ATTACHMENT ELEVEN

Assessment of Underwater Noise Effects (Styles Group)

McCALLUM BROS LTD

Established 1904

Styles Group
Underwater Acoustics

ASSESSMENT OF UNDERWATER NOISE LEVELS

PROPOSED SAND EXTRACTION: TE ĀKAU BREAM BAY

PREPARED FOR

McCallum Bros Limited®

DATE

10 April 2025

Assessment prepared by Styles Group for McCallum Bros Limited®.

REVISION HISTORY

Rev:	Date:	Comment:	Version:	Prepared by:	Reviewed by:
1	7/11/24	Confidential draft for client review.	Draft	Matt Pine, PhD MASNZ Principal Styles Group	Jon Styles, MASNZ Director and Principal Styles Group
2	18/11/24	Confidential draft for client review.	Draft	Matt Pine, PhD MASNZ Principal Styles Group	Jon Styles, MASNZ Director and Principal Styles Group
3	12/02/25	Update to include turtles and NZ effects terms	Draft	Matt Pine, PhD MASNZ Principal Styles Group	Jon Styles, MASNZ Director and Principal Styles Group
4	1/04/25	Confidential draft for final team/legal review.	Final Draft	Matt Pine, PhD MASNZ Principal Styles Group	Jon Styles, MASNZ Director and Principal Styles Group
5	10/04/25	Final for Issue.	Final	Matt Pine, PhD MASNZ Principal Styles Group	Jon Styles, MASNZ Director and Principal Styles Group

Table of Contents

Figures

List of Tables

Appendices

Appendix H	Vessel and extraction noise models
Appendix I	Sound source characterisation for the TSHD *William Fraser*

Acronym List

AIS: Automatic Identification System
CPA: Closest Point of Approach
EF: Energy-Flux
EFRD: Energy-Flux Range Dependent
Fc: Centre-Frequency
HF: High-Frequency
LEQ: Equivalent Continuous Sound Level
LTSA: Long-Term Spectral Average
LSR: Listening Space Reduction
LF: Low-Frequency
NOAA: National Oceanic Atmospheric Administration
OCW: Otariid Carnivore in Water
PCW: Phocid Carnivore in Water
PSD: Power Spectral Density
PTS: Permanent Threshold Shift
PTL: Port Taranaki Ltd
SE: Signal Excess
SEL: Sound Exposure Level
SPL: Sound Pressure Level
SOG: Speed Over Ground
TOL: Third Octave Level
TSHD: Trail-Suction-Hopper Dredger
TTS: Temporary Threshold Shift
URN: Underwater Radiated Noise
VHF: Very High-Frequency

Note from Author

Code of Conduct Reference for Application Material

Although this is not a hearing before the Environment Court, I record that I have read and agree to comply with the Environment Court's Code of Conduct for Expert Witnesses as specified in the Environment Court's Practice Note 2023 as relevant to preparation of a report for this Fast-track application. In particular, I confirm that this report is within my area of expertise, except where I state that I rely upon the evidence or reports of other expert witnesses lodged forming part of the project's application material. I have not omitted to consider any material facts known to me that might alter or detract from the opinions expressed.

Foreword

This report is technical. It describes advanced underwater noise modelling techniques, assessment methods and results that are complex and often esoteric. This report has been prepared to inform specific ecological assessments. This report contains results and conclusions that describe potential effects based on models prepared using input data specific to Te Ākau Bream Bay. The results and conclusions of this report have been developed for the specific purpose of informing the more detailed ecological reports that accompany the application. These specific ecological reports set out the potential effects on specific species and habitats in Te Ākau Bream Bay, and the conclusions of these reports take precedence over this report.

This report aims to be accessible to a range of different audiences, ranging from technical acoustic experts, academics, ecologists, planners, lawyers, decision makers and the lay person. Readers are cautioned that the report's broad scope has necessitated some simplified descriptions or generalisations of technical concepts. As a consequence, careful consideration of the context and potential limitations of the terminology, technical concepts, and conclusions presented is advised.

Executive Summary

Styles Group has predicted the underwater noise levels from the proposed sand extraction activities in the Te Ākau Bream Bay embayment. This report has been prepared to accompany the resource consent application and Assessment of Environmental Effects for the proposal.

The purpose of this assessment is to set out the general nature and extent of underwater noise levels and to quantify the spatial extent of acoustic-related effects/impacts on the different marine taxa (**animal groups**).

The results of our assessment inform the specialist ecology reports on marine mammals, benthic ecology, avifauna, and fisheries. These specialist assessments deal with the potential effects in the context of the overall marine ecology, species populations and ecological communities specifically within Te Ākau Bream Bay.

Noise criteria

This report presents the modelling of underwater noise levels using international guidelines for noise effects on marine mammals and peer-reviewed studies for kororā (little penguin), fishes, invertebrates and sea turtles.

We have adopted the thresholds set out in the marine mammal acoustic technical guidance (updated in 2024) from the National Marine Fisheries Service of the U.S. Department of Commerce and the methods used in peer-reviewed scientific studies where specific thresholds or specific technical guidance is not available.

These international studies and guidance documents use effects-rating frameworks, or levels, that are dependent on the type of effect/impact and the animal groups being assessed.

We have summarised the overall level of effects/impacts using a framework that is more often applied in a New Zealand (NZ) regulatory environment. The framework is described in Table 2 of this report.

Noise effects on marine life

It is widely accepted internationally that underwater noise has the potential to cause detrimental impacts on marine mammals, fishes, invertebrates, seabirds and sea turtles.

The five primary effect categories that are relevant to the animal groups in Te Ākau Bream Bay are physiological effects, behavioural effects, masking effects, simple audibility and anthrophony/soundscape changes.

Generally speaking, the significance of these effect categories are relative to the distance between the anthropogenic noise source and the animal receiver, with physiological impacts occurring closest to the source and audibility being the furthest.

