	950

Table 18: Ranges from the centre of the proposed 5,420 CUI (in³) array where the predicted maximum SELs for all azimuths equal the SEL threshold levels for the source locations S. *Source*: OSC (2025).

Considering the mitigation protocols specified by the 2013 Code of Conduct, the likelihood of TTS and PTS was considered low given that animals will be excluded from the area where these sound levels will occur (110 m). Given the likely avoidance behaviour of marine mammals prolonged exposure leading to auditory damage is unlikely to occur. Furthermore, the use of PAM during *Level 1* seismic activity will allow for improved detection of deep diving species that could be missed by MMOs (**Table 19**). The residual risk category did not exceed Minor across all species.

Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
Minke whale	3.5	5	1	4	0.88	Negligible
Dwarf minke whale	5	8	1	4	2	Minor
Sei whale	4	6	1	4	1.2	Negligible
Bryde’s whale	7.5	0	1	4	0	Non
Blue whale	4	4	1	4	0.8	Negligible
Pygmy blue whale	4	4	1	4	0.8	Negligible
Fin whale	3	6	1	4	0.9	Negligible
Pygmy right whale	5	4	1	4	1	Negligible
Humpback whale	1	4	1	4	0.2	Non
Arnoux’s beaked whale	5	8	1	4	2	Minor
Common dolphin	3.5	2	1	4	0.35	Non
Short-finned pilot whale	5	6	1	4	1.5	Minor
Long-finned pilot whale	3.5	6	1	4	1.05	Negligible
Risso’s dolphin	5	7	1	4	1.75	Minor
Southern bottlenose whale	5	8	1	4	2	Minor

Pygmy sperm whale	5	8	1	4	2	Minor
Dwarf sperm whale	5	4	1	4	1	Negligible
Dusky dolphin	3.5	1	1	4	0.18	Non
Southern right-whale dolphin	5	8	1	4	2	Minor
Andrew's beaked whale	5	8	1	4	2	Minor
Dense-beaked whale	5	8	1	4	2	Minor
Ginkgo-toothed whale	5	4	1	4	1	Negligible
Gray's beaked whale	3.5	8	1	4	1.4	Negligible
Hector's beaked whale	5	4	1	4	1	Negligible
Strap-toothed whale	5	4	1	4	1	Negligible
Spade-toothed whale	5	2	1	4	0.5	Negligible
Killer whale	7.5	4	1	4	1.5	Minor
Sperm Whale	5.5	7	1	4	1.93	Minor
False killer whale	4.5	8	1	4	1.8	Minor
Striped dolphin	5	8	1	4	2	Minor
Shepherd's beaked whale	5	8	1	4	2	Minor
Bottlenose dolphin	6.5	5	1	4	1.63	Minor
Goose-beaked whale	5	8	1	4	2	Minor
New Zealand fur seal	3.5	0	1	4	0	Non

Table 19: Residual risk of onset of TTS and PTS from the seismic source. Residual risk category is based on the residual risk score than is calculated based on the likelihood, severity, exposure and valuation scores for each species. *Source*: OSC (2025).

6.2.2.9. *Masking*

Seismic airgun pulses have predominant frequencies below 1 kHz that directly overlap with the vocalisations of baleen whale species. Due to this overlap masking may reduce the effective communication range of baleen whales (Cholewiak *et al.*, 2018). As stated in **section 6.2.2.5**, chronic masking effects may lead to long-term population-level consequences by reducing reproductive success and altering migration patterns.

As seismic survey noise typically occurs at frequencies lower than echolocation click peak frequencies, masking is not as likely for odontocetes as with low frequency specialist baleen whales; however, seismic noise may have an effect at short distances from the array. Seismic noise may also mask sounds that animals use passively such as detecting predators or other threats, that may have population consequences.

For pinnipeds (that also use low frequencies for communication) masking caused by seismic surveys occurs predominantly underwater, where noise from airgun arrays interferes with their ability to detect low-frequency environmental sounds. For example, Southall *et al.* (2007) describe how airgun pulses can mask conspecific vocalisations, potentially disrupting social cohesion during critical periods such as mating or pup rearing. Additionally, masking can impair the ability of pinnipeds to detect predators or prey, particularly in areas of high seismic survey activity. This issue is exacerbated in coastal regions, where overlapping anthropogenic activities and confined habitats increase the likelihood of masking effects, potentially driving pinnipeds away from critical haul-out or foraging areas.

Given the short duration of the *Level 1* activities during the BRASS survey and that the period and location are not known areas of importance or migratory routes for any species, the severity of masking was considered low. Furthermore, long range transmission loss modelling indicate that received noise levels in coastal areas from the relevant long-range source location are predicted to be below 110 dB re $1\mu Pa^2\cdot s$, while for Te Paepae o Aotea (Volkner Rocks) Marine Reserve, the received noise levels are predicted to reach 115 dB re $1\mu Pa^2\cdot s$. These levels suggest that masking at critical near shore habitats will not be significantly impacted by the seismic survey. A likelihood score of 4 was considered appropriate, as the airgun array would produce a greater sound pressure level compared to vessel noise (likelihood score 3), resulting in a greater probability of masking for animals in the operational area (**Table 20**).

Species	**Valuation**	**Exposure**	**Likelihood**	**Severity**	**Risk score**	**Risk category**
Minke whale	3.5	5	4	1	0.88	Negligible
Dwarf minke whale	5	8	4	1	2	Minor
Sei whale	4	6	4	1	1.2	Negligible
Bryde's whale	7.5	0	4	1	0	Non
Blue whale	4	4	4	1	0.8	Negligible
Pygmy blue whale	4	4	4	1	0.8	Negligible
Fin whale	3	6	4	1	0.9	Negligible

Pygmy right whale	5	4	4	1	1	Negligible
Humpback whale	1	4	4	1	0.2	Non
Arnoux's beaked whale	5	8	4	1	2	Minor
Common dolphin	3.5	2	4	1	0.35	Non
Short-finned pilot whale	5	6	4	1	1.5	Minor
Long-finned pilot whale	3.5	6	4	1	1.05	Negligible
Risso's dolphin	5	7	4	1	1.75	Minor
Southern bottlenose whale	5	8	4	1	2	Minor
Pygmy sperm whale	5	8	4	1	2	Minor
Dwarf sperm whale	5	4	4	1	1	Negligible
Dusky dolphin	3.5	1	4	1	0.18	Non
Southern right-whale dolphin	5	8	4	1	2	Minor
Andrew's beaked whale	5	8	4	1	2	Minor
Dense-beaked whale	5	8	4	1	2	Minor
Ginkgo-toothed whale	5	4	4	1	1	Negligible
Gray's beaked whale	3.5	8	4	1	1.4	Negligible
Hector's beaked whale	5	4	4	1	1	Negligible
Strap-toothed whale	5	4	4	1	1	Negligible
Spade-toothed whale	5	2	4	1	0.5	Negligible
Killer whale	7.5	4	4	1	1.5	Minor
Sperm whale	5.5	7	4	1	1.93	Minor
False killer whale	4.5	8	4	1	1.8	Minor
Striped dolphin	5	8	4	1	2	Minor
Shepherd's beaked whale	5	8	4	1	2	Minor

Bottlenose dolphin	6.5	5	4	1	1.63	Minor
Goose-beaked whale	5	8	4	1	2	Minor
New Zealand fur seal	3.5	0	4	1	0	Non

Table 20: Residual risk of auditory masking from the seismic source. Residual risk category is based on the residual risk score than is calculated based on the likelihood, severity, exposure and valuation scores for each species. *Source*: OSC (2025).

6.2.2.10. Behavioural disturbance

Exposure to seismic noise may cause behavioural responses in marine mammals. Depending on the magnitude, these may have significant impacts on individual fitness, by affecting energy budgets or reducing reproductive fitness. Behavioural disturbance experienced during biologically critical periods, such as migration or breeding, poses population level risks.

For baleen whales, studies have shown various behavioural responses to seismic noise, including changes in calling behaviour, swim speed, and direction. Responses are variable, for example baleen whales have been shown to both increase and decrease calling behaviour when exposed to seismic noise (Di Iorio and Clark, 2010; Blackwell *et al.*, 2015). This has also been shown in a single species, with both increase and decrease in singing behaviours of humpback whales been documented, although the potential impact on reproductive success in not known (Cerchio *et al.*, 2014; Dunlop *et al.*, 2018). Observations of humpback whales have also shown changes in behaviour when exposed to seismic noise (Dunlop *et al.*, 2017). Although no abnormal behaviours were observed, there were changes in their movement patterns, dive and respiratory rates, and in breaching behaviours. The magnitude of changes, and the lack of abnormal behaviour suggested that responses were not biologically significant.

Behavioural responses in odontocetes can be more severe. Beaked whales, particularly goose-beaked whales, are frequently associated with mass strandings linked to acoustic disturbances, including seismic surveys and naval sonar (Fernández *et al.*, 2005). These strandings are attributed to a stress response that can lead to decompression sickness, by rapid surfacing following noise exposure (Jepson *et al.*, 2003). Sperm whales exposed to seismic airguns in the Gulf of Mexico have demonstrated reduced foraging effort and altered dive patterns, indicative of behavioural stress (Miller *et al.*, 2009).

Pinniped species are generally considered to have a reduced behavioural response to seismic airgun noise (Affatati and Camerlenghi, 2023). In Alaska, seal species showed some avoidance for the vessel but this was mostly limited to within <250 m from the vessel during seismic activity (Harris *et al.*, 2001). In New Zealand, the New Zealand fur seal was observed during seismic activity, however; results were inconclusive due to confounding effects of sea state on the observation process and the potential for the physical presence of the equipment eliciting a response (Lalas and McConnell, 2016).

The mitigation zones for seismic surveys in New Zealand waters are designed to minimise disturbance to marine mammals, with specific measures for different species and life stages. For Species of Concern, which include all New Zealand cetacean species except common and dusky dolphins, as well as the New Zealand sea lion (see **APPENDIX D - SPECIES OF CONCERN**), a 1.5 km mitigation zone is enforced if a mother and calf pair is detected, requiring a delay in survey start-up or shutdown until the animals move beyond this range or remain undetected for 30 minutes. For individuals of these species without calves, the mitigation zone is reduced to 1 km, with the same monitoring and clearance protocols applied. These distances are subject to a SEL threshold of 171 dB re 1 μPa2s (SEL). Sound transmission loss modelling (**APPENDIX B – SOUND TRANSMISSION LOSS MODELLING**) identified that this SEL level occurred at a distance of 950 m (**Table 19**), providing confidence in the effectiveness of the mitigation zones for this survey.

Long range transmission loss modelling indicate that received noise levels in coastal areas from the relevant long-range source location are predicted to be below 110 dB re $1\mu Pa^2\cdot s$, while for Te Paepae o Aotea (Volkner Rocks) Marine Reserve, the received noise levels are predicted to reach 115 dB re $1\mu Pa^2\cdot s$. At the nearest 12 nautical mile offshore boundary to each of the long-range source locations, noise levels are predicted to be within the range of 110–120 dB re $1\mu Pa^2\cdot s$. These levels suggest that critical near shore habitats will not be significantly impacted by the seismic survey operating at the Brothers Caldera area.

For the proposed study, considering the mitigation protocols specified by the 2013 Code of Conduct, the likelihood of significant behavioural response, significant was considered low given that animals will be excluded from the area where disruptive noise levels would be experienced. Use of a ramp-up procedure is important in the reduction in risk to beaked whales, as it should limit the startle response that can lead to decompression sickness. The use of PAM is also important to allow for improved detection of beaked whale species that could be missed by MMOs. This combination of increased detection and ramp-up start allowed beaked whale species behavioural response severity to be considered low. The maximum risk category across all species was Low (**Table 21**).

Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk Category
Minke whale	3.5	5	3	2	0.875	Negligible
Dwarf minke whale	5	8	3	2	2	Minor
Sei whale	4	6	3	2	1.2	Negligible
Bryde's whale	7.5	0	3	2	0	Non
Blue whale	4	4	3	2	0.8	Negligible
Pygmy blue whale	4	4	3	2	0.8	Negligible
Fin whale	3	6	3	2	0.9	Negligible
Pygmy right whale	5	4	3	2	1	Negligible
Humpback whale	1	4	3	2	0.2	Non
Arnoux's beaked whale	5	8	3	2	2	Minor
Common dolphin	3.5	2	3	2	0.35	Non

Short-finned pilot whale	5	6	3	2	1.5	Minor
Long-finned pilot whale	3.5	6	3	2	1.05	Negligible
Risso's dolphin	5	7	3	2	1.75	Minor
Southern bottlenose whale	5	8	3	2	2	Minor
Pygmy sperm whale	5	8	3	2	2	Minor
Dwarf sperm whale	5	4	3	2	1	Negligible
Dusky dolphin	3.5	1	3	2	0.175	Non
Southern right-whale dolphin	5	8	3	2	2	Minor
Andrew's beaked whale	5	8	3	2	2	Minor
Dense-beaked whale	5	8	3	2	2	Minor
Ginkgo-toothed whale	5	4	3	2	1	Negligible
Gray's beaked whale	3.5	8	3	2	1.4	Negligible
Hector's beaked whale	5	4	3	2	1	Negligible
Strap-toothed whale	5	4	3	2	1	Negligible
Spade-toothed whale	5	2	3	2	0.5	Negligible
Killer whale	7.5	4	3	2	1.5	Minor
Sperm whale	5.5	7	3	2	1.925	Minor
False killer whale	4.5	8	3	2	1.8	Minor
Striped dolphin	5	8	3	2	2	Minor
Shepherd's beaked whale	5	8	3	2	2	Minor
Bottlenose dolphin	6.5	5	3	2	1.625	Minor
Goose-beaked whale	5	8	3	2	2	Minor
New Zealand fur seal	3.5	0	3	2	0	Non

Table 21: Residual risk of behavioural disturbance from the seismic source. Residual risk category is based on the residual risk score than is calculated based on the likelihood, severity, exposure and valuation scores for each species. *Source*: OSC (2025).

6.2.2.11. Indirect effects on prey species

Baleen whales rely on large aggregations of zooplankton and small schooling fish as their primary food sources (Goldbogen *et al.*, 2019). The impact of seismic surveys on prey species can potentially affect the foraging efficiency and nutritional intake of baleen whales (Carroll *et al.*, 2017).

Seismic airgun noise has been documented to cause displacement of fish and zooplankton, leading to prey reduction in critical feeding areas (Fewtrell and McCauley, 2012; McCauley *et al.*, 2017). McCauley *et al.* (2017) found that airgun exposure led to a substantial decline in zooplankton abundance, with mortality rates increasing by 50% within one hour of exposure. Since baleen whales engage in lunge feeding and are dependent on dense prey patches, even temporary displacement of prey can lead to increased energy expenditure and reduced foraging success (Goldbogen *et al.*, 2013).

Cephalopods, an essential prey group for deep-diving toothed whales, have shown significant sensitivity to intense sound exposure. (André *et al.*, 2011) demonstrated that seismic airgun pulses caused statocyst damage in cephalopods, impairing their ability to maintain buoyancy and evade predators. Additionally, exposure to seismic noise has been linked to increased stress levels and erratic swimming behaviour in squid species (Fewtrell and McCauley, 2012), potentially leading to decreased prey availability for sperm whales and other deep-diving odontocetes.

Furthermore, fish species that serve as prey for dolphins and smaller toothed whales may exhibit reduced schooling behaviour and heightened startle responses due to seismic exposure (Løkkeborg *et al.*, 2010). The disruption of these prey aggregations can negatively impact the foraging efficiency of predators such as the common dolphin and dusky dolphin, both of which rely on coordinated group hunting strategies (Würsig *et al.*, 2007).

Fish species that serve as primary prey for pinnipeds have demonstrated significant avoidance behaviour in response to seismic noise. For example, Engås *et al.* (1996) observed that cod and haddock populations exhibited large-scale displacement from seismic survey areas, leading to reduced catch rates for weeks post-exposure.

For the assessment, given the short duration of the *Level 1* survey and the relatively discrete zone of influence in comparison to the distribution ranges of offshore marine mammal, both likelihood and severity scores were considered negligible for all species. Final residual risk did not exceed negligible for all species (**Table 22**).

Species	Valuation	Exposure	Likelihood	Severity	Risk score	Risk category
Minke whale	3.5	5	1	1	0.35	Non
Dwarf minke whale	5	8	1	1	0.8	Negligible
Sei whale	4	6	1	1	0.48	Non
Bryde's whale	7.5	0	1	1	0	Non
Blue whale	4	4	1	1	0.32	Non
Pygmy blue whale	4	4	1	1	0.32	Non
Fin whale	3	6	1	1	0.36	Non
Pygmy right whale	5	4	1	1	0.4	Non
Humpback whale	1	4	1	1	0.08	Non
Arnoux's beaked whale	5	8	1	1	0.8	Negligible

Common dolphin	3.5	2	1	1	0.14	Non
Short-finned pilot whale	5	6	1	1	0.6	Negligible
Long-finned pilot whale	3.5	6	1	1	0.42	Non
Risso's dolphin	5	7	1	1	0.7	Negligible
Southern bottlenose whale	5	8	1	1	0.8	Negligible
Pygmy sperm whale	5	8	1	1	0.8	Negligible
Dwarf sperm whale	5	4	1	1	0.4	Non
Dusky dolphin	3.5	1	1	1	0.07	Non
Southern right-whale dolphin	5	8	1	1	0.8	Negligible
Andrew's beaked whale	5	8	1	1	0.8	Negligible
Dense-beaked whale	5	8	1	1	0.8	Negligible
Ginkgo-toothed whale	5	4	1	1	0.4	Non
Gray's beaked whale	3.5	8	1	1	0.56	Negligible
Hector's beaked whale	5	4	1	1	0.4	Non
Strap-toothed whale	5	4	1	1	0.4	Non
Spade-toothed whale	5	2	1	1	0.2	Non
Killer whale	7.5	4	1	1	0.6	Negligible
Sperm whale	5.5	7	1	1	0.77	Negligible
False killer whale	4.5	8	1	1	0.72	Negligible
Striped dolphin	5	8	1	1	0.8	Negligible
Shepherd's beaked whale	5	8	1	1	0.8	Negligible
Bottlenose dolphin	6.5	5	1	1	0.65	Negligible
Goose-beaked whale	5	8	1	1	0.8	Negligible
New Zealand fur seal	3.5	0	1	1	0	Non

Table 22: Residual risk for the indirect effect on prey species. Residual risk category is based on the residual risk score than is calculated based on the likelihood, severity, exposure and valuation scores for each species. *Source*: OSC (2025).

6.2.2.12. In-combination and cumulative effects

In-combination and cumulative effects were considered for marine mammal species. In-combination considers the combined impacts of the survey and how there may have a synergistic impact on marine mammals in the operational area. Cumulative effects consider additional causes of disturbance that may alter the impact severity or likelihood of the identified risks with the survey.

Given the relatively low impacts identified for marine mammals across risks associated with the survey in-combination effects were also considered low.

Cumulative effects were considered negligible due to the location and duration of the survey. There will be no other seismic surveys conducted in the local area and given its location far from the coast there are unlikely to be any additional sources of disturbance.

6.2.2.13. Unplanned events

Risks associated with unplanned events such as oil spills and loss of equipment are included in this section. Due to the low probability of these events, risks were considered for all marine mammals.

Vessel collision or sinking, and release of hazardous substances

A vessel collision involving a large ship can have significant consequences for marine mammals, primarily through underwater pollutant release, and habitat degradation. Fuel spills from breached tanks and potential cargo leakage can introduce toxic substances into the marine environment, leading to direct toxic effects and impact of critical habitats. Debris from the wreckage, including floating and submerged materials, can pose entanglement and injury risks, particularly for species inhabiting coastal or near-surface waters.

As is expected of all international research vessels, RV Sonne will adhere to strict operational safety procedures during transit and operational periods which make collision with other ships extremely unlikely. Given that this event is highly unlikely during the relatively short period of the survey the residual risk for all marine mammals was considered negligible.

Equipment loss

The loss of streamers and airgun arrays during a seismic survey poses both physical hazards and environmental contamination risks to marine mammals. Streamers, which are long cables used to capture acoustic signals, can drift or sink, creating entanglement risks for whales, potentially leading to restricted movement, injury, or death. Additionally, the introduction of debris from lost equipment can contribute to habitat degradation, particularly if materials such as hydraulic fluids or insulating components are released into the water.

The seismic acquisition system used during the BRASS survey will be equipped with a flashing light on the tail buoy, which enables the array to be identified at all times during surveying. In the unlikely event that the array is broken apart during acquisition, the flashing tail buoy means that it can be identified and recovered from the ocean. Such an event would be identified very quickly, due to 24-hour watch keeping and monitoring of the system by watch-keepers and by the ship's crew. With these protocols in place the residual risk for all marine mammals form loss of equipment was considered negligible.

6.2.3. Impact assessment – other receptors

In this section impacts across additional receptors are presented.

6.2.3.1. Seabirds

While few studies on seabird underwater hearing exist, with most studies focusing on hearing in air (Mooney *et al.*, 2020; Smith and Barclay, 2024), emerging evidence suggests that seabirds may experience significant behavioural and physiological disturbances from seismic surveys and have been shown to avoid them (Seco Pon *et al.*, 2019). Pichegru *et al.* (2017) demonstrated that African penguins (*Spheniscus demersus*) altered their foraging behaviour to avoid areas within 100 km of active seismic operations, raising concerns over the energetic costs associated with displacement from critical feeding grounds. Similarly studies on the auditory capabilities of seabirds indicate that species like cormorants possess the ability to detect auditory cues underwater (Crowell, 2016; Hansen *et al.*, 2017; Larsen *et al.*, 2020). This suggests that seismic noise could interfere with their sensory perception, potentially disrupting key activities such as foraging, predator detection, and communication. While the precise impacts of seismic noise on seabird hearing remain underexplored, evidence of behavioural avoidance and possible auditory masking suggests some level of impact.

The primary risk to seabirds from the seismic survey is an indirect reduction in prey availability, as fish and squid may temporarily disperse or alter their vertical distribution in response to acoustic disturbance. However, given the short duration of the survey, any shifts in prey behaviour are likely to be transient. Diving seabirds, such as shearwaters, may be exposed to elevated underwater noise levels while foraging, but the likelihood of direct auditory damage is low due to their limited time spent submerged. Vessel activity associated with the survey could also influence seabird behaviour, either attracting birds due to potential feeding opportunities or causing avoidance responses depending on the species. Residual risk category was considered negligible.

6.2.3.2. Marine reptiles

High-intensity underwater noise may pose risks to marine reptiles. Research has shown that these animals can detect low-frequency sounds, which makes them susceptible to disturbances from seismic airgun pulses (Piniak *et al.*, 2012; Chapuis *et al.*, 2019).

Information on the risk of seismic surveys is sea snakes is limited but turtles have been shown to alter their movements and diving behaviour when exposed to seismic noise which may be an avoidance strategy (Weir, 2007; DeRuiter and Doukara, 2012). Turtles have been noted getting tangled in seismic survey cables (Nelms *et al.*, 2016). They are also difficult to detect visually, suggesting mitigation methods used for mammals may not be appropriate (Nelms *et al.*, 2016).

Sea turtles, particularly pelagic juveniles and migrating adults, may transit through the Brothers Volcano region, although the area is not considered a primary aggregation site. The short duration of the seismic survey reduces the likelihood of prolonged displacement, but individual turtles in the vicinity may exhibit avoidance behaviours or altered diving patterns in response to high-intensity sound exposure. Leatherback turtles (*Dermochelys coriacea*), which forage on gelatinous zooplankton, could experience indirect effects if seismic pulses impact the distribution of their prey. Given that turtles rely on acoustic cues for navigation, there is a possibility of short-term disorientation, particularly if noise levels interfere with their ability to detect environmental sounds. However, since the exposure window is brief, the risk of long-term displacement or physiological impacts remains low. Residual risk category was considered negligible.

6.2.3.3. Fish

Anthropogenic noise, particularly from seismic surveys, has been recognised as a significant stressor affecting fish behaviour, physiology, and ecosystem dynamics (Popper and Hawkins, 2019). Fish species exhibit varying auditory sensitivities, which influence their susceptibility to noise-induced impacts (Popper *et al.*, 2014b). Seismic airgun pulses can interfere with essential biological functions such as communication, foraging, predator avoidance, and reproduction. The transient and repeated nature of these pulses may cause temporary or permanent threshold shifts in hearing sensitivity, disrupting an individual's ability to detect biologically relevant sounds (Carroll *et al.*, 2017). Empirical evidence suggests that seismic surveys can alter fish habitat use, with studies demonstrating that fish abundance on temperate reefs decreases significantly following exposure to airgun pulses (Paxton *et al.*, 2017). (Sivle *et al.*, 2021)

Physiological effects of seismic surveys mainly affect younger life stages of fish such as eggs, larvae, and fry, which are stages in development where the organisms have limited ability to escape (Popper *et al.*, 2005; DNV Energy, 2007). Boeger *et al.* (2006) carried out experiments on coral reef fish in field enclosures before, during, and after exposure to airguns. Experiments did not result in mortality or obvious external damage. The majority of airgun shots resulted in a startle response in the form of a temporary increase in swimming velocity and/or a lateral shift in swimming direction, returning to normal swimming velocities shortly thereafter. Repeated exposure to air guns seemed to result in increasingly less obvious startle responses, indicating possible habituation to the disturbance.

In extreme cases, direct physical injuries such as barotrauma, swim bladder rupture, and internal haemorrhaging have been documented, particularly in species that possess gas-filled cavities (Popper *et al.*, 2014a). The broader ecological consequences of these disruptions remain a critical area of investigation, as they may lead to alterations in species distributions and population dynamics, with potential cascading effects on trophic interactions (Popper and Hawkins, 2019).

The Brothers Volcano is a hydrothermally active seamount within the Kermadec Ridge, supporting a range of deep-sea and mesopelagic fish species, including those adapted to the chemically and thermally dynamic environment. A three-day seismic survey using a *Level 1* airgun array is unlikely to cause widespread fish mortality but may result in short-term displacement, particularly for species sensitive to sound pressure waves. Mesopelagic fish, which undertake diel vertical migrations and form an essential prey base for larger predators, may alter their movement patterns, potentially affecting trophic interactions. Given the limited duration of the survey, any displacement is likely to be temporary, but repeated disturbances could have cumulative effects on fish populations over time. Residual risk category was considered negligible.

6.2.3.4. Sharks and rays

Research on the effects of seismic airgun noise on elasmobranchs is limited. Stingrays have been shown to respond to noise (Mickle *et al.*, 2020), while benthic sharks and great white sharks (*Carcharodon carcharias)* show no significant response to sound stimuli (Ryan *et al.*, 2018). In general, elasmobranchs do not have swim bladders, so are not thought to be significantly disturbed by anthropogenic noise.

Carroll *et al.* (2017) provide a broader perspective on marine organisms, reviewing the impacts of seismic surveys on fish and invertebrates. The study examines physiological stress responses, potential auditory damage, and avoidance behaviours, reinforcing concerns that seismic noise may disrupt key biological processes. While their focus is not explicitly on elasmobranchs, some of these findings may have implications for sharks and rays, given their sensitivity to underwater sound and potential behavioural responses to anthropogenic noise

The broader ecological context of anthropogenic stressors further complicates the assessment of seismic impacts. Pacoureau *et al.* (2023) examine the global decline of sharks and rays, attributing increasing extinction risks to cumulative human-induced pressures, including habitat degradation and noise pollution. While their study does not focus noise, it underscores the vulnerability of elasmobranch populations to multiple, overlapping threats. Given their slow growth and low reproductive rates, many species may be particularly sensitive to chronic disturbances.

Deep-sea elasmobranchs in the Brothers Volcano region, including deepwater dogfish and skates, may exhibit behavioural responses to the seismic survey, such as temporary avoidance of the survey area. While these species are less prone to barotrauma due to their lack of a swim bladder, their reliance on electrosensory and mechanosensory systems for prey detection and navigation raises concerns about potential disruptions. The intermittent nature of seismic pulses over three days may cause short-term stress responses, but given the low mobility of some deep-sea elasmobranchs, displacement could be limited. However, if the survey overlaps with key foraging or resting areas, individual fitness could be affected, particularly for slow-growing species with low reproductive rates. The broader ecosystem effects would likely be minimal unless seismic activity disrupts prey availability or triggers avoidance behaviours that persist beyond the survey period. Residual risk category was considered minor.

6.2.3.5. Invertebrates

Hight intensity sound can impact a range of marine invertebrates through physical, physiological, and behavioural mechanisms. Tank-based experiments testing sound exposure on several mollusc, squid, and octopus species have shown significant behavioural responses to seismic survey noise (Day *et al.*, 2017); however, it is unclear how results from these lab experiments relate to wild environments. Day *et al.* (2017) conclude that seismic survey exposure has potential to be harmful but cannot provide criteria for noise management due to data gaps. Thresholds for harmful sound exposure levels have not been developed for bivalves, cephalopods, or zooplankton (Buscaino *et al.*, 2019; Jones *et al.*, 2019). Invertebrates and fish in coral reefs have been shown to produce and be able to detect low frequency sounds (Tricas and Boyle, 2014; Jones *et al.*, 2022). Coral larvae have been shown to use these sounds to identify reefs and to be disturbed by vessel noise, resulting in reduced recruitment (Lecchini *et al.*, 2018).

Research indicates that while direct mortality is less common in adult corals, seismic exposure may disrupt key biological functions such as feeding, reproduction, and symbiotic relationships. One study has shown that mesophotic corals exposed to seismic surveys exhibit no immediate physical damage to their tissues or skeletal structures, suggesting resilience in certain species (Heyward *et al.*, 2018). The impact of seismic noise on sensory structures such as statocysts in molluscs and echinoderms suggests a risk to marine invertebrates (Carroll *et al.*, 2017), while alterations in the surrounding soundscape due to seismic surveys could further disrupt invertebrate behaviour through particle motion (Jones *et al.*, 2022).

Marine invertebrates exhibit diverse responses to anthropogenic noise, yet significant knowledge gaps remain regarding the long-term ecological consequences of seismic survey exposure. A recent review by (Solé *et al.*, 2023) synthesises current understanding of invertebrate bioacoustics and highlights the growing body of evidence suggesting that seismic noise can induce physiological stress, behavioural changes, and even mortality in some taxa. The review emphasises that while studies have reported disruptions in feeding, locomotion, and reproductive behaviours in response to seismic exposure, the lack of standardised methodologies complicates the establishment of universal impact thresholds. Furthermore, observed reductions in invertebrate catch rates following seismic surveys suggest broader ecological implications, highlighting the need for further research to inform effective noise management strategies.

The Brothers Volcano hosts a unique assemblage of hydrothermal vent invertebrates, including deep-sea crabs, vent mussels, and tube worms reliant on chemosynthetic productivity. The impact of seismic activity on vent-specific invertebrates is poorly understood, but studies on other benthic invertebrates suggest potential risks such as stress-induced changes in behaviour, reduced feeding efficiency, and reproductive impacts. While a three-day seismic survey is unlikely to cause direct mortality in most invertebrate species, sensitive taxa, particularly larvae and early life stages, could experience adverse effects. Additionally, if seismic pulses disturb the fine sediment layers surrounding vent ecosystems, there is a potential for localised smothering effects on sessile invertebrates. Given the resilience of vent communities to natural disturbances such as volcanic activity and hydrothermal fluctuations, the long-term consequences of a brief seismic survey are likely to be limited and as such residual risk category was considered minor.

6.2.3.6. Zooplankton

Exposure to airgun pulses has been associated with increased mortality rates, with effects observed across various developmental stages, including eggs and nauplii. This elevated mortality extends over considerable distances, reaching up to 1.2 km from the sound source, demonstrating the extensive spatial impact of seismic activity (McCauley *et al.*, 2017). Physical damage, including tissue destruction and exoskeletal compromise, is a key concern, particularly in species with gas-filled structures vulnerable to rapid pressure changes. Additionally, seismic noise disrupts normal zooplankton behaviour, particularly diel vertical migration, which is critical for nutrient cycling and predator-prey interactions in marine ecosystems. Displacement resulting from these disturbances can alter species distributions, reducing prey availability for fish and higher trophic levels, which depend on zooplankton as a primary food source (McCauley *et al.*, 2017).