Auditory masking is an important impact because it can occur over a large area (transversing multiple habitat boundaries), have an indiscriminate impact on species, and lead to behavioural changes if the masking level is high or sustained.

The simple audibility of a sound does not necessarily mean there will be an impact. But understanding the spatial extent of audibility can help regulators/decision makers understand the maximum extent of even the smallest effects that might occur.

The rationale and methods used for quantifying the different effect categories for each animal group is provided in Table 1.

Physiological effects

Physiological effects include the risk of auditory injury and temporary threshold shift or hearing loss.

Our modelling demonstrates that there is no risk of auditory injury or temporary threshold shift for marine mammals beyond 0.5m from the TSHD "*William Fraser"* when it is actively extracting sand.

The spatial extent of the potential onset of auditory injury and temporary threshold shift (or hearing loss) in fishes, invertebrates, kororā/little penguins and sea turtles were unable to be quantified with specific ranges due to a lack of thresholds in the scientific literature.

Behavioural effects

Behavioural effects/responses include a large range of effects from small changes such as vigilance, brief interruptions to activity and minor changes that will not have a significant impact when intermittent over short time frames, to medium sized behavioural changes that are increasingly likely to have negative consequences on an individual by increasing disruptions to essential behaviours.

Behavioural responses in cetaceans were quantified using dose-response functions based on the recommendations in Southall et al. (2021).

Dose-response functions were unavailable for pinnipeds so step-function thresholds were used to predict ranges within which fur seals and leopard seals may show a behavioural change.

Neither step function thresholds, or dose-response functions were available for kororā/little penguins, fishes, invertebrates, or sea turtles. Auditory masking ranges were quantified for these groups (as well as marine mammals) as higher levels (>75% reduction in active listening space, for example) could indicate an onset potential for behavioural changes in these animal groups.

Our modelling demonstrates that small behavioural response in baleen whales (including Bryde's whales) could occur (i.e., >0% probability of occurring) at up to 1115m from the TSHD actively extracting. Small behavioural responses could be possible within 596m for delphinids and 700m for pinnipeds.

Medium level behavioural response in pinnipeds and delphinids could occur within 203m and 227m, respectively, from the TSHD actively extracting.

Medium level responses in baleens could not be determined with the required level of certainty due to an absence of relevant data. These will however occur in an area substantially smaller than the ranges over which a small response was calculated (i.e., 1115m).

Small behavioural responses in fishes, invertebrates, kororā/little penguin, and sea turtles were unable to be determined accurately due to an absence of relevant data. However, our assessment is that small responses are unlikely to occur beyond 205m. Beyond 205m, the level of masking is likely too low (i.e., below 75% reduction in an animal's active listening space) for the onset of small behavioural responses.

Auditory masking effects

Auditory masking is the interference of a biologically important signal (such as vocalisations) by an unimportant noise (i.e., anthropogenic noise in this case) that prevents the listener from properly perceiving the signal.

Masking release mechanisms are various strategies that allow an animal to continue detecting and discriminating ecologically important signals in noisy environments, thereby allowing them to overcome the effects of masking in some cases.

Our assessment of auditory masking is informed by our own measurements of the ambient sound levels within the proposed extraction area between May and June 2024.

Baleen whales are generally the more sensitive of animals to auditory masking effects compared to other marine mammals (i.e., delphinids and pinnipeds) due to their peak hearing sensitivities and vocalisations overlapping very well with the low-frequency noise from the TSHD. The lowest level of auditory masking effects for baleen whales could occur within 16.2km from the TSHD actively extracting (i.e., >0% reduction of their active listening space (LSR) may occur). However, the level of masking effects at that range is **Negligible** and it is not until an individual baleen whale is within 2.8km that a 50% LSR occurs. This is a small effect since the TSHD is a moving noise source at a constant speed of 1.5-2.5 knots (while extracting) and the animal's masking release mechanisms are unlikely to be overwhelmed.

Auditory masking effects (50% LSR) could occur within 2.02 – 2.66km for pinnipeds (both phocid and otariid species).

Delphinids have mid-to-high frequency peak hearing sensitivities and vocal behaviours and are therefore less sensitive to auditory masking effects. Small masking effects could occur within 933m and medium-level masking effects could occur within 170m, compared to 319m for NZ fur seals (Otariidae).

Low level masking effects calculated from particle acceleration audiograms for common triplefins and the NZ bigeye can be expected for fishes within 333m to 607m. These species are common in northern NZ reefs and both rely on sound during several life-history stages. The 300m range between these two species is because the NZ bigeye's audiogram shows a more sensitive hearing than the common triplefin. Since NZ Bigeye's are highly vocal, with specialist hearing structures that allow them to also detect sound pressure at lower levels, they were used to represent the upper limit (worst case) of masking effects in fishes that can be found in the sandy bottom habitats in Te Ākau Bream Bay. Based on the same particle acceleration models and crustacean audiograms (NZ paddlecrab and snapping shrimp), invertebrates could experience low level masking effects within 151m from the TSHD actively extracting, increasing to low-medium levels within 113-132m.

Kororā/little penguins and sea turtles are also susceptible to possible masking effects, with low-medium level effects occurring within 135m and 185m, respectively.

Audibility

Audibility of the anthropogenic noise simply means that an animal may hear the noise from the TSHD actively extracting sand, including when other sounds are at their quietest. The simple audibility of an anthropogenic noise does not necessarily mean there will be detrimental effects on an animal group. The spatial extent of audibility is simply the maximum range at which the sound of sand extraction may be audible.

The audibility ranges are calculated in individual frequency bands and the propagation of noise within certain frequency bands relative to the hearing thresholds of the receiving animal.

Audibility ranges in pinnipeds was the highest of all animal groups, at approximately 18.6 – 18.9km.

The audibility range for baleen whales is slightly less at 18km, and substantially less for delphinids at approximately 10.4km.

Audibility ranges for fishes and invertebrates were calculated based on particle acceleration and are up to 2.8km (for fishes) and 189m (for invertebrates).