Zooplankton in the Brothers Volcano region form the base of the pelagic food web and support higher trophic levels. As discussed above seismic pulses can cause significant mortality in planktonic organisms within the immediate vicinity of an airgun array. A large airgun array as used in this study could result in localised declines in zooplankton abundance within a few kilometres of the survey area, potentially affecting short-term prey availability for filter feeders and small pelagic fish. However, the high dispersal and reproductive rates of many zooplankton species suggest that any population declines would be quickly replenished after the survey ends. While transient disruptions in zooplankton density may occur, the broader ecological consequences are likely to be minimal unless the survey coincides with peak spawning or larval settlement periods. Residual risk category was considered minor.

6.3. Summary

The impact assessment evaluated the effects of increased vessel activity and seismic operations on marine mammals and other marine organisms, identifying key risks such as collision risk, behavioural disturbance, habitat displacement, underwater radiated noise, and cumulative effects. Each risk was examined in relation to species group vulnerabilities and the residual risk after implementing prescribed mitigation measures outlined in the 2013 Code of Conduct.

Increased vessel activity presents a notable threat to marine mammals, particularly baleen whales such as Bryde's whales, which occupy surface waters in areas that intersect with the vessel route. The collision risk for this species was classified as moderate, whereas other marine mammals were assessed at lower risk levels. The mitigation strategy, in alignment with national voluntary guidelines, includes vessel speed restrictions and the deployment of MMOs to detect and respond to potential encounters with Bryde's Whales in the Hauraki Gulf. Behavioural disturbances linked to vessel presence were also identified, although the impact was considered low due to the limited survey duration and the vessel's slow operational speed. The risk of habitat displacement was similarly deemed negligible, given that vessel movements were restricted in both extent and duration. Underwater radiated noise was recognised as a potential cause of temporary auditory masking, but the impact was assessed as minimal due to the short exposure period and the moderate noise output of the survey vessel.

The seismic survey introduced additional risks, including physical injury, auditory damage, behavioural disturbance, and potential prey reduction. The potential for physical injury due to seismic noise was minimised through adherence to the Code's mitigation protocols, including the use of exclusion zones and a soft-start procedure requiring a gradual increase in acoustic source intensity over a minimum 20-minute period. Auditory damage, encompassing TTS and PTS, was assessed as a low risk due to the enforcement of mitigation zones that exclude marine mammals from high-intensity noise areas. The mitigation zone sizes were identified as sufficient from short-range transmission loss modelling using the specific airgun signature of the array. PAM will be employed to supplement visual detection, enhancing the effectiveness of marine mammal exclusion, with this being particularly important for deep diving species such as beaked whales and sperm whale. Masking effects, particularly for baleen whales that rely on low-frequency vocalisations, were identified as a concern, though long-term consequences were not anticipated. Behavioural disturbances were observed in some species, such as beaked whales and sperm whales, which exhibited modifications in dive patterns and foraging behaviour. These responses can be severe but the implementation of the ramp up and the presurvey observations (including PAM) decrease the risk of serious impacts. The potential for prey reduction was also identified, as seismic noise has been shown to reduce zooplankton and fish densities within the immediate vicinity of airgun operations. While temporary, such disruptions may affect foraging success in cetaceans; however, the survey's limited duration mitigated the likelihood of long-term ecological consequences.

Cumulative and in-combination effects were assessed, with overall impacts deemed negligible due to the remote location of the survey and the absence of concurrent seismic activities in the region. In-combination effects, arising from the interaction between vessel activity and seismic noise, did not present a substantial increase in risk beyond that identified for each factor independently.

The assessment was also extended to other marine receptors. Fish species exhibited short-term behavioural changes, including avoidance and displacement, though the overall risk was classified as negligible. Sharks and rays were considered unlikely to experience significant disruption, given the limited data suggesting sensitivity to seismic noise. Marine reptiles, particularly sea turtles, were recognised as potentially altering movement or diving behaviour in response to seismic noise, yet the survey location was not identified as a critical habitat for these species, thereby reducing the associated risk. Seabirds faced indirect effects through potential prey displacement, but the transitory nature of the disturbance limited any lasting consequences. Invertebrates, particularly those with statocysts sensitive to acoustic pressure waves, were identified as being at some risk, with potential physiological impacts affecting sensory structures and biological functions, although residual risk remained minor. Zooplankton, fundamental to the marine food web, are particularly vulnerable to seismic noise, with mortality documented within proximity to airguns. While such reductions could momentarily affect prey availability for higher trophic levels, rapid population recovery was expected.

Overall, the assessment confirmed that, while some level of impact on marine mammals and other receptors was expected, adherence to the mitigation measures prescribed in the Code of Conduct, including speed restrictions, exclusion zones, and soft-start procedures, will effectively minimise risks. The requirement for MMOs and PAM operators ensured compliance with observational and mitigation protocols, further reducing the likelihood of significant disturbance. The offshore location and short duration of the survey were additional factors contributing to a reduction in long-term ecological effects. Residual risks remained minor to negligible across all species, with no significant population-level impacts anticipated.

7. RESEARCH OPPORTUNITY

The BRASS survey provides the opportunity to collect data on marine megafauna species in an area that is relatively understudied. Although MMO and PAM are only required for the *Level 1* part of the survey, dedicated observers will be monitoring for marine mammals and other species during the entire survey providing valuable data for the area and contribute to filling a knowledge gap.

Following the survey a report will be produced focusing on marine mammal and other fauna observed in the area. This will include MMO observation to species level where possible. Photographs will also be taken to potentially allow for species identification post survey. Environmental data and geographical information will also be recorded for each period of effort and for every sighting. Additionally, PAM data could also be recorded to provide information on deep diving odontocetes that may be present in the area.

In summary, the survey is a rare opportunity to collect valuable data on marine species at an offshore habitat. Observations will be made available to interested parties after being cleared by the appropriate authorities.

7.1. Future research opportunities

In addition to the potential for data collection from the BRASS survey, future research opportunities were identified that have the potential to facilitate marine mammal mitigation onboard seismic surveys.

OSC recently conducted a study on behalf of the Exploration & Production (E&P) Sound & Marine Life Joint Industry Programme (JIP) (https://www.soundandmarinelife.org/low-visibility-marine-mammal-detection/) that is highly relevant to future seismic surveys off New Zealand, regarding the effectiveness of marine mammal monitoring methods in low-visibility conditions. In this study Infra-Red (IR), RAdio Detection And Ranging (RADAR), and SOund Navigation And Ranging (SONAR) were tested during vessel-based field trials, with both IR and RADAR showing promise as potential technologies.

Future research opportunities form seismic surveys off New Zealand could include integration of multi-modal detection technologies and real-time sensor fusion algorithms that integrate MMO data with PAM, IR, and RADAR detections. Integrating this mitigation technology would provide better monitoring options at night and during other periods of low visibility.

8. CONCLUSIONS

This assessment has comprehensively evaluated the potential environmental effects of the BRASS seismic survey on marine mammals and other ecological receptors, integrating a structured impact evaluation framework with mitigation strategies prescribed in the 2013 Code of Conduct. While some level of disturbance was anticipated, particularly regarding auditory masking and behavioural responses, the implementation of exclusion zones, soft-start procedures, and continuous monitoring ensures that residual impacts remain within acceptable ecological thresholds.

The review of the operational area within the Kermadec Arc and the associated transit route through the Hauraki Gulf provides a comprehensive understanding of the physical, biological, cultural, and socio-economic environment relevant to the proposed activities. The Kermadec Arc is a dynamic and ecologically significant region, characterised by unique geological formations, complex oceanographic processes, and a diverse array of marine species. The transit through the Hauraki Gulf introduces further considerations, given the presence of critical habitats and a high level of human activity.

Marine mammal distribution within the study area is not well understood given the remote location and lack of targeted studies; however, available information highlights the potential presence of numerous species, many of them classified as data deficient. The potential environmental effects associated with vessel activity and seismic survey operations have been assessed using a structured impact evaluation framework. This framework accounts for the likelihood and severity of impacts, population exposure, and conservation value of affected species. The findings indicate that key concerns include physical injury, behavioural disturbance, displacement, auditory masking, and the potential reduction of prey availability due to seismic activity. The transit route further elevates risks of vessel strike and noise pollution, particularly within the Hauraki Gulf, an area already experiencing anthropogenic pressures.

Mitigation measures have been integrated into the operational planning to minimise environmental risks. These include adherence to established seismic mitigation protocols as prescribed in the 2013 Code of Conduct (DOC, 2013) and adhering to voluntary speed reduction and marine mammal monitoring during transit through the Hauraki Gulf. The evaluation suggests that while residual risks remain for certain species, the adoption of these mitigation strategies significantly reduce the residual impact that is likely to be experienced and the potential for long-term or irreversible ecological effects, reducing residual risk levels to acceptable levels.

In conclusion, for the planned activities within the Kermadec Arc and transit through the Hauraki Gulf, existing environmental protections set out in the 2013 Code of Conduct, coupled with targeted mitigation measures during transit, are expected to minimise adverse effects on the marine mammal populations and the region’s biodiversity. Continued monitoring and adaptive management will be essential in ensuring that conservation priorities are upheld while allowing for the successful completion of the proposed operations.

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APPENDIX A – MITIGATION PROTOCOL

Mitigation strategies

This appendix outlines comprehensive mitigation strategies and protocols for the proposed seismic survey of the Brothers Volcano in the Kermadec Arc 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.

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.

Observer requirements

A team of four observers will be onboard *RV Sonne* throughout the survey, adhering to the requirements of the 2013 Code and approved by the DOC. This team will consist of two Marine Mammal Observers (MMOs) and two Passive Acoustic Monitoring Operators (PAMOs).

All MMO and PAMO personnel are required to hold valid certification recognised by DOC, along with a minimum of 12 weeks of offshore experience as an MMO or PAMO in New Zealand waters. Additionally, each observer must possess the required sea survival and offshore medical certifications and be equipped with suitable 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.

<u>PAM specifications</u>

Acoustic monitoring will be conducted using a purpose-built towed array (as an example shown in **Figure 18** and **Table 23**) 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 19**.

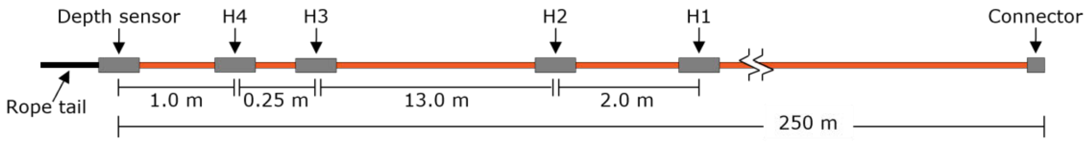


Figure 18: Example schematic of a towed hydrophone array. H1 and H2 are the broadband hydrophone (H) element and H3 and H4 are the high frequency hydrophone elements. *Source*: OSC (2025).

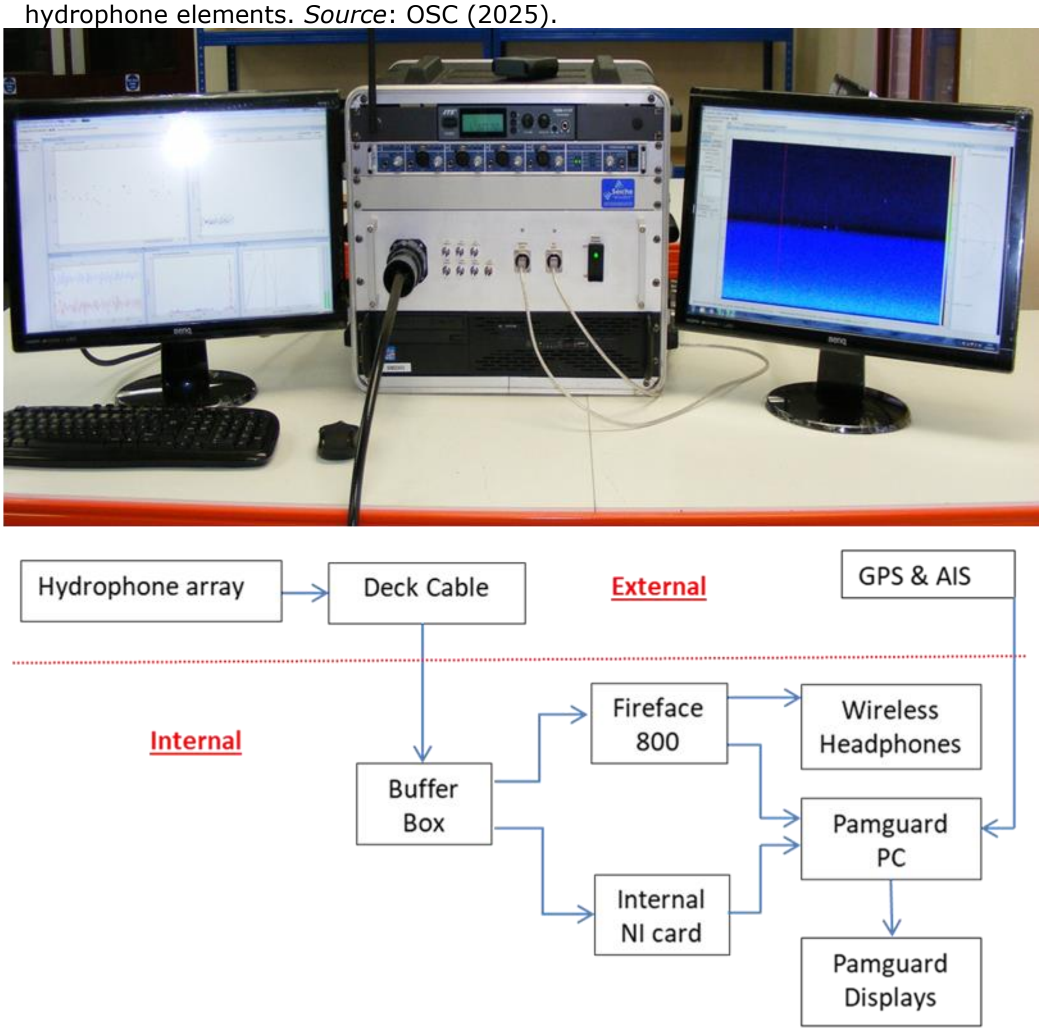


Figure 19: Schematic diagram of the internal PAM system components, including the PAM base (top panel, centre), which consists of a buffer box and a PAMGuard PC, as well as PAMGuard displays (top panel, sides). External components are not shown. *Source*: OSC (2025).

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 23: Specifications of hydrophone system. DAQ = Data AcQuisition, PC = Personal Computer. *Source*: OSC (2025).

PAMGuard configuration

PAMGuard will be configured with a specific data model for BRASS 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).

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.

The duties of the 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.

Observer effort

Two MMOs and two PAMOs will be present onboard the survey vessel. 24-hour observations will be conducted, where necessary, during operational periods from a suitable viewing platform allowing maximum visibility of the mitigation zone (typically the vessel bridge, top deck, or helipad). MMO efforts will take place during daylight hours which is typically 30 minutes after sunrise until 30 minutes before sunset (health and safety permitting) with two MMOs on effort during operational periods.

<u>Pre-start observations</u>

The sound source may only be activated once the observer confirms that there are no marine mammal detections within the mitigation zone.

Operations during daylight hours may commence once at least one MMO has conducted continuous visual observations for 30 minutes around the sound source for the presence of marine mammals with either no marine mammal detections, the detected marine mammals have moved outside of the mitigation zone, or at least 30 minutes have passed since the last detection. In addition, a PAMO has conducted observations for at least 30 minutes before the activation of the sound source with no vocalising detections.

During nighttime observations or poor visibility periods, operations may commence once a PAMO has conducted acoustic monitoring for a minimum of 30 minutes prior to sound source activations with no vocalising detections.

When arriving at a new location in the operational area for the first time, in addition to the normal pre-start observation requirements outlined above, 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 of the planned start up position), the source may be activated if:
  - PAM monitoring has been conducted for 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 during visual monitoring in the relevant mitigation zone in the 10 minutes immediately preceding proposed operations; 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).

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. 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.

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. Acoustic seismic sources will not be activated outside the specified operational areas at any time, including for any necessary seismic data acquisition, acoustic source testing, and soft start initiation.

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 D - SPECIES OF CONCERN**) with a calf within 1.5 km from the sound source, operations must be delayed or shut down immediately. Reactivated 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. Reactivated 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 continual observations.

Other marine mammals (not Species of Concern)

If a 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.

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.

Reporting requirements

MMOs and PAMOs are jointly responsible for recording and reporting all sighting data collected during the survey, along with a summary report. This report must include the required information in a standardized 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.

Key contacts and communication protocol

All enquiries or notifications to DOC must be directed to David Lundquist via phone at +64 27 201 3529 or email at dlundquist@doc.govt.nz. 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 gcrutchley@geomar.de.

Navigational safety

The vessel will transit from the Port of Aukland through the Hauraki Gulf to the operational area. The transit is expected to take 1 day.

The Hauraki Gulf Transit Protocol for commercial shipping (Port of Auckland, 2024), which provides recommended approaches to the port, as well as advice for reducing the risk of death to whales, includes:

- Reducing vessel speed (from 15 to 10 knots);
- Having a dedicated observer watching for Bryde's whales during daylight hours; and,
- Report any whale sightings so that other vessels can be aware and avoid the whale.

This protocol will be followed during transit through the Hauraki Gulf.

APPENDIX B – SOUND TRANSMISSION LOSS MODELLING

Project description

GEOMAR is undertaking a seismic survey within the proposed seismic survey area in New Zealand waters in the Kermadec Arc (**Figure 20**). OSC has been engaged by GEOMAR to provide Sound Transmission Loss Modelling (STLM) services for the proposed seismic survey. Bounding coordinates of the survey area:

Western boundary: 178° East
Eastern boundary: 180° East
Northern boundary: 34° South
Southern boundary: 35.5° South

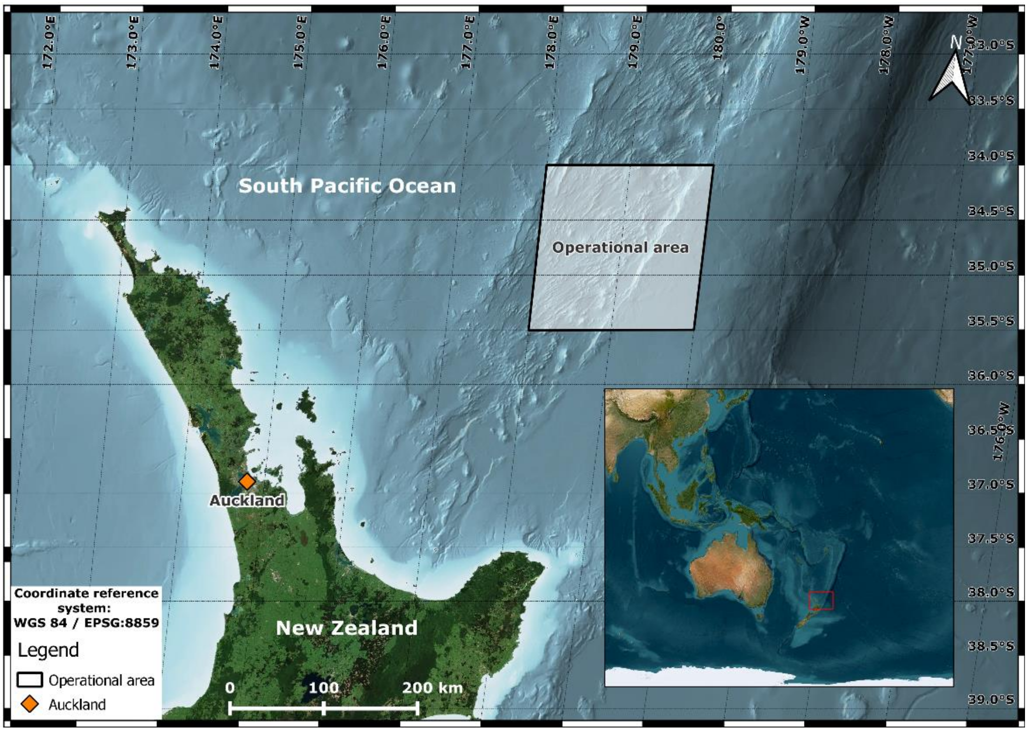


Figure 20: BRASS survey operational area. Coordinate reference system: WGS 84/Equal Earth Asia-Pacific (EPSG:8859). *Source*: OSC (2025).

Statutory requirement for STLM

In New Zealand, the 2013 Code of Conduct was developed by the Department of Conservation (DOC) in consultation with a broad range of stakeholders in marine seismic survey operations (DOC, 2013).

The 2013 Code of Conduct requires sound transmission loss modelling to be undertaken to determine whether received SELs exceed 171 dB re 1μPa^2·s (the behavioural threshold) at ranges of 1.0 km and 1.5 km from the source or 186 dB re 1μPa^2·s (the injury threshold) at a range of 200 m from the source.

Structure of the appendix

This STLM study includes the following three modelling components:

- Array source modelling, *i.e.* modelling the sound energy emissions for the array source, including its acoustic signatures and directivity characteristics;
- Short range modelling, *i.e.* prediction of the received SELs over a range of 2,000 m from the array source location, in order to assess whether the proposed survey complies with the near-field mitigation zone requirements imposed by the 2013 Code of Conduct; and,
- Long range modelling, *i.e.* prediction of the received SELs over a range of tens to hundreds of kilometres from the array source location, in order to assess the noise impact from the survey on the surrounding marine mammal sanctuary or other areas of ecological importance.

Seismic array source modelling details the modelling methodology, procedure, and results for the array source modelling. **Transmission Loss Modelling** outlines the methodologies and procedures associated with the short- and long-range transmission loss modelling, with the major modelling results presented in **Results.**

Seismic array source modelling

<u>Source array configuration</u>

The acoustic source array proposed for the Kermadec Arc survey area is a 5,420 CUI (in^3) G.Gun source array with 12 sources paired into six clusters. The configuration is presented in **Figure 21**. The towing depth of the array is 12 m and has an operating pressure of 3,000 Pounds per Square Inch (PSI).

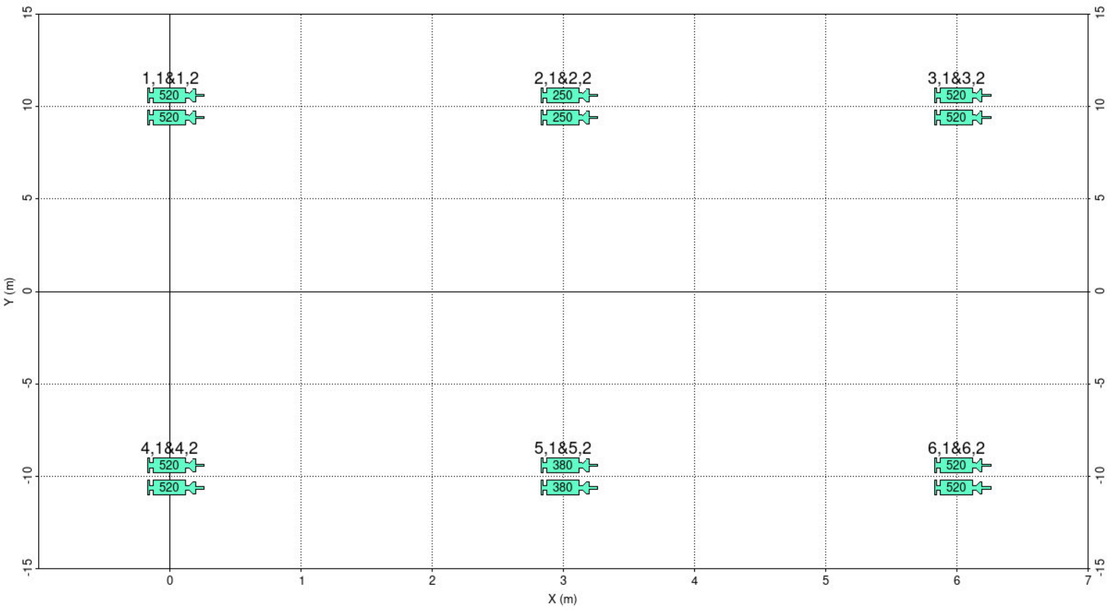


Figure 21: The configuration of the 5,420 CUI (in^3) acoustic source array. X-dimension is distance in line with ship's course. Y-dimension is starboard (+ve) and port(-ve). *Source*: GEOMAR (2025).

Modelling methodology

The outputs of the acoustic array source modelling include:

- A set of "notional" signatures for each of the array elements; and
- The far-field signature of the array source, including its beam patterns.

Notional signature

The notional signatures are the pressure waveforms of individual source elements at a standard reference distance of 1 m.

Notional signatures are modelled using the Nucleus+ Designer software package. The Nucleus+ source model was developed based on the fundamental physics of airgun bubble oscillation and radiation, incorporating non-linear interactions between array elements to accurately predict source waveforms and their corresponding spectral characteristics. The underlying physical principles are derived from bubble dynamics theory, accounting for heat transfer, damping effects, and pressure interactions between airgun elements. (Ziolkowski *et al.*, 1982; Vaage *et al.*, 1983; Dragoset, 1984; Parkes *et al.*, 1984; Laws *et al.*, 1988; Laws *et al.*, 1990).

The Nucleus+ model solves a set of coupled differential equations governing bubble expansion and collapse, incorporating both thermodynamic and hydrodynamic effects. The model has been extensively calibrated against field measurements of individual airgun sources and full arrays across various operating depths and pressures.

Nucleus+ is capable of predicting source spectra over a wide frequency range, extending up to tens of kHz. At frequencies above 1 kHz, the spectral shape follows a 1/f decay, consistent with theoretical and experimental observations (Landrø, 2011). As the noise emissions from an acoustic source array are predominantly below hundreds of Hz, modelling results within frequency range below 1 kHz is demonstrated in this report.

Far-field signatures

The notional signatures from all sources in the array are combined using appropriate phase delays in three dimensions to obtain the far-field source signature of the array. This procedure to combine the notional signatures to generate the far-field source signature is summarised as follows:

- The distances from each individual acoustic source to nominal far-field receiving locations are calculated. A 9 km receiver set is used for the current study;
- The time delays between the individual acoustic sources and the receiving locations are calculated from these distances with reference to the speed of sound in water;
- The signal at each receiver locations from each individual acoustic source is calculated with the appropriate time delay. These received signals are summed to obtain the overall array far-field signature for the direction of interest; and,
- The far-field signature also accounts for ocean surface reflection (termed the 'surface ghost') effects. An additional ghost source is added for each acoustic source element using a sea surface reflection coefficient of -1.

Beam patterns

The beam patterns of the acoustic source array are obtained as follows:

- The far-field signatures are calculated for all directions from the source using azimuthal and dip angle increments of 1-degree;
- The Power Spectral Density (PSD) - dB re 1 μPa^2/Hz @ 1m - for each pressure signature waveform is calculated using a Fourier transform technique; and,

The PSDs of all resulting signature waveforms are combined to form the frequency-dependent beam pattern for the array.

<u>Modelling results</u>

Notional signatures

Figure 22, **Figure 23**, and **Figure 24** show the notional source signatures for the 250 CUI (in^3), 380 CUI (in^3), and 520 CUI (in^3) air gun, corresponding to acoustic source elements in the array configuration shown in **Figure 21**.

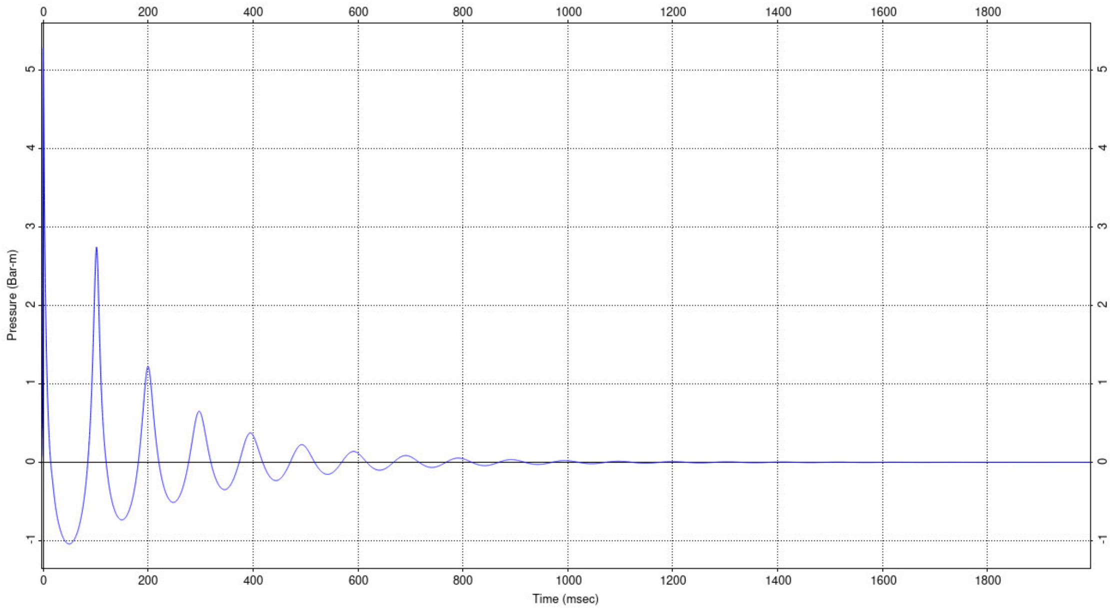


Figure 22: Notional source signature for the 250 CUI (in^3) air gun. *Source*: GEOMAR (2025).

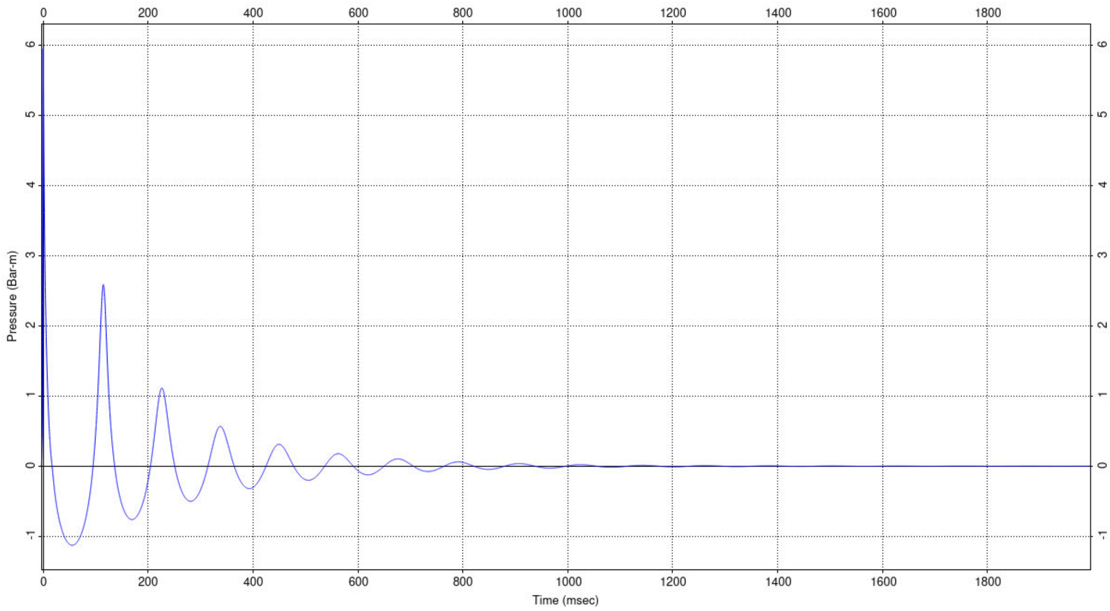


Figure 23: Notional source signature for the 380 CUI (in^3) air gun. *Source*: GEOMAR (2025).