The audibility range is approximately 5.9km for kororā/little penguins and 4.8km for sea turtles.

Soundscape changes

A soundscape is all sounds within a specific area, including the spectral, temporal and spatial variation of biologically-generated sounds (termed biophony), natural sounds such as wind and rain (termed geophony) and man-made noise (termed anthrophony). The soundscape of Te Ākau Bream Bay is made up of these three sources. Fish, invertebrates and marine mammals make up the bay's biophony, weather and sand movements make up the geophony and vessels (both commercial, shipping and recreational) control the anthrophony. We undertook passive acoustic monitoring as part of the underwater noise assessment to determine how the sand extraction might alter the soundscape in Te Ākau Bream Bay.

We have used cumulative ship noise models based on AIS data for shipping traffic during same period as the passive acoustic monitoring (May – June 2024). This assessment is to understand how the sand extraction will add to the existing anthrophony. Our assessment also assesses the potential increases in the broadband monthly average sound level (referred to as monthly L_{eq}, dB re 1 μPa) arising from adding the sand extraction.

The cumulative noise modelling of AIS traffic and sand extractions demonstrates that the sand extraction may increase the monthly L_{eq} by up to 2 dB re 1 μPa within Te Ākau Bream Bay (outside the extraction area).

The cumulative noise model does not take into account the recreational (non-AIS) boat traffic in the area and the AIS-records for the year we modelled (2024) show vessel movements were the lowest since 2014. AIS traffic in 2024 recorded a total of 866 ship movements (e.g bulkers, tankers, cargo vessels) in and out of Whangārei Harbour (and therefore transiting Te Ākau Bream Bay), compared to 908, 1012, 1068, 1190 during 2023, 2022, 2021, and 2020, respectively. The low AIS traffic in 2024 and absence of any recreational boating traffic in the model will likely mean that the predicted cumulative noise levels are overstated.

The concentrated nature of the sand extraction means that the sand extraction may increase the cumulative noise level by up to 37 dB re 1 μPa inside the extraction area.

Outside Te Ākau Bream Bay, such as Parry Channel which is between Taranga and the islands of the Marotere group (Hen and Chicken Islands) and the bay's northern and southern headlands, the current level of shipping is high enough that there are very low cumulative effects from the extraction activity on the ambient sound levels (i.e., <1 dB re 1 μPa).

1.0 Introduction

McCallum Bros Limited® (**MBL**) has engaged Styles Group to provide an underwater noise assessment of the proposed sand extraction activities in the coastal marine area of Te Ākau Bream Bay (**the Project**).

The purpose of this underwater noise assessment is

- To demonstrate the nature and extent of noise emissions,
- Quantify, if any, the spatial extent of various acoustic-related effects on marine fauna within Te Ākau Bream Bay.

This assessment is for the purposes of informing the specialist ecology reports, and as such, discussion of the results and conclusions around effects/impact levels on various marine taxa in the context of Te Ākau Bream Bay's ecology and literature are contained in those reports.

1.1 Aims of this assessment

The underwater noise assessment has the following aims:

- To set out the predicted noise levels from the trailing-suction hopper dredge (**TSHD**) *William Fraser* while extracting within the proposed extraction area.
- To provide underwater cumulative noise models of the existing anthropogenic noise environment from vessels based on the AIS records between April and June 2024.
- To provide underwater cumulative noise models of the TSHD *William Fraser* while extracting within the proposed extraction area.
- To use cumulative noise models to show the potential cumulative noise effects on the existing anthropogenic soundscape.
- To use the predicted noise levels to determine the potential effects radii for marine mammals, fishes, invertebrates, kororā/little penguins, and sea turtles to inform the ecological assessments.

Discussion of the modelled effects radii in the context of Te Ākau Bream Bay is provided in the marine mammal, fisheries, benthic ecology and avifauna reports. The underwater noise levels and ranges within which certain effects may occur inform those reports.

2.0 The site and proposal

MBL is seeking a coastal permit to undertake sand extraction in the Te Ākau Bream Bay embayment for up to 35 years. Figure 1 shows the proposed sand extraction area and distance (m) to shore.

The proposed extraction volumes are:

- 150,000m^3 per annum for the first 3 years, and;
- Maximum of 250,000m^3 per annum for the remaining 32 years.

This assessment therefore reflects these two extraction volumes, where appropriate. From an underwater noise effects perspective, an increase by 100,000m^3 will lead to an increase in the number of trips per month (increase of 9 trips per month), and therefore changes in the cumulative noise exposure for marine mammals.

The TSHD *William Fraser* has undergone several upgrades/alterations to improve extraction efficiency so to reduce the time for which the activity will be occurring per day. These improvements mean the hopper is filled quicker and therefore can be filled in 3.5 hours instead of the historical times of up to 6 hours. As such, the sand extraction itself will operate under the following restrictions:

- The extraction activity within the proposed extraction area will be a maximum of 3.5 hours per day.
- The extraction windows will be between 12:00hrs and 18:00hrs (April – September) and 12:00hrs to 20:00hrs (October – March) only. This timing is to align with daylight hours and during the afternoon when ambient sound levels will be higher due to recreational vessel activity and when marine mammals are not resting (SLR 2025).