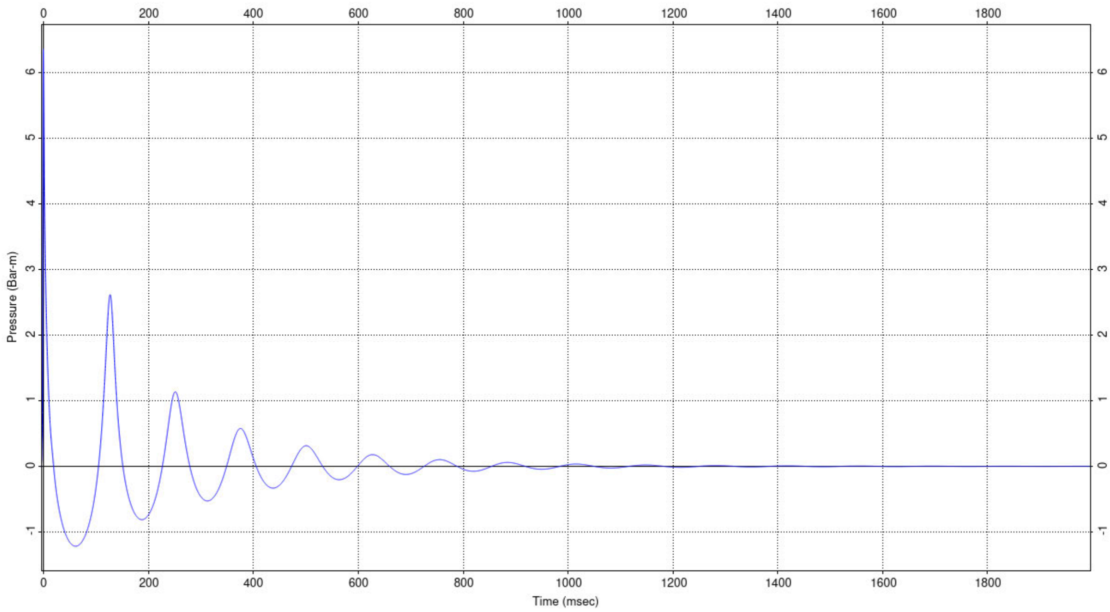


Figure 24: Notional source signature for the 520 CUI (in^3) air gun. *Source*: GEOMAR (2025).

Far-field signature and PSD

Figure 25 and **Figure 26** show the far-field signature waveform and its power spectral density for the proposed acoustic source array. The signatures are for the vertically downward direction with surface ghost included.

The source modelling result shows that the peak-to-peak sound pressure level ($SPL_{p\text{-}peak}$) is 262.4 dB re 1 µPa @ 1m (131.5 bar), the Root-Mean-Square Sound Pressure Level (RMS SPL) 231.0 dB re 1 µPa @ 1m with a 90% energy pulse duration of 90 milliseconds, and the SEL 230.5 dB re µPa^2·s @ 1m.

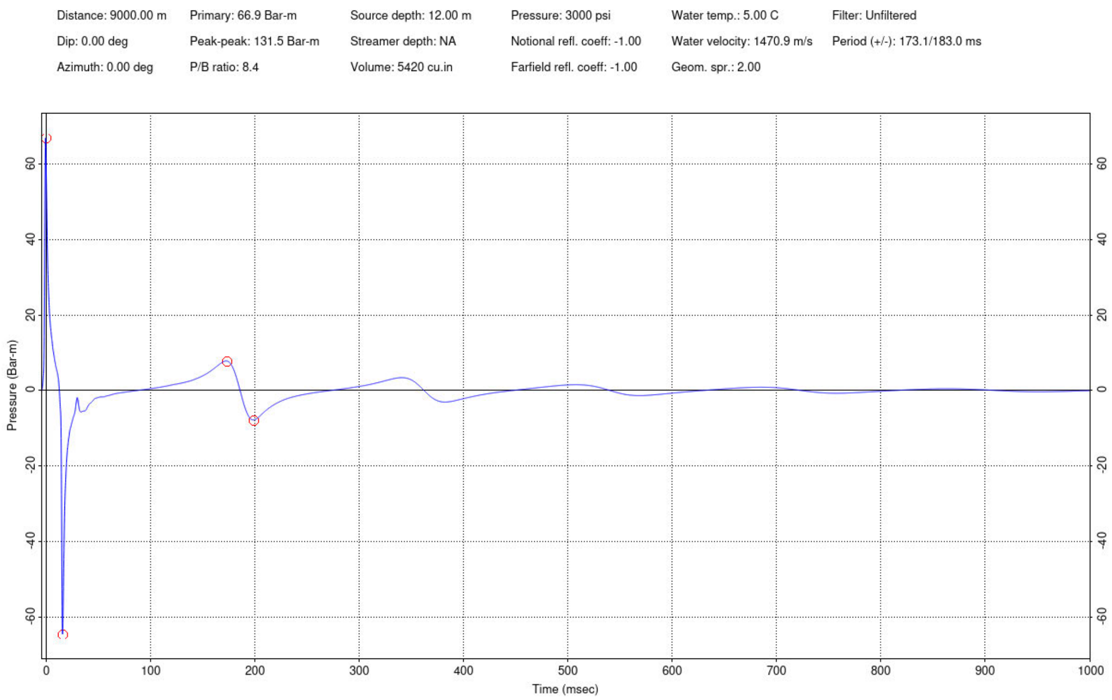


Figure 25: Far-field signature in vertically downward direction for the 5,420 CUI(in^3) acoustic array. *Source*: GEOMAR (2025).

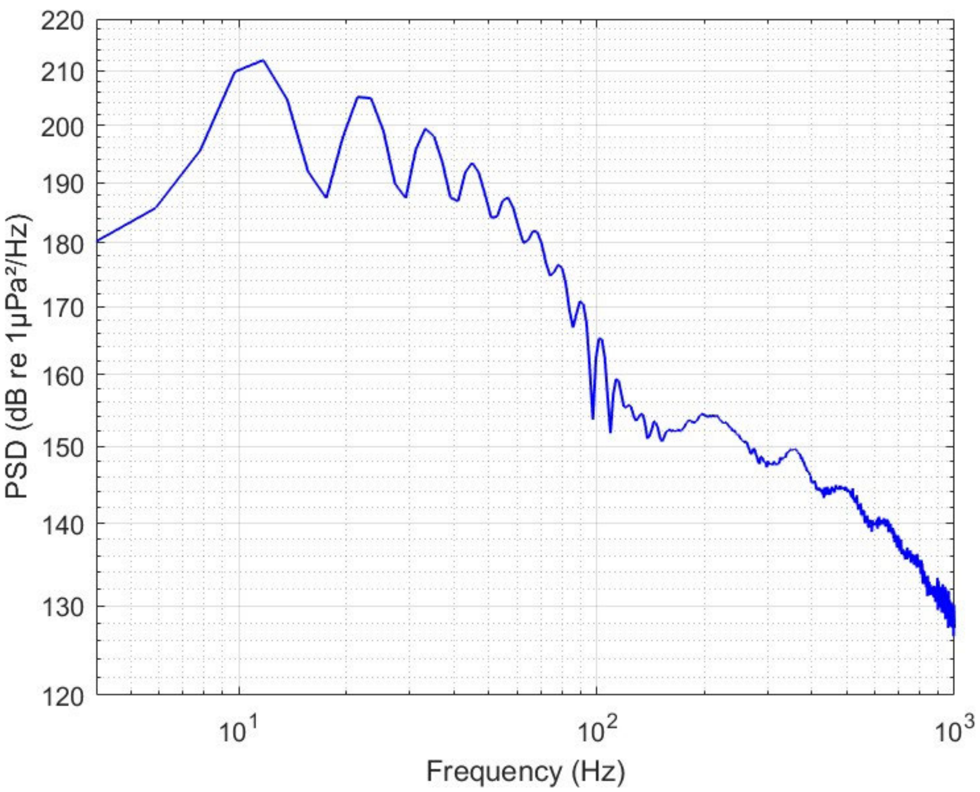


Figure 26: PSD of the far-field signature in vertically downward direction for the 5,420 CUI(in^3) acoustic array. *Source*: OSC (2025).

Beam patterns

Array far-field beam patterns of the following three cross sections are presented in **Figure 27**, **Figure 28**, and **Figure 29**.

- The horizontal plane (*i.e.* dip angle of 90 degrees) with azimuthal angle of 0 degree corresponding to the in-line direction;
- The vertical plane for the in-line direction (*i.e.* azimuthal angle of 0 degree) with dip angle of 0 degree corresponding to the vertically downward direction; and,
- The vertical plane for the cross-line direction (*i.e.* azimuthal angle of 90 degrees) with dip angle of 0 degree corresponding to the vertically downward direction.

The beam patterns in **Figure 27**, **Figure 28**, **Figure 29**, and **Figure 30** illustrate strong angle and frequency dependence of the energy radiation from the array. The beam pattern of the horizontal plane shows relatively stronger energy radiation in the cross-line direction than in the in-line direction. The beam patterns of the in-line and cross-line vertical planes have the strongest radiation in the vertical direction.

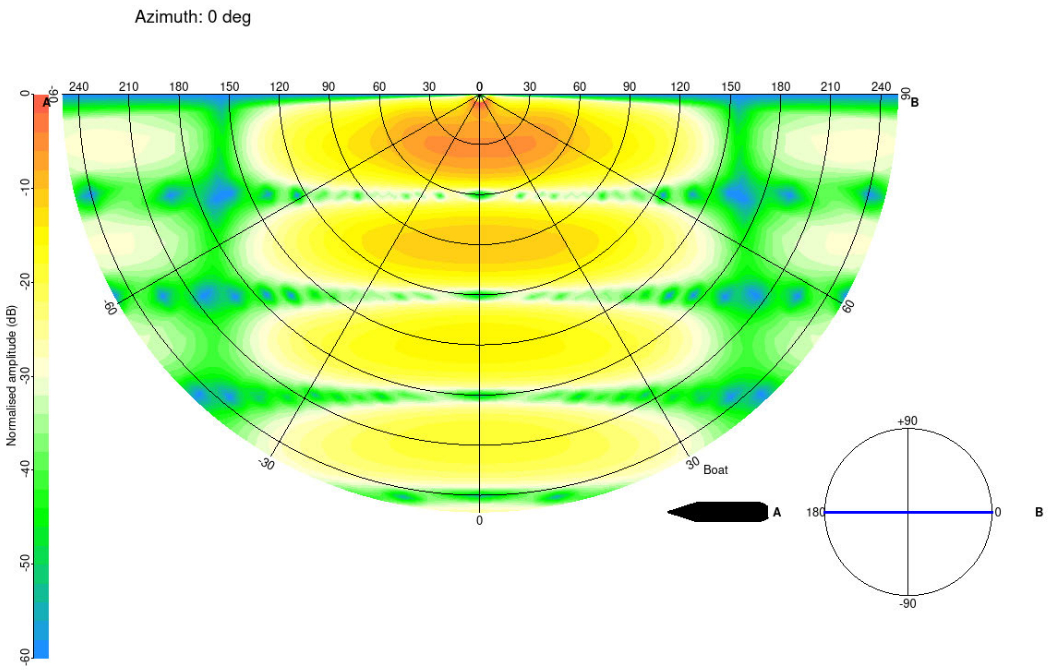


Figure 27: Array far-field beam patterns for the 5,420 CUI (in^3) source array. Vertical plane is for the in-line direction. *Source*: GEOMAR (2025).

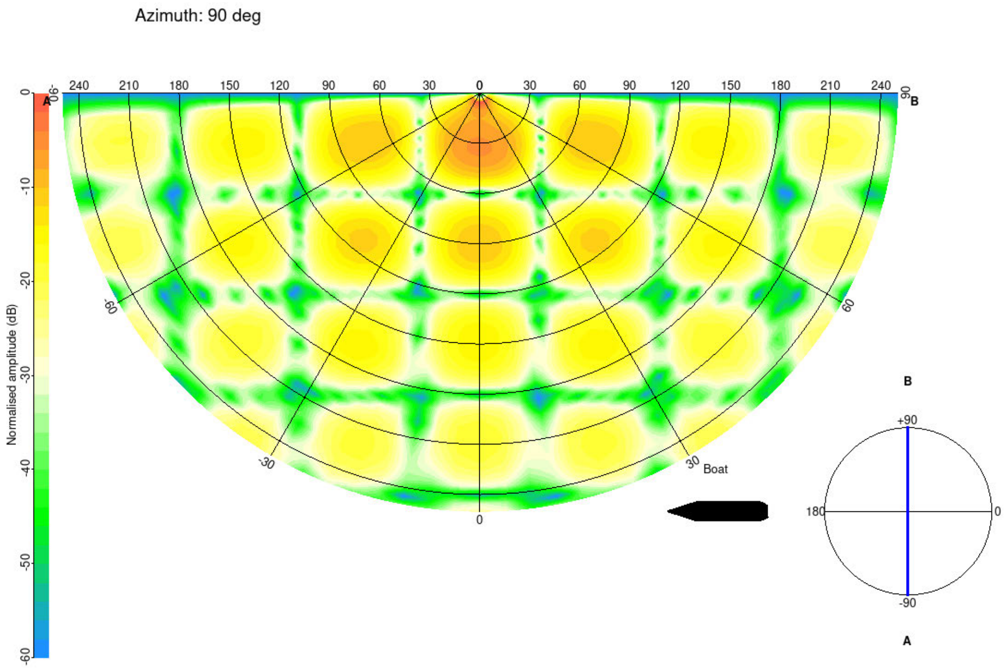


Figure 28: Array far-field beam patterns for the 5,420 CUI (in^3) source array. Vertical plane is for the cross-line direction. *Source*: GEOMAR (2025).

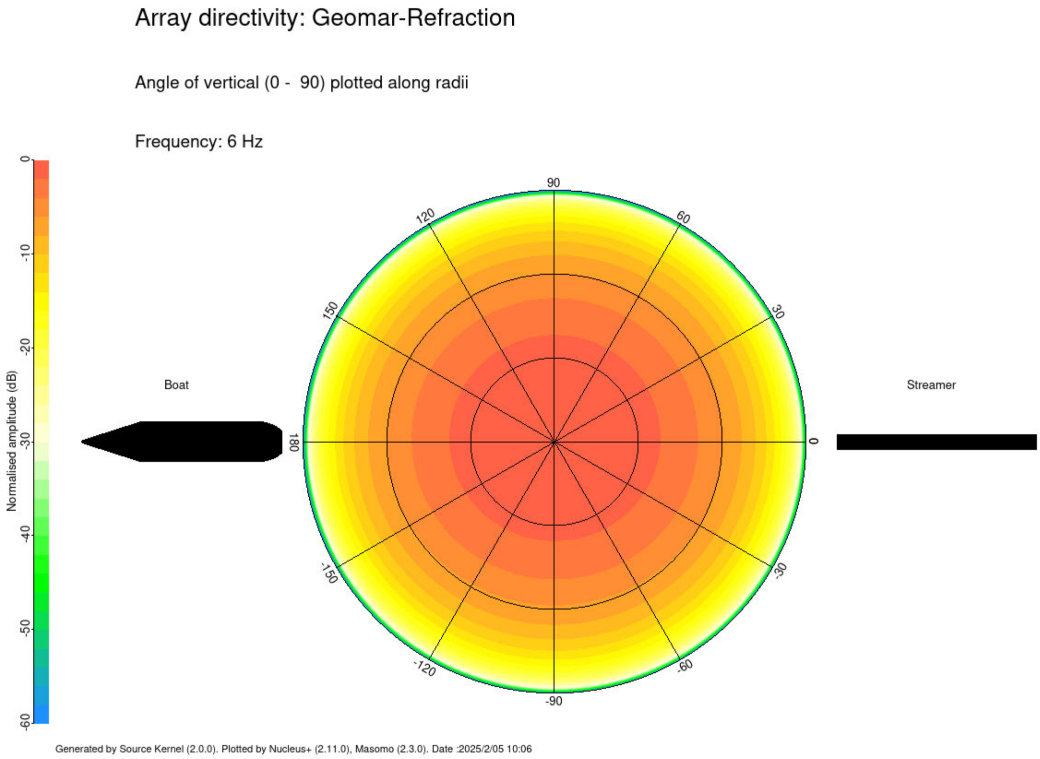


Figure 29: Array far-field beam patterns at 6 Hz for the 5,420 CUI (in^3) source array Horizontal plane with 0 degree corresponding to the in-line direction. *Source*: GEOMAR (2025).

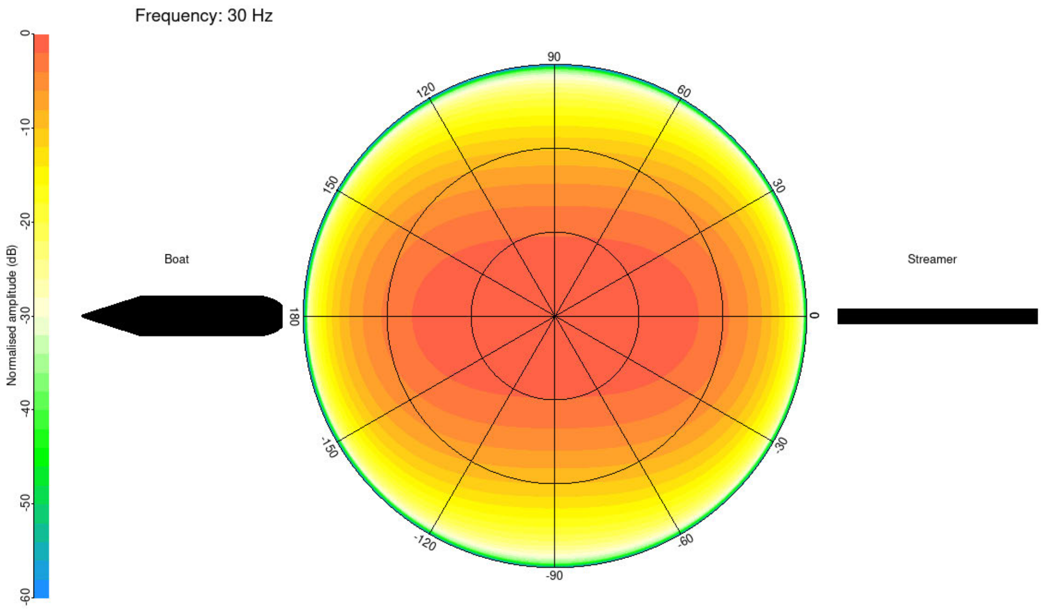


Figure 30: Array far-field beam patterns at 30 Hz for the 5,420 CUI (in³) source array Horizontal plane with 0 degree corresponding to the in-line direction. *Source*: GEOMAR (2025).

Transmission Loss Modelling

Modelling input parameters

Bathymetry

The full bathymetry dataset used for the sound propagation modelling was obtained from the General Bathymetric Chart of the Oceans (GEBCO) on a 15 arc-second interval grid (GEBCO_2024). The sound source coordinates for noise propagation modelling are 179.1° East, 34.9° South according to the planned seismic experiments (**Figure 31**).

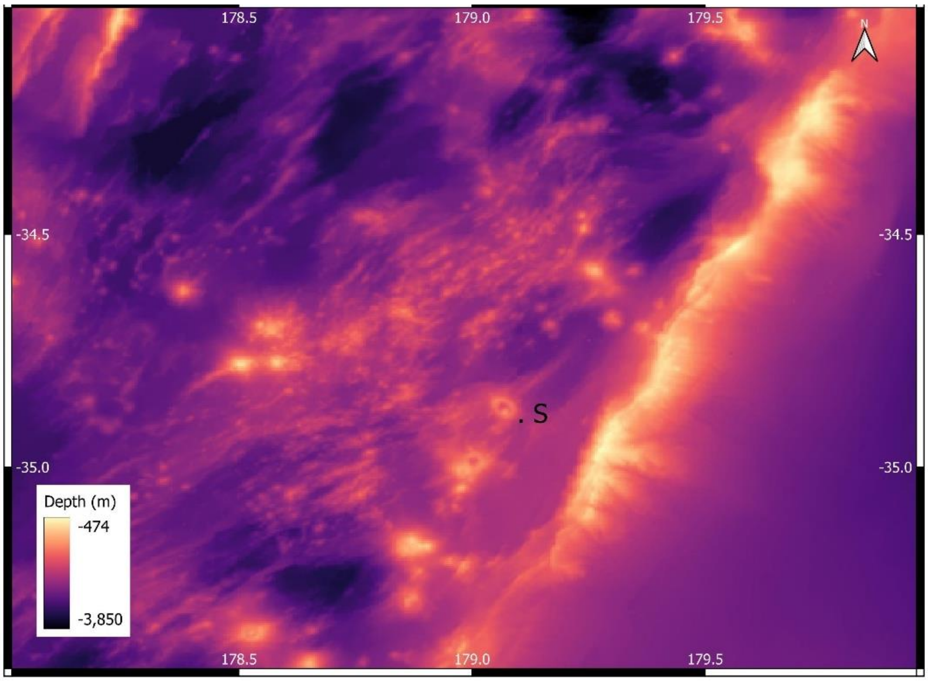


Figure 31: Bathymetric imagery in a resolution of 500 m covering survey areas. Black dot (S) indicates the selected source location for the short range and long-range modelling cases. Coordinate reference system World Geodetic System (WGS) '84. *Source*: OSC (2025).

Sound speed profile

Temperature and salinity data required to derive the sound speed profiles were obtained from the World Ocean Atlas 2018 (WOA18) (Locarnini *et al.*, 2018; Zweng *et al.*, 2019). The hydrostatic pressure used to calculate the sound speed based on depth and latitude of each particular modelling location was obtained using Saunders and Fofonoff (1976)'s formula. The sound speed profiles were derived based on Del Grosso (1974)'s equation.

Figure 32 presents the typical sound speed profiles for four Southern Hemisphere seasons in close proximity to the survey areas within the Pegasus Basin. The figure demonstrates that the most significant distinctions for the profiles of four seasons occur within the mixed layer near the surface.

The proposed BRASS survey is scheduled to occur in May 2025; therefore, the autumn sound speed profile has been selected to provide the most conservative sound propagation modelling scenarios.

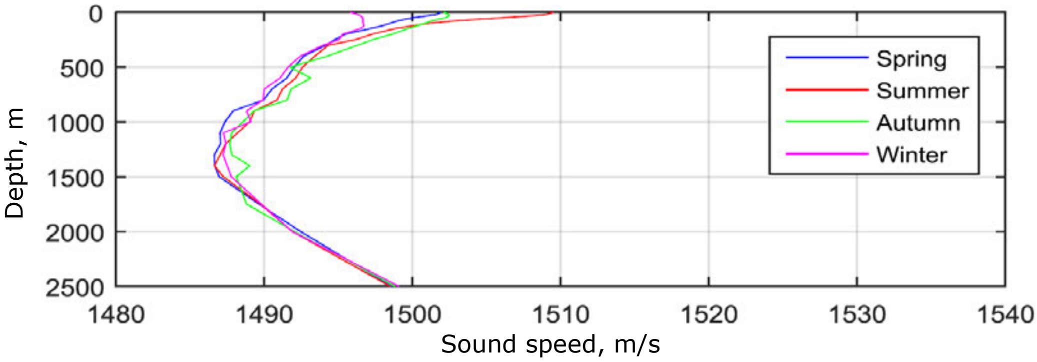


Figure 32: Typical sound speed profiles north of the North Island within the Kermadec Arc for different Southern Hemisphere seasons. *Source*: OSC (2025).

Sediment properties

New Zealand has diverse seafloor sediments thanks to its variable and dynamic marine and terrestrial environments. National Institute of Water and Atmosphere (NIWA) has over many years produced a variety of marine sediment charts illustrating the ocean bottom types around coastal New Zealand and some offshore areas. The map in **Figure 33** extracted from NIWA illustrates the distribution of the main types of marine sediments found on the ocean floor around New Zealand (Lewis *et al.*, 2006a; Lewis *et al.*, 2006b).

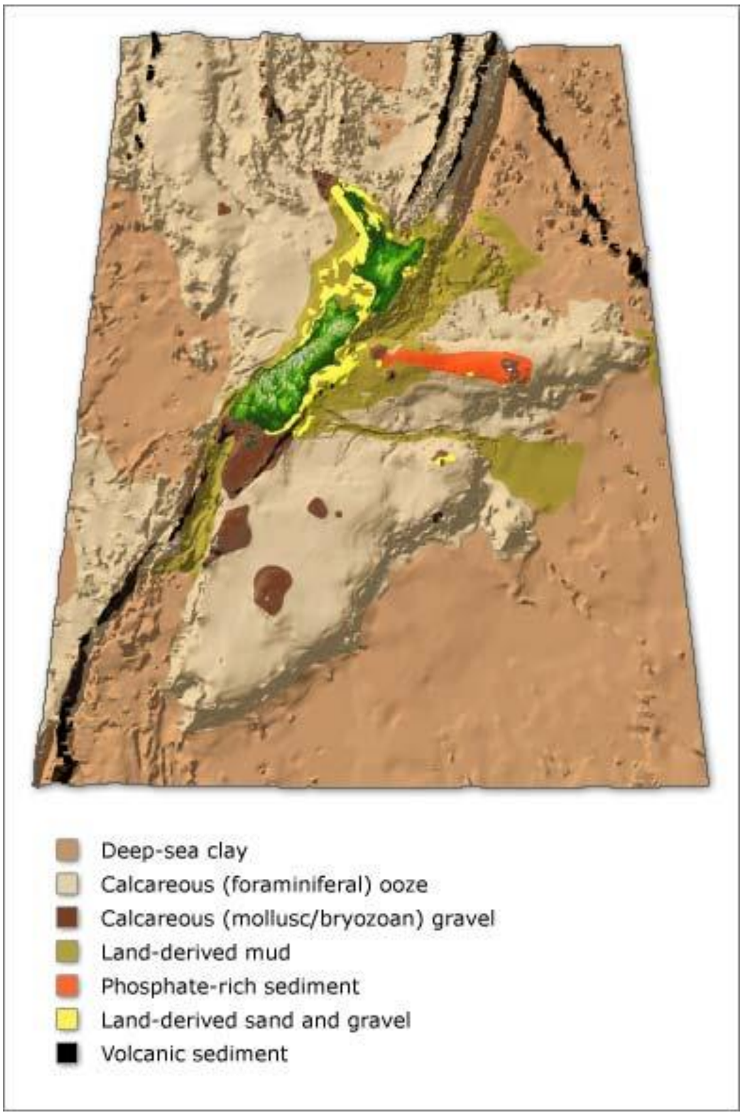


Figure 33: Distribution of the main types of marine sediment on the seafloor within coastal and offshore regions around New Zealand. *Source*: Lewis *et al.* (2006b).

The continental shelf is covered mainly with land-derived sand, gravel, and mud sediment, except at the northern and southern extremities where the shelly sediment from once-living sea creatures prevails due to the lack of major rivers. In the operational area, within the Kermadec Arc region, deep-sea calcareous ooze is prevalent, particularly at greater depths where sedimentation is primarily controlled by the deposition of marine planktonic remains.

Detailed sediment classifications for various coastal and offshore regions are available in New Zealand marine sediment charts and technical reports (Galindo-Romero and Duncan, 2014). A summary of the sediment characteristics in and around the Kermadec Arc is provided in **Table 24**, where clayey silt is used in the modelling to approximate the acoustic properties of the Calcareous (Foraminifera) Ooze seafloor.

Sediment Type	Density, ρ (kg/m³)	Compressional Wave Speed, c_p (m/s)	Compressional Wave Attenuation, α_p (dB/λ)
Sand			
Coarse sand	2,035	1,835	0.8
Fine sand	1,940	1,750	0.8
Very fine sand	1,855	1,700	0.8
Silt-clay			
Silt	1,740	1,615	1
Sand-silt-clay	1,595	1,580	0.4
Clayey silt	1,490	1,550	0.2
Silty clay	1,420	1,520	0.2

Table 24: Geoacoustic properties for various possible sediment types within the coastal and offshore regions in the Kermadec Arc. *Source*: OSC (2025).

Detail modelling methodologies & procedures

The modelling accuracy requirements, source directivity characteristics, and computational cost of the short range and long-range modelling cases are different. The following sections describe the different modelling methodologies and procedures employed for the short range and long-range modelling cases.

Short-range modelling

Short-range modelling is used to verify mitigation zones in close proximity to the acoustic source array, where accurate predictions are essential due to the strong interference effects from multiple sources in the array. At short ranges, wave interactions, refraction, reflection, and seabed scattering play a significant role in shaping the acoustic field, making full-wave numerical modelling necessary.

For this study, COMSOL Multiphysics version 6.3 (2025, Stockholm) was used to model the short-range sound propagation. COMSOL's Finite Element Method (FEM) solver allows for a high-resolution simulation of the acoustic field, accounting for complex interactions between waves, the water column, and the seabed. The Pressure Acoustics module was used to solve the Helmholtz equation, providing accurate simulations of sound propagation in a stratified underwater environment.

The following procedures have been followed to calculate received SELs for short range modelling cases:

1. A finite element simulation project is constructed and solved for from 1 Hz to 1 kHz, in 1 Hz increments. The source depth is taken to be the array depth of 12 m, corresponding to the operational depth of the system. The seabed was modelled with layered acoustic and elastic properties, ensuring accurate representation of bottom interactions. A receiver grid of 1 m in range (maximum range 2.0 km) and 1 m in depth is applied for the selected receivers;
2. The wave equation was solved for monopole point sources representing the airgun array. Absorbing boundary conditions (Perfectly Matched Layers)

were applied at the domain edges to prevent artificial reflections. The seabed layers were assigned acoustic impedance values based on sediment type;
3. The model was solved in the frequency domain over a range of 1 Hz to 1 kHz, ensuring coverage of the dominant energy spectrum of the airgun array. The wave equation was solved at each frequency step, computing the acoustic pressure field at all receiver locations; and,
4. The overall acoustic pressure field at each grid elements is integrated over the frequency domain to obtain the received SEL.

Long-range modelling

The long-range modelling case provides reasonable accuracy in predicting underwater noise propagation, considering the complex and variable environmental factors, such as sound speed profiles and bathymetric variations. Given these complexities, the modelling prediction for long-range propagation is conducted using far-field source levels in one-third octave frequency bands, combined with transmission loss calculations to determine the received SEL levels.

For this study, the Parabolic Equation (PE) method was implemented using the dBSea version 2.4.17 acoustic modelling software, which is well-suited for low-frequency deep-sea range-dependent propagation conditions and efficiently solves underwater transmission loss in variable bathymetric and oceanographic environments. The modelling process follows these steps:

1. Source SEL levels calculation:

One-third octave source levels for each azimuth are obtained by integrating the horizontal plane source spectrum over the corresponding frequency bands. These levels are converted to SEL levels for input into the propagation model.

2. Transmission-Loss Modelling using dBase:

The PE solver in dBSea is run for one-third octave band central frequencies from 8 Hz to 1 kHz. Transmission loss is computed for the whole bathymetric grid, at 5-degree azimuth increments.

3. Received SEL calculation

The source SEL levels and transmission loss results from dBSea are combined to compute the received SEL levels as a function of range, depth, and frequency.

4. Overall SEL computation

The total received SEL levels are determined by summing the SEL values across all one-third octave frequency bands.

By using the PE solver, this approach ensures an accurate and computationally efficient representation of long-range underwater noise propagation, incorporating realistic environmental conditions, bathymetric effects, and range-dependent acoustic properties.

<u>Results</u>

Short range modelling

The received SEL levels from the proposed 5,420 CUI (in^3) source array for the source modelling location S, with the autumn season sound speed profile and the corresponding clayey silt seabed have been calculated. The maximum received SELs across the water column are presented as a function of azimuth and range from the centre of the array in **Figure 34**. It illustrates that the source array has relatively poor directivities in both the in-line and cross-line directions.

The scatter plots of the predicted maximum SELs across the water column from the source array for all azimuths are displayed in **Figure 35**. This data is presented as a function of range from the centre of the source array and is illustrated together with the mitigation threshold levels (*i.e.* 186 dB and 171dB re 1μPa^2·S) and mitigation ranges (*i.e.* 200 m, 1.0 km, and 1.5 km).

For the selected source location, the maximum received SELs over all azimuths are predicted to be below 186 dB re 1μPa2·s at 200 m and below 171 dB re 1μPa^2·s at 1.0 km.