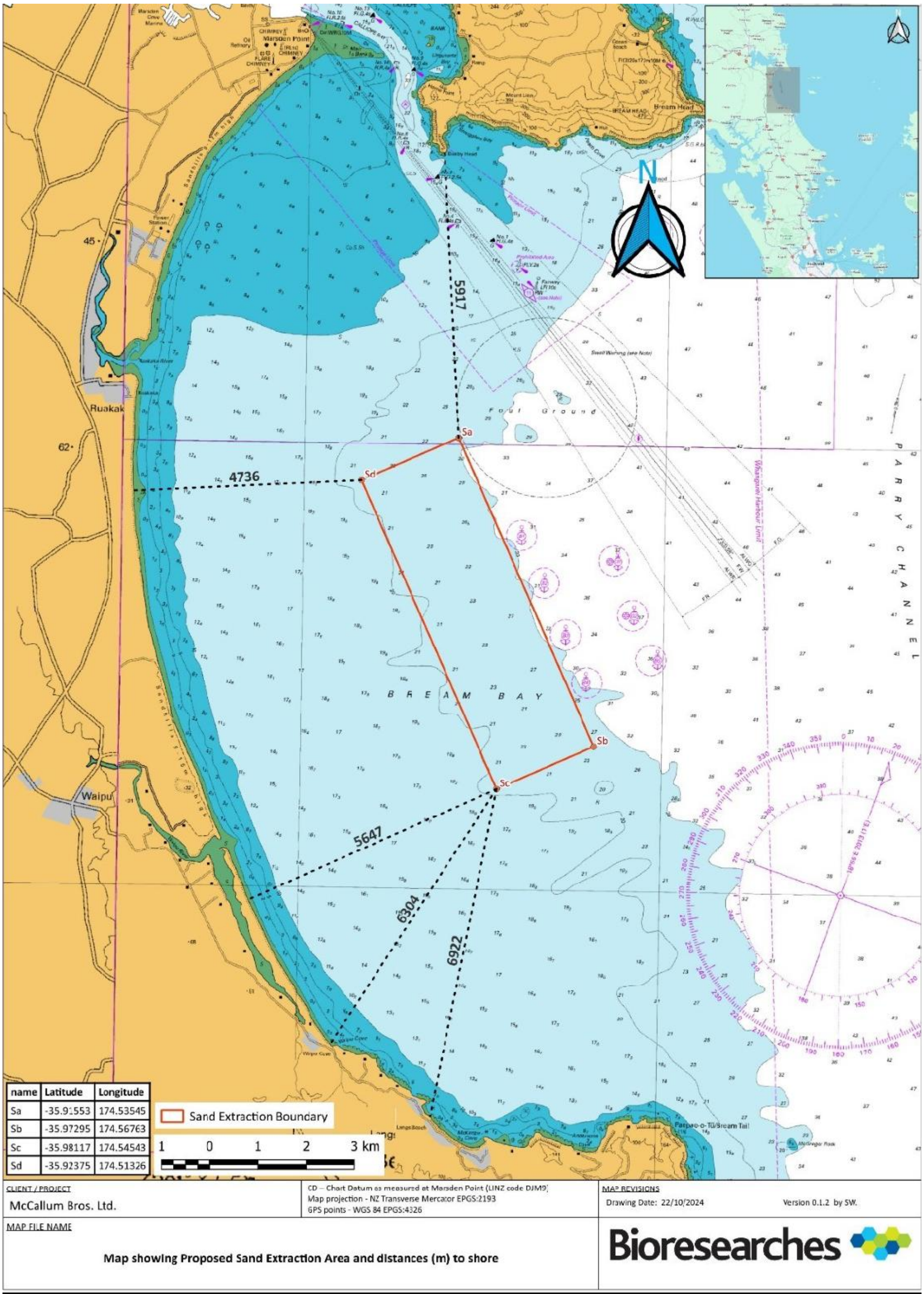

Figure 1: Map showing the proposed sand extraction area and distances (m) to shore.

3.0 Assessing levels of acoustic-related effects

There is a growing body of evidence that underwater noise pollution can, and does, have detrimental impacts on marine mammals, fish, invertebrates, seabirds and sea turtles. Approximately 538 studies have been recently reviewed in a 2021 review paper, providing a relatively high level of confidence that anthropogenic noise can negatively affect marine fauna (Duarte et al. 2021). Specifically, a significant percentage of quantitative studies report negative impacts across a variety of noise sources, including vessels, sonars, acoustic deterrent devices, energy and construction infrastructure and seismic surveys (Figure 2, taken directly from Duarte et al. 2021). While underwater noise is typically a point- source pollutant (Duarte et al. 2021) with effects that decline when the source is removed, it should be included in assessment of cumulative pressures on marine ecosystems.

This report constitutes a comprehensive assessment of the underwater noise associated from the sand extraction activity, both instantaneous and cumulative. It is based on advanced computer modelling of the noise propagation field that is generated by the TSHD *William Fraser*. The models are then used as the basis for assessing the level of effect on marine mammals, fishes, invertebrates, kororā/little penguins, and sea turtles.

The purpose of the underwater noise assessment is to quantify the spatial extent of various effects related to marine fauna, using the available data from international technical guidance and peer-reviewed studies. A complete discussion of the underwater noise effects on various animal groups in the context of the ecology of Te Ākau Bream Bay are not contained within this report. Instead, that is provided in the specialist ecology reports (marine mammals, benthic ecology, fisheries, and avifauna), where the level of impact on the bay's ecology is assessed.

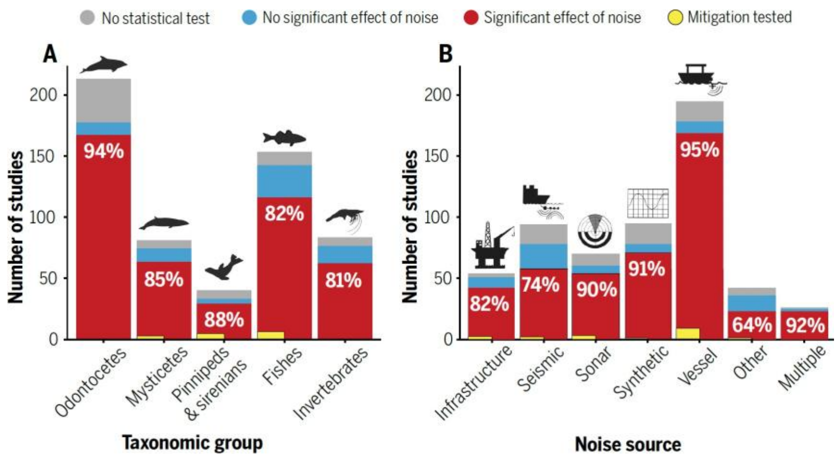

Figure 2: Plot showing the number of studies reviewed in Duarte et al. (2021), broken down by taxa (A) and anthropogenic noise source (B). The percentages represent the proportion of studies that report evidence of impacts (of any magnitude). The plot is taken directly from Duarte et al. (2021).