The predictions of the maximum SELs received at the three mitigation ranges for the selected short range modelling location are listed in **Table 25**. **Table 26** presents the ranges from the centre of the source array to where the predicted maximum SELs meet the threshold levels (186 dB and 171 dB re 1μPa^2·s) for the modelling scenario.

Source depth (m)	Water depth (m)	Sediment type	SEL at different ranges (dB re 1μPa^2·s)		
			200 m	**1.0 km**	**1.5 km**
12	2,000	Clayey silt	181.5	170.3	168.7

Table 25: Predicted maximum SELs for all azimuths at ranges of 200 m, 1 km, and 1.5 km from the centre of the proposed 5,420 CUI (in^3) array for the selected source locations S. *Source*: OSC (2025).

Source depth (m)	Water depth (m)	Sediment type	Ranges complying with the following SEL thresholds (m)	
			SEL<186dB re 1μPa^2·s	**SEL<171dB re 1μPa^2·s**
12	2,000	Clayey silt	110	950

Table 26: Ranges from the centre of the proposed 5,420 CUI (in^3) array where the predicted maximum SELs for all azimuths equal the SEL threshold levels for the source locations S. *Source*: OSC (2025).

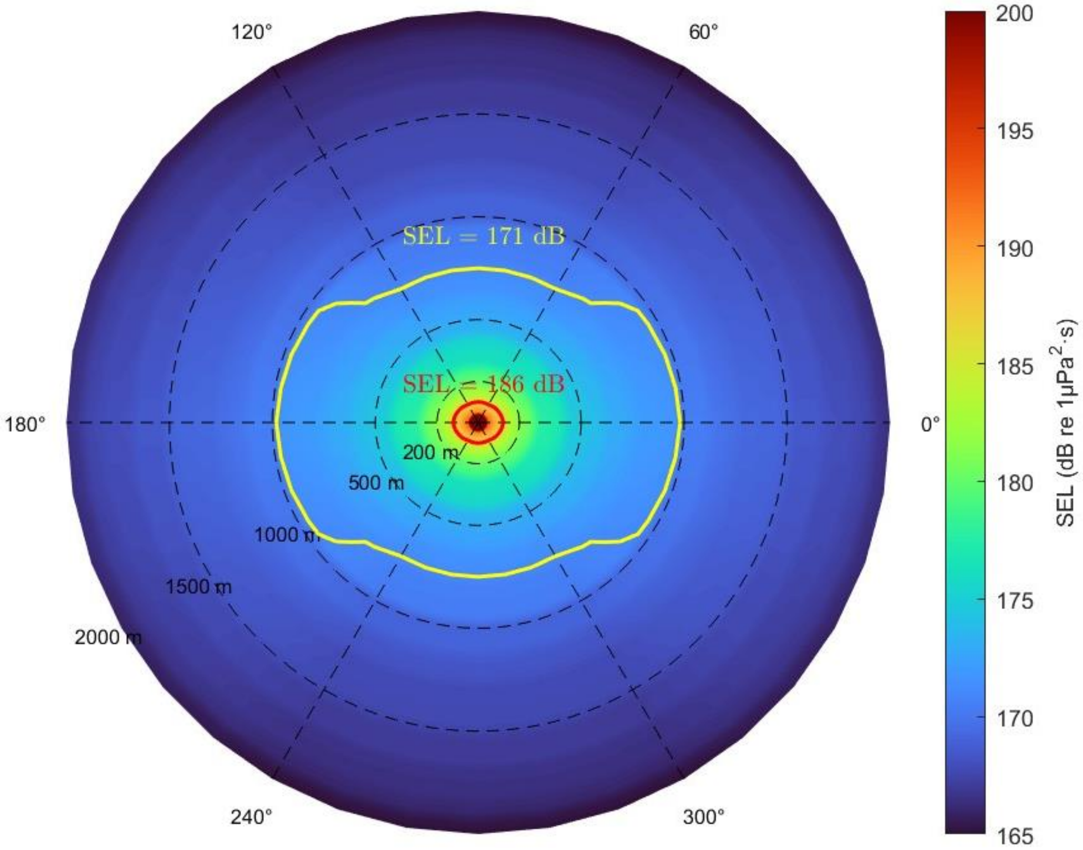


Figure 34: Predicted maximum received SELs across the water column from the proposed 5,420 CUI (in^3) source array as a function of azimuth and range from the centre of the array for source location S. 0-degree azimuth corresponds to the in-line direction. Solid circles represent the mitigation SEL threshold of 186 dB re 1μPa^2·s (red) and 171 dB re 1μPa^2·s (yellow). *Source*: OSC (2025).

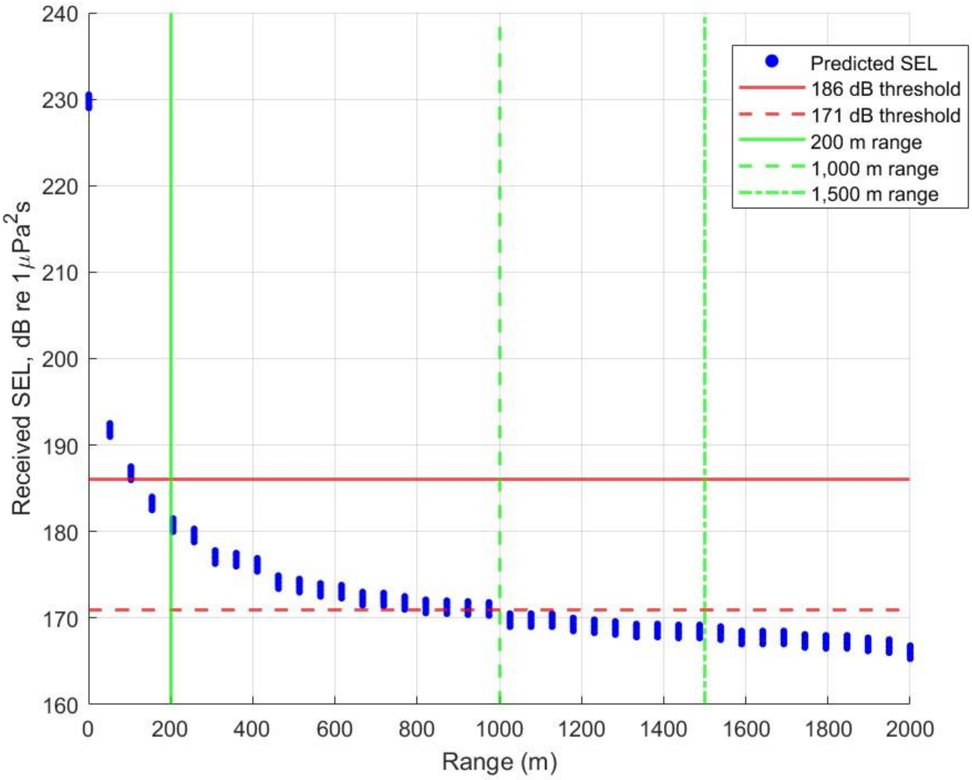


Figure 35: Scatter plots of predicted maximum SELs across water column from the proposed 5,420 CUI (in^3) source array for all azimuths as a function of range from the centre of the source array for source location S. Horizontal red lines show mitigation thresholds of 186 dB re 1μPa^2·s (solid) and 171dB re 1μPa^2·s (dash). Vertical green lines show mitigation ranges of 200 m (solid), 1 km (dash), and 1.5 km (dash-dot). *Source*: OSC (2025).

Long-range modelling

Figure 36 shows the contour images of the predicted maximum SELs received at locations up to 200 km from the selected source location S, overlaying the local bathymetry contours. As can be seen from the figure, the received noise levels at far-field locations vary at different angles and distances from the source locations. This directivity of received levels is due to a combination of the directivity of the source array, and propagation effects caused by bathymetry and sound speed profile variations. **Figure 37**, **Figure 38**, **Figure 39**, **Figure 40**, and **Figure 41** present the modelled SELs across range and depth along the cross-line and in-line directions for the source location S.

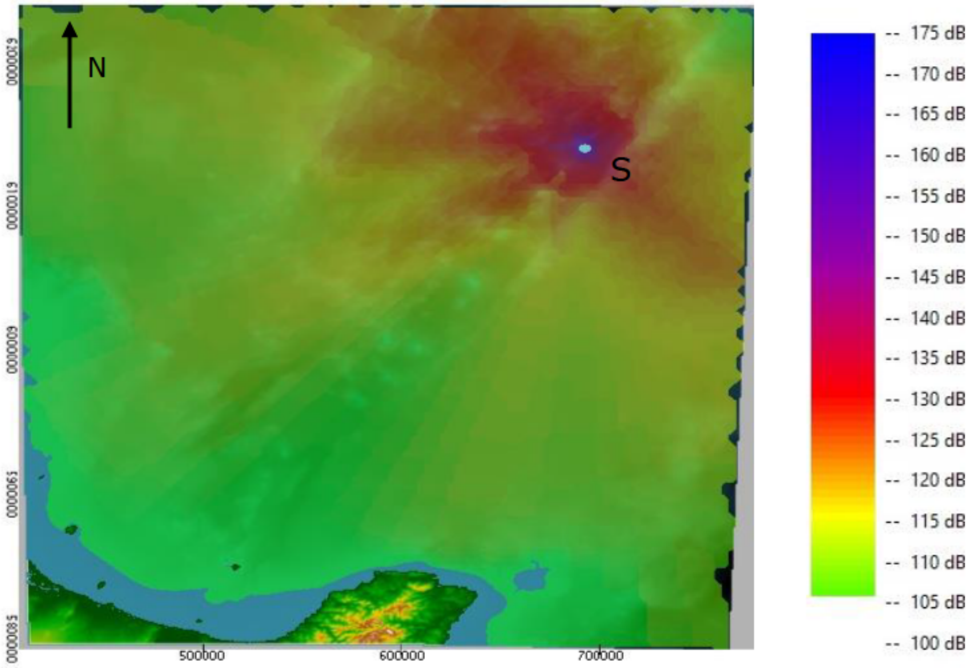


Figure 36: Modelled maximum SEL (maximum level at any depth) contour for source location S. X, Y axis distances in m. *Source*: OSC (2025).

Higher noise attenuations are predicted for the propagation paths with upslope bathymetry profiles, particularly for the directions towards the continental slope sections, due to the lower reflection coefficient at higher grazing angles for the silty seabed. The paths towards deep water tend to favour noise propagation. Received noise levels are predicted to be lower than 110 dB re 1μPa²·s at coastal areas.

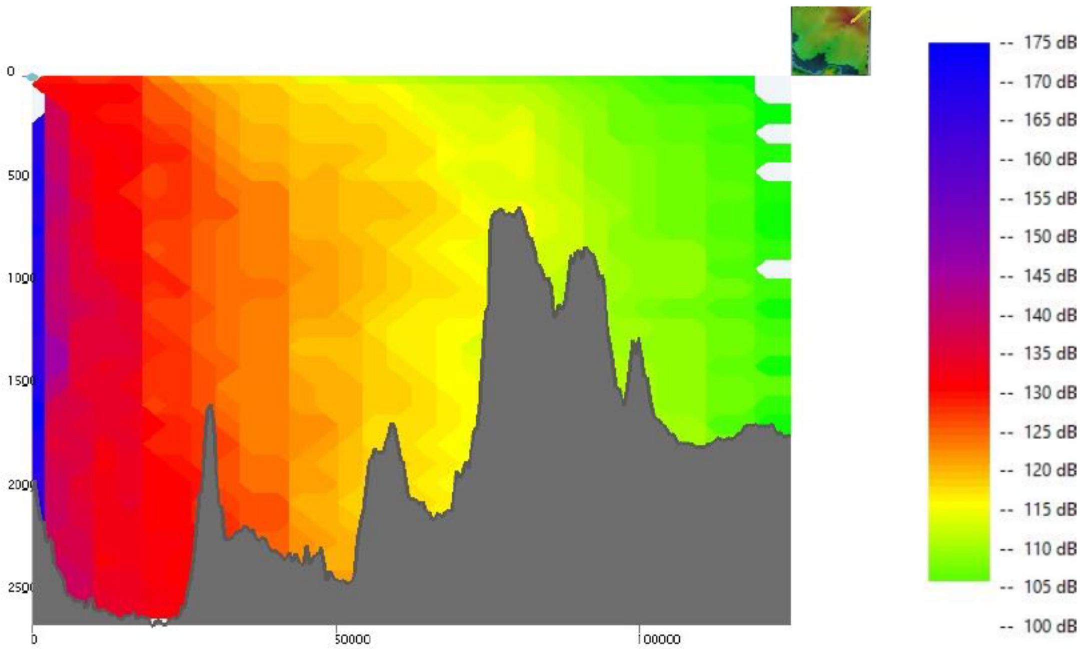


Figure 37: Modelled SELs vs. range and depth along the propagation path towards northeast cross-line direction from the source location S. X, Y axis distances in m. *Source*: OSC (2025).

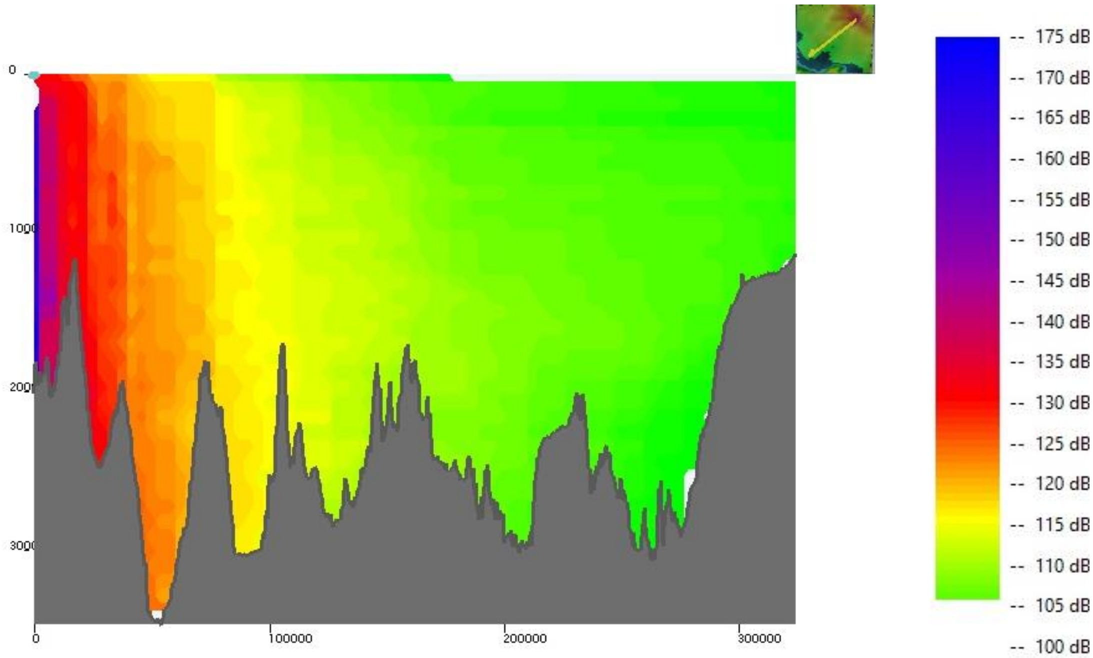


Figure 38: Modelled SELs vs. range and depth along the propagation path towards southwest cross-line direction from the source location S. X, Y axis distances in m. *Source*: OSC (2025).

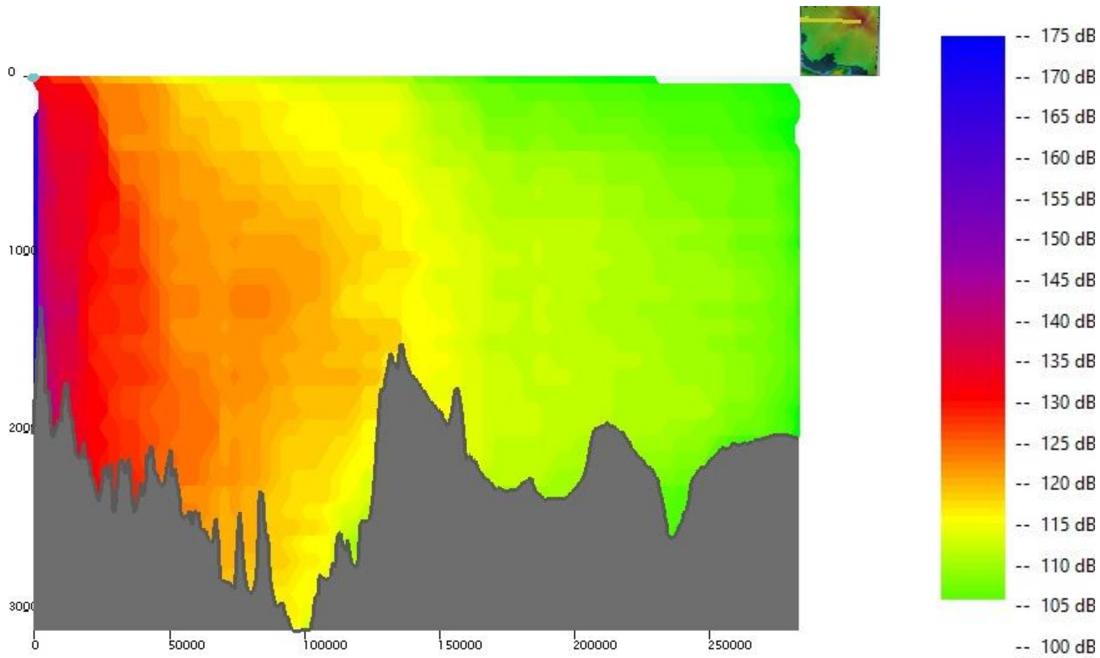


Figure 39: Modelled SELs vs range and depth along the propagation path towards west cross-line direction from the source location S. X, Y axis distances in m. *Source*: OSC (2025).

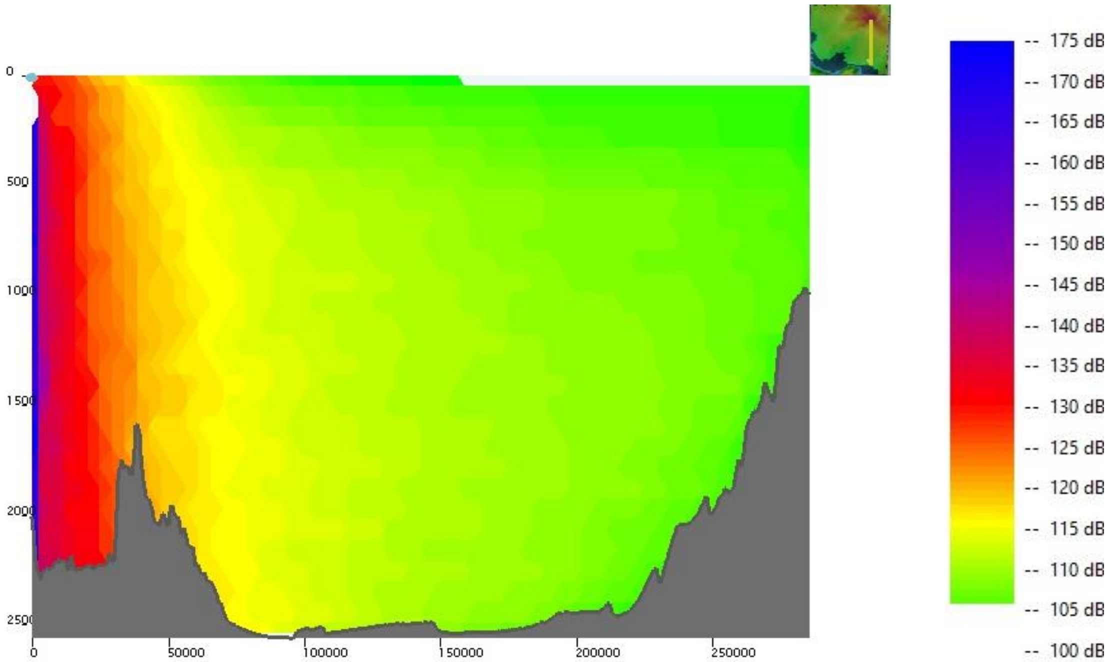


Figure 40: Modelled SELs vs range and depth along the propagation path towards south cross-line direction from the source location S. X, Y axis distances in m. *Source*: OSC (2025).

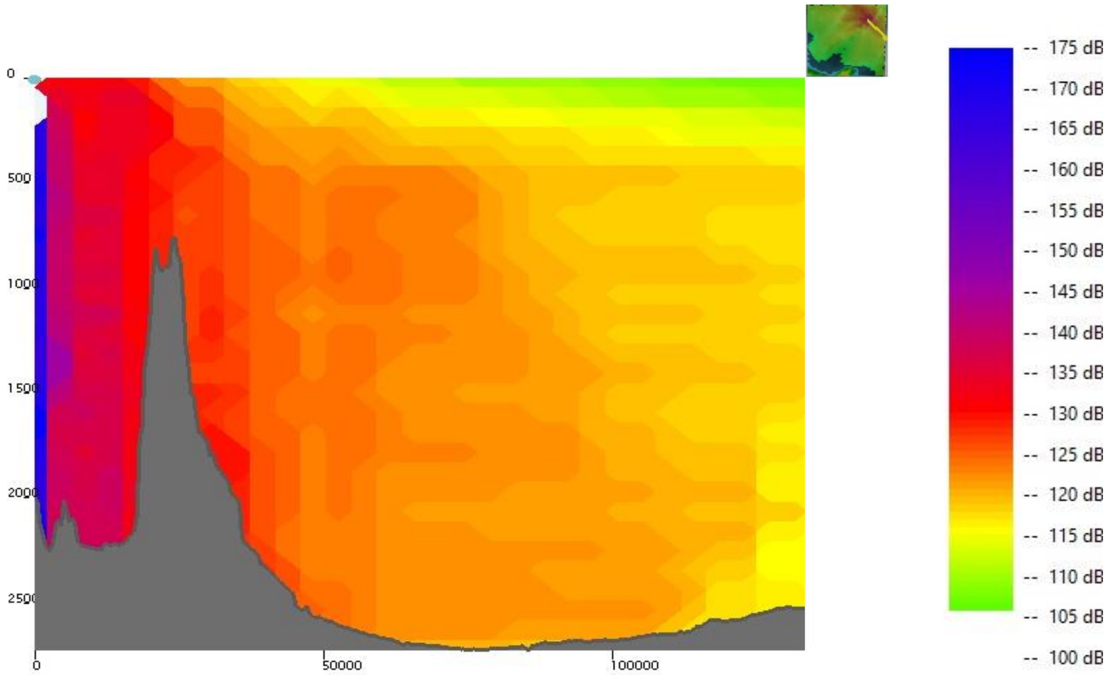


Figure 41: Modelled SELs vs range and depth along the propagation path towards southeast cross-line direction from the source location S. X, Y axis distances in m. *Source*: OSC (2025).

Conclusions

GEOMAR proposes to undertake a 3D marine seismic survey in the Kermadec Arc in May 2025. This appendix details the STLM study that has been carried out for the proposed survey, which includes three modelling components: array source modelling, short range modelling, and long-range modelling.

The acoustic source array configuration that will be used for the BRASS survey is the proposed 5,420 CUI (in^3) source array. The array source modelling illustrates distinctive array directivity of angle and frequency dependence for the energy radiation from the array, as a result of interference between signals from different array elements.

The short-range modelling predictions using worst case modelling conditions (*i.e.* the seasonal sound speed profile of autumn and a clayey silt seabed) demonstrate that the maximum received SELs over all azimuths are predicted to be below 186 dB re $1\mu Pa^2 \cdot s$ at 200 m and below 171 dB re $1\mu Pa^2 \cdot s$ at 1.0 km for the selected short-range modelling source location. Although the volume of the seismic source array is comparatively large, the deep water within the survey area (average 2,000 m) and relatively weak directivities of the source array result in energy emissions from the source dissipating more evenly over the water column and azimuths.

The long-range modelling shows that the received SELs vary at different angles and distances from the source. This directivity of received levels is due to a combination of the directivity of the source array, and particularly the propagation effects caused by bathymetry and sound speed profile variations.

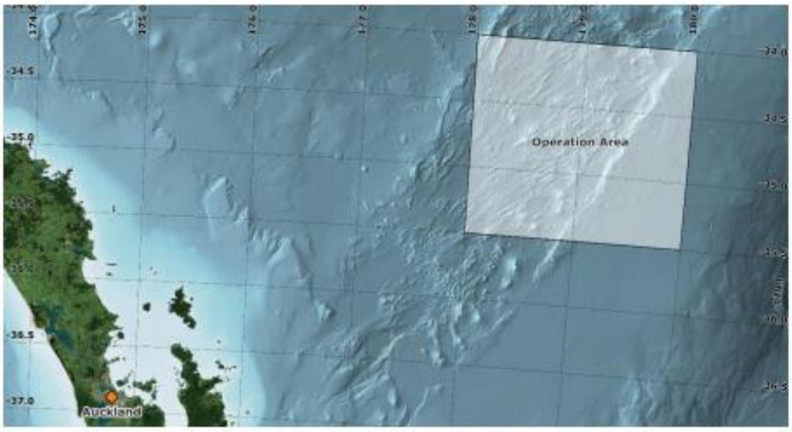
The received noise levels within the coastal areas from the relevant long range source location are predicted to be below 110 dB re $1\mu Pa^2 \cdot s$. For Te Paepae o Aotea (Volkner Rocks) Marine Reserve, the received noise levels are predicted to be 115 dB re $1\mu Pa^2 \cdot s$. At the nearest 12 nautical mile offshore boundary to each of the long-range source locations, the received noise levels are predicted to be up to 110 dB - 120 dB re $1\mu Pa^2 \cdot s$.

APPENDIX C – STAKEHOLDER ENGAGMENT

Consultations were undertaken with undertaken with key stakeholders, *iwi*, and *tangata whenua* that were identified in relation to the seismic activities within the Kermadec Ridge. A poster was provided for communities (**Figure 42**) and a letter (**Figure 43**) was sent *via* email to key contacts (**Table 27**).

Kermadec Arc Research Cruise

Information for the local community



GEOMAR Helmholtz Centre for Ocean Research Kiel is one of the world's leading institutions in marine research. In May 2025, GEOMAR will be involved in a research cruise aboard a German research vessel (*RV Sonne*) in New Zealand waters. In this work they will be supported by Ocean Science Consulting (OSC) Asia-Pacific who specialise in underwater noise and its impact on marine mammals and other wildlife.

At the beginning of the cruise a large airgun survey will be undertaken for five days with a 3,000 cubic inch G-gun array. During this period two trained Marine Mammal Observers (MMO) and two Passive Acoustic Monitoring Operators (PAMO) will always be onboard. Passive Acoustic Monitoring (PAM) will be undertaken 24 hours a day during operations to detect the presence of marine mammals. Following this only the MMOs will remain onboard.

Seismic exploration includes the input of sound into the marine environment at frequencies that overlap with auditory frequencies used by many marine mammals. Impacts vary species to species but can include behavioural changes and hearing loss.

Environmental responsibility

GEOMAR and OSC understand their environmental duty and are undertaking this Marine Mammal Impact Assessment to greater understand the risks and potential impacts in this area. OSC is an industry leader to conducting safe operations in environmentally sensitive areas and both companies will ensure that all seismic activity will adhere to the Department of Conservations Code of Conduct for minimising acoustic disturbance to marine mammals.

Please contact Dr. Matt Sharpe (Head of Acoustics) and Áine Thomas (Marine Consultant) via email at ms@osc.co.uk, at@osc.co.uk, and projects@osc.co.uk should you have any questions concerning the survey.

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T: +44 (0)1368 865 722 ● E: info@osc.co.uk ● W: www.osc.co.uk
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Figure 42: Information poster provided for communities. *Source*: OSC (2025).

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NZ ASIA-PACIFIC

17/01/2025

M: [redacted]
T: [redacted]
E: at@osc.co.uk
projects@osc.co.uk

2025 Scientific Survey – Kermadec Ridge by GEOMAR Helmholtz Centre for Ocean Research Kiel

Dear Sir/Madam,

We write on behalf of the GEOMAR Helmholtz Centre for Ocean Research Kiel regarding the Marine Mammal Impact Assessment (MMIA) for a scientific seismic acquisition survey, which is currently schedule for 2nd May to 29th May 2025. During approximately five days of the four-week survey, seismic airguns will be utilised. Further information regarding the mitigation measures to be taken during the survey and a brief explanation of the effects of underwater noise on marine mammals are provided in the accompanying summary sheet.

Ocean Science Consulting (Asia-Pacific) Ltd has been appointed to undertake an MMIA in advance of the survey and provide personnel for the survey. The aim of the MMIA is to determine the potential impact on local marine mammal populations. The team is currently collating data and undertaking a consultation of all relevant stakeholders in accordance with the guidelines of the '2013 Code of Conduct for minimising acoustic disturbance to marine mammals from seismic survey operations', published by the New Zealand Department of Conservation.

To assist us with compiling a robust MMIA, we welcome any comments or concerns you may consider relevant to either the assessment itself, or the survey. We are working to a strict schedule, and would there be grateful if you could respond at the first possible instance or at least by 31 January 2025.

Please do not hesitate to contact us with any queries you may have regarding the proposal.

Yours sincerely,
Áine Thomas
Marine Consultant

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Figure 43: Letter sent to with key stakeholders, *iwi*, and *tangata whenua*. *Source*: OSC (2025).

Name of Organisation	Type/date of contact	Comments received	Outcome
Dave Lundquist – Department of Conservation	17/01/2025 email 27/01/2025 response & email	Recommendation to contact Ngāti Kuri, Te Aupouri, Rochelle Constantine, and Tom Trsnki	First three recommendations already contacted, Tom Trsnki contacted 27/01/2025
Malene Felsing – Department of Conservation	17/01/2025 email 19/01/2025 response 20/01/2025 email 27/01/2025 response 28/01/2025 email	Will liaise with people internally who can provide guidance on which iwi to engage with Recommendation to contact Ngāti Kuri and Te Aupouri	Already contacted recommended
Ngāti Kuri Iwi Trust Board	17/01/2025 email 27/01/2025 phone declined 28/01/2025 left voice mail		
Te Rūnanga-ā-Iwi o Ngāti Kahu	17/01/2025 email 27/01/2025 phone declined 28/01/2025 phone	Confirmation it has been forwarded to Rueben, their marine guy, and is seeking permission from their managers to send it on to the Māori they work with	
Te Runanga Nui o Te Aupouri Trust	17/01/2025 email 27/01/2025 phone declined 28/01/2025 phone voice mail		
Auckland Council	27/01/2025 phone declined 28/01/2025 phone		
Sealord	17/01/2025 email 27/01/2025 phone declined 28/01/2025 line busy		
Sanford Fisheries	17/01/2025 email 27/01/2025 phone to voice mail		
Department of Conservation – National Office	17/01/2025 email 27/01/2025 phone 27/01/2025 email	Given personal email to forward initial contact to.	

Department of Conservation – Auckland Office	17/01/2025 email		
University of Auckland – Dr Rochelle Constantine	17/01/2025 email		
Massey University - Dr Karen Stockin	17/01/2025 email		
Port of Auckland	17/01/2025 call & email		
Project Jonah	28/01/2025 phone voice mail left		
NZ Whale and Dolphin Trust	17/01/2025 email 27/01/2025 phone declined 28/01/2025 phone malfunctioned, no noise on other end of line 03/02/2025 email response	'Confident that sperm whales inhabit the waters where you are planning your survey from towed array data collected in 2003. Concerns about impact from seismic surveys on deep diving species. No time to contribute further but interest in data from survey being made available.'	Data will be provided to NZ Whale and Dolphin Trust after review.
Te Ohu Kaimoan	17/01/2025 email		
Environmental Protection Authority	17/01/2025 email 22/01/2025 response 29/01/2025 GM response	Enquiry passed on to General Manger, response expected in 10 working days. 'No comment to provide.'	
Te Hiku / Kaitaia Office	17/01/2025 email		
Tom Trsnki	27/01/2025 research gate		

Table 27: List of key stakeholders, *iwi*, and *tangata whenua* contact dates and responses. *Source*: OSC (2025)

APPENDIX D - SPECIES OF CONCERN

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

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

Table 28: Species of concern. *Source*: DOC (2013).