3.1 Noise criteria and applying international technical guidance and peer-reviewed studies to the assessment.

This report describes the modelling of underwater noise that has been undertaken to inform the effects on the marine environment using international guidelines for noise effects and peer-reviewed studies on marine mammals, fishes, invertebrates, sea turtles, and kororā/little penguins. Based on the current state of knowledge, there are five effect categories that are relevant to all marine fauna in Te Ākau Bream Bay. These are:

1. **Physiological effects**: Include auditory injury that may or may not result in permanent hearing loss (termed permanent threshold shift, PTS). Also includes temporary hearing loss (temporary threshold shift, TTS).

2. **Behavioural effects**: Behavioural responses or changes due to the anthropogenic noise exposure.

3. **Masking effects**: The interruption or interference of a biologically important signal by an invading noise (i.e., a masking noise).

4. **Audibility**: Where the anthropogenic noise is at the level of the background noise or hearing threshold in some critical bandwidth, and signals the animal is aware of the source's presence simply by being able to hear it. It does not mean an effect.

5. **Anthrophony/Soundscape changes**: Changes to the background noise levels or soundscape.

Generally speaking, the severity of effects (as termed in the literature or guidance, for example Southall et al. (2019, 2021)) decreases with increasing range from the noise source (see Figure 3). Physiological effects generally occur closest to a noise source and can have direct impacts on an animal's survival, foraging, and reproduction (referred to as *vital tracks* or *vital rates* (Southall et al. 2021))[1]. Behavioural effects can range from minor to major (that can impact an individual's vital rates) depending on many variables, but generally beginning at the higher levels of masking. Masking in and of itself is not necessarily a significant effect if the masking is short-lived and/or mild, but when it reaches a level that overwhelms an individual's masking release mechanisms, is complete, or continuous enough at those higher levels, animals will alter their behaviours to escape the noise or move away, potentially to a less suitable habitat (which would be a significant effect).

[1]Vital tracks/rates are the three parallel categories within the severity scale in field studies for free-ranging (i.e., wild) marine mammals that can be considered, based on their impact on individual fitness and population parameters (Southall et al. 2021).

Figure 3: Effects categories in order of increasing distance from the noise source.

While these effects categories relate to all marine fauna, not all of the effects categories could be specifically predicted (i.e., effects ranges being calculated) for all marine animal groups (being cetaceans, pinnipeds, fishes, invertebrates, kororā/little penguins, and sea turtles) due to data deficiencies in the scientific literature. Table 1 provides details on the overall method used for each effect category and which animal group were included in each effect category.

Table 1: Methods used for assessing effects in this assessment for certain animal groups.

Effects category	Assessment Guidance/Methods used.	Rationale for use	Relevant animal group
Physiological	NMFS 2024	International standard for physiological effects threshold	Cetaceans, Pinnipeds
	Safe-distance method	National Marine Fisheries Service (NMFS) discussed method for assessment a stable moving source	Cetaceans, Pinnipeds.
	ANSI draft guidance (Popper et al. (2014))	Scientific standard for physiological effects in fishes and turtles.	Fishes*.
Lack of thresholds/guidance for invertebrates, kororā/little penguins and sea turtles.			
Behavioural	Probabilistic dose-response curves	Recommended in Southall et al. (2021).	Cetaceans
	Step functions		Pinnipeds**.

Effects category	Assessment Guidance/Methods used.	Rationale for use	Relevant animal group
Lack of dose-response curves, step function thresholds or technical guidance for quantifying behavioural risk isopleths for fishes, invertebrates, kororā/little penguins and sea turtles.			
Masking	Active listening space reduction (LSR)	LSR is based on environmental conditions that is better understood and more robust for this application (see Figure 5 for recommendation in Pine et al. 2020).	Cetaceans, Pinnipeds, Fishes, Invertebrates, Kororā/little penguins, sea turtles.
Audibility	Signal excess	Range at which the anthropogenic sound equals either the ambient sound level (L_p) or hearing threshold in some critical bandwidth, i.e. signal exceed is zero (Clark et al. 2009).	Cetaceans, Pinnipeds, Fishes, Invertebrates, Kororā/little penguins, sea turtles.
Anthrophony/Soundscape	Cumulative noise models of existing AIS traffic and the TSHD *William Fraser*, and passive acoustic monitoring data.	No guidance exists for assessing long-term soundscape change effects on marine fauna. Instead, the physical addition of noise to monthly averages and cumulative sound exposure levels was assessed.	Cetaceans, Pinnipeds, Fishes, Invertebrates, Kororā/little penguins, sea turtles.

*We note no thresholds or guidance exists for dredging or vessel noise, and therefore could not be directly applied in this assessment for fishes.

**Only used as no dose-response function available for pinnipeds in Bream Bay, and their different hearing physiology precluded the use functions from cetaceans.

To relate the level of effect using terms that are more commonly used within some New Zealand decision frameworks, each effect in the results would be classed as negligible, very small, small, medium, large, very large and significant. Table 2 explains how these NZ-specific effect levels relate to the levels provided in the scientific literature and international guidelines.

Table 2: Various noise effect levels referred to in this assessment for each of the effects categories.

Effects Category	Effect / Response Score in literature or technical guidance	Explanation	Generic magnitude of effect equivalence to NZ regulatory frameworks.
Physiological			
Auditory Injury	AUD-INJ, including Pernament Treshold Shift (PTS), onset risk	Includes permanent hearing loss	**Very Large/Very High**
Temporary Threshold Shift (hearing loss)	Temporary threshold shift (TTS) onset risk	Temporary hearing loss	**Large/High**
Behavioural			
Behavioural response	Low (Joy et al., 2019) / Response Score 1-3 (Southall et al., 2021).	Represents initial and less severe behavioural changes, primarily involving vigilance, brief interruptions of activities, and minor changes in behaviour. Infrequent low-severity responses may not lead to significant consequences but repeated or cumulative low-severity responses in the same area could potentially have more substantial consequences.	**Very Small to Small/Very Low to Low Negligible** if very infrequent

Effects Category	Effect / Response Score in literature or technical guidance	Explanation	Generic magnitude of effect equivalence to NZ regulatory frameworks.
Behavioural response	Moderate (Joy et al. (2019) / Response Score 4-6 (Southall et al. 2021).	Responses are more severe and are increasingly likely to have negative consequences on an individual by increasing disruptions to essential behaviours. This negatively affects an animal's net fitness through energetic costs, reduced foraging success, impaired social interactions, and decreased reproductive success.	**Small/Low** if short-lived, spatially limited, and unlikely to have immediate or significant energetic or fitness consequences for the individual. For example, a brief cessation of foraging behavior, or brief or minor disruption of mating behaviour, such as a temporary interruption of courtship displays or vocalizations that does not lead to the abandonment of mating opportunities. **Medium/Moderate** if moderate responses are frequent enough. **Large/High** if more severe individual responses, especially if occurring across a significant portion of the population or repeatedly in key individuals (e.g., mothers), are more likely to translate to population-level effects.
Auditory Masking			
Listening Space Reduction (LSR)	75% of animal's listening space lost.	Higher levels of masking, likelihood of behavioural responses occurring increases, especially if sustained.	**Small-Medium/Low-Moderate** for mobile species and/or discrete masking event. **Large/High** if an important habitat with immobile species and sustained at this level of masking.
	50% of animal's listening space lost.	Median level of masking, above which effect on animal increases.	**Very Small/Very Low** if moving noise source and relatively stationary listener, masking release mechanisms can mitigate effect.
	25% of animal's listening space lost.	Low level of masking, unlikely to overwhelm masking release mechanisms by animals.	**Small/Low**

Effects Category	Effect / Response Score in literature or technical guidance	Explanation	Generic magnitude of effect equivalence to NZ regulatory frameworks.
	0% of animal's listening space lost.	No masking.	**Negligible**
Audibility			
	Signal Excess (SE) equals zero.	The noise from the TSHD does not exceed the background noise level or hearing threshold in the relevant critical bandwidths and is therefore inaudible to the listener.	**Negligible**
Anthrophony/Soundscape			
Cumulative increases to monthly average/sound exposure levels.	<1 dB re 1 mPa	Difficult to measure in situ.	**Negligible**
	1-3 dB re 1 mPa	Likely measurable in situ.	**Small/Low**
	4-6 dB re 1 mPa	Measurable in situ.	**Medium/Moderate**
	>7 dB re 1 mPa	Substantial increase that is easily measurable in situ.	**Large/High**

3.2 Species assessed

Throughout this assessment, specific species within Te Ākau Bream Bay are grouped/pooled into larger groups for the purposes of assessing effects. These groups are referred to as *animal groups*[2] and the assessment of each effects category is provided for each of them. This was done because:

- Technical guidance provide data that represent functional hearing groups based on overlapping hearing capabilities, hearing anatomies and acoustic ecologies between certain species. For example, the National Marine Fisheries Service (NMFS (2024)) in the U.S. provide composite audiogram functions for each functional hearing group of marine mammals that represent the various species within Te Ākau Bream Bay. Or, the frequency range of vocalisations overlap, and/or the role of sound in each species' life history is similar, such as for fish or crustacean larva.
- Data on hearing anatomies and hearing thresholds for all species within Te Ākau Bream Bay do not exist. For example, specific audiograms for some fish species are unavailable, but some do share anatomical similarities in hearing structures with some species for which audiogram data are available.

Please refer to Table 3 below for specific details on how these animal groups were defined and the rationale for doing so.

[2] These are cetaceans (whales/dolphins), pinnipeds (seals), fishes, invertevrates, little penguins (kororā), and sea turtles.

Table 3: Species/groups used to represent various species within Te Ākau Bream Bay in this assessment.

Method	Species or groups that data is from to assess effects category in this assessment	Taxa/Species within Bream Bay represented.	Rationale
Physiological Effects			
AUD INJ/TTS Thresholds	Functional hearing groups, as defined in NMFS (2024)	Cetaceans, Pinnipeds (see Table 4)	Species are grouped into their respective functional hearing groups based on a combination of factors related to their hearing capabilities, auditory anatomy and acoustic ecology. Species that overlap in these three general areas are pooled together for quantifying effects ranges.
Behavioural			
Probabilistic dose-response curves	Orca (Southern Residents)	Delphinids	Recent peer-reviewed dose response function using real-world data on a delphinid species that is pooled in the same functional hearing group and compositive audiogram as other dolphin species. Therefore, considered appropriate to represent dolphin species for Te Ākau Bream Bay.
	NMFS (2024) threshold used for continuous noise*.	Mysticetes	NMFS (2024) level used in the dose-response function due to data deficiencies for mysticetes.
Step functions	Southall et al. thresholds for pinnipeds.	Leopard seals, NZ fur seals	Dose-response curve for vessel noise unknown for these species, and hearing anatomy substantially differs to cetaceans.
Auditory masking & audibility			

Method	Species or groups that data is from to assess effects category in this assessment	Taxa/Species within Bream Bay represented.	Rationale
LSR & signal excess (simplified sonar equation)	Functional hearing groups & composite audiograms	Marine mammals (see Table 4)	NMFS (2024) composite audiograms are based on all available audiogram data, which are derived for each functional hearing group after compiling all available hearing threshold data for representative species. These are therefore superior in terms of robustness than using single audiograms for specific species as they can suffer from small sample sizes.
	Little penguin (*Eudyptula minor*) audiogram	Kororā/little penguin (*E. minor*)	Estimated audiogram of same species of penguin from microCT (see Wei et al 2024). This is the best hearing data for *E. minor* at the time of this assessment being written.
	Bigeye (*Pempheris adspera*) & Triplefin (*Forsterygion lapillum*) particle acceleration audiograms.	Fishes	Bigeye possess specialist hearing structures for sound pressure that are not found in snapper (Caiger et al. 2012; Mensinger et al. 2018), john dory or gurnard. However, they do have similar hearing thresholds in particle acceleration to some other species, including triplefins (Radford et al. 2012). NZ Bigeye species present the larger effects ranges for most common species within Te Ākau Bream Bay, including demersal and pelagic species. Triplefins do not have specialist hearing structures for pressure detection (Radford et al. 2013) and therefore could represent the lower ranges of effects for fishes in Te Ākau Bream Bay.
	Snapping Shrimp (*Alpheus richardsoni*) & Paddle Crab (*Ovalipes catharus*) particle acceleration audiograms.	Invertebrates, including all crustaceans.	These are common crustacean species that occur in Te Ākau Bream Bay and for which hearing data are available. They also share similar hearing structures and acoustic ecology with other crustacean species and are likely to be as sensitive, if not more so, to sound as other marine invertebrate groups, particularly around larval orientation and settlement.

Method	Species or groups that data is from to assess effects category in this assessment	Taxa/Species within Bream Bay represented.	Rationale
	Loggerhead (*Caretta caretta*) behavioural audiogram	Sea turtles	Hearing data for loggerhead, green and leatherback turtles are available, and some audiograms are available. Behavioural audiogram for loggerhead turtle was used as the basis for masking assessment as generally lower thresholds than AEPs but also overlapped that of the other species. In lieu of direct evidence and data, these sea turtle species are likely to share psychoacoustic data with those in Te Ākau Bream Bay.
Anthrophony/Soundscape			
Daily, monthly average and cumulative energy shifts in the Te Ākau's anthrophony/soundscape	NMFS Functional hearing groups	Cetaceans, pinnipeds	Anthrophonic/Soundscape changes are based on physical changes in sound energy, summed or averaged over some period. Because there is a good understanding of how marine mammals detect and perceive sound underwater, the use of composite audiograms provides a more focused assessment.
	Unweighted noise levels.	Fishes, Invertebrates, kororā/little penguins, sea turtles.	Generalised audiogram functions for these groups are not available, and therefore assessing effects based on unweighted noise levels provides a more conservative (i.e., worst-case) soundscape change. Notwithstanding, however, fishes and invertebrates are more sensitive to low frequency noise, which is well characterised in these unweighted noise levels.

Table 4: Marine mammal species within Te Ākau Bream Bay, as identified by the project's marine mammal specialist.

Functional hearing group	Generalised hearing range (kHz)	Species	Likelihood of occurrence
High Frequency (HF)	0.15 – 160	Common dolphin	Likely
High Frequency (HF)	0.15 – 160	Bottlenose dolphin	Likely
High Frequency (HF)	0.15 – 160	Killer whale	Likely
Low Frequency (LF)	0.007 – 36	Bryde's whale	Likely
High Frequency (HF)	0.15 – 160	LF pilot whale	Likely
Otariid Pinnipeds (OCW)	0.06 – 68	NZ fur seal	Likely
High Frequency (HF)	0.15 – 160	False killer whales	Likely
Low Frequency (LF)	0.007 – 36	Humpback whale	Possible
Low Frequency (LF)	0.007 – 36	Southern right whale	Possible
Phocid Pinnipeds (PCW)	0.04 – 90	Leopard seal	Possible
Low Frequency (LF)	0.007 – 36	Blue whale	Possible
High Frequency (HF)	0.15 – 160	Gray's beaked whale	Possible
High Frequency (HF)	0.15 – 160	Sperm whale	Possible
Low Frequency (LF)	0.007 – 36	Sei whale	Possible
Low Frequency (LF)	0.007 – 36	Minke whale	Possible

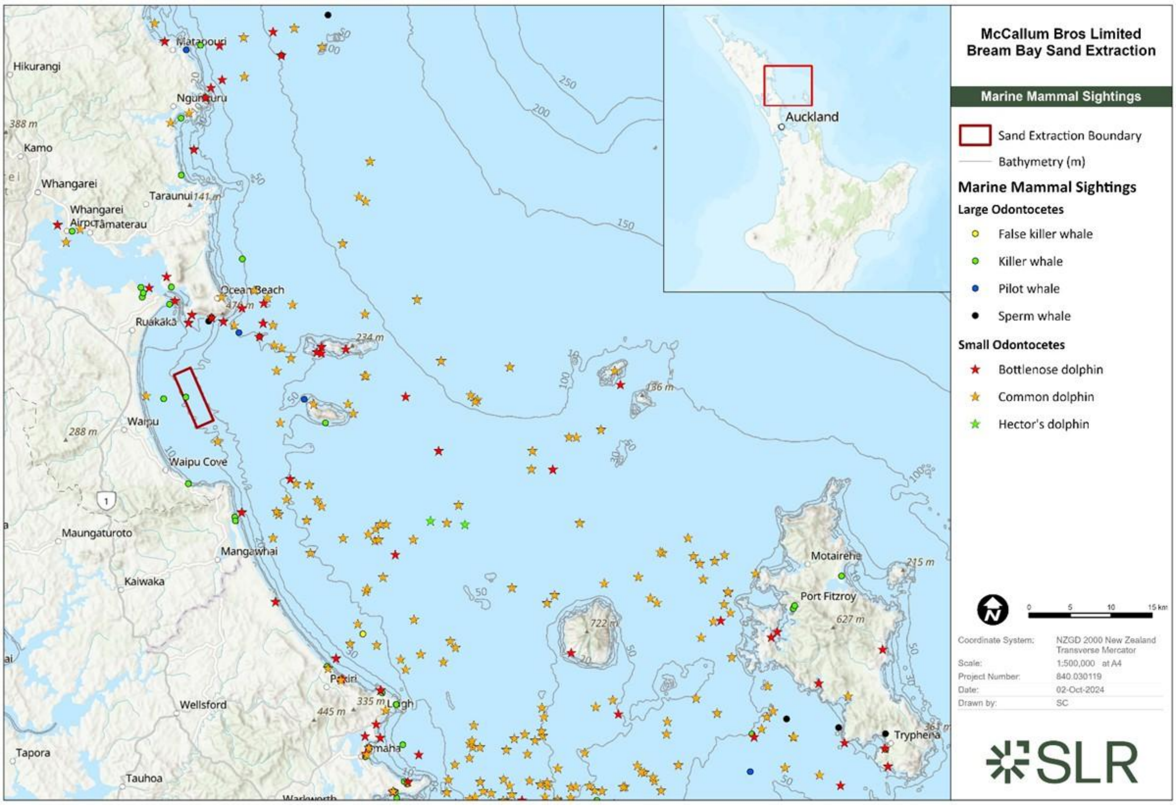

Figure 4: Odontocete sightings reported by DOC in the vicinity of the proposed sand extraction. Note: each depicted point represents a sighting entry within the DOC database, where each sighting entry can be either a single animal or a group of animals. Sightings from 1968 - 2024, Strandings from 1873–2024.

4.0 Underwater noise and effects modelling

We have prepared several underwater noise models to:

- investigate the existing anthropogenic (i.e., vessel) noise within Te Ākau Bream Bay;
- how the proposed sand extraction activity may increase it, and;
- instantaneous effects radii for marine fauna.

Appendices C through I set out the methodology for the underwater noise modelling, as well as effects, including details on the source levels, propagation models, environmental inputs, ground-truthing and effects thresholds/methods used.

The key aspects of the underwater noise modelling and outputs are:

- Empirical source level data of the TSHD *William Fraser* while actively extracting (draghead on seafloor, pumps and generators all operating while the vessel was underway at approximately 1.5-2.5knots[3]) was used in the extraction noise model.

- Existing shipping traffic was modelled from automatic identification system (AIS) data. The source spectrum of each vessel class for the specific vessel speeds (directly from the AIS data) and vessel sizes was estimated using the JONOPANS-ECHO reference ship noise model (see McGillivray & de Jong (2021) for the model and details).

- All noise models incorporated bathymetry, sound speed, frequency-dependent absorption, and seafloor data. The required environmental parameters were provided by NIWA, MBL, Tonkin & Taylor and literature.

- The primary propagation model used was the energy flux (EF) model (Western et al. 1971). The EF model has high computational efficiency over range-dependent scenarios and can be used to model cumulative ship noise (Farcas et al. 2020; de Jong et al. 2021). Due to the models' computational efficiency, very high-resolution models can be used to investigate a range of scenarios. Its use, therefore, presents several advantages for quantifying cumulative noise effects on the existing soundscape, or anthrophony, within Te Ākau Bream Bay.

- Monthly average (L_{eq}) and cumulative sound exposure levels (L_E) from vessels transmitting their positions via AIS[4], were mapped to understand the existing anthrophony of the embayment for the period between April and June 2024.

- The underwater radiated noise from the TSHD *William Fraser* was based on empirical measurements collected during 2019 while in extraction mode (see Appendix I). Noise levels were averaged over a month, resulting in noise maps.

- The cumulative noise models from the extraction were run based on:

    - 150,000m^3 extracted annually, requiring 13 trips per month ((150,000m^3/923m^3 hopper capacity)/12months).

    - 250,000m^3 extracted annually, requiring 22 trips per month ((250,000m^3/923m^3 hopper capacity)/12 months).

- The cumulative noise models from the extraction do not consider future increases in commercial shipping traffic within Te Ākau Bream Bay, increasing use of ship

[3]Also referred to as 'extraction mode'.

[4]Focusing on AIS-carrying vessels is known to substantially underestimate true vessel traffic as it not a requirement for recreational vessels and some commercial vessels maybe not be broadcasting at all times.

anchorages or inter-annual variation in AIS traffic levels. There is also no consideration of recreational boating traffic within Te Ākau Bream Bay.

- Passive acoustic monitoring during May and June 2024 was used to inform the effects modelling. The passive monitoring work included marine mammal detectors for cetaceans (a global detection model using convoluted neural networks was used to detect all species listed in Table 1, while the baleen detection model included a species classifier).
- The resulting noise maps were used to assess each effects category (physiological, behavioural, auditory masking, audibility and anthrophony/soundscape changes. General audibility ranges were also considered as the theoretical maximum area[5] for which the potential onset of the smallest of noise impacts could occur in theory.

Please refer to Appendices B through F for technical details, including the criteria for the assessment of noise effects on marine mammals, along with the rationale for why certain impacts were assessed.

5.0 Results

This section sets out the noise modelling results for the proposed extraction activity with the TSHD *William Fraser*, providing ranges for each effects category (please refer to Table 1).

Appendix G provides the spatial maps for each of these effect categories.

We note that the auditory masking and audibility ranges are based on the median ambient noise levels during the daytime[6] (for all frequency bands) calculated over 8 May and 22 June 2024, representing the median sound levels. Daytime levels only were used because the sand extraction activity will not be operating at night. Anthrophony/Soundscape changes were assessed using averaged modelled levels over the month, above the averaged (Root-Mean-Squared, RMS) daytime ambient sound level.

5.1 Marine mammals

This section presents a series of tables for each of the effects categories for marine mammal groups, based on the definitions outlined in Table 1, 2 and 3 above.

[5] Based on the median sound levels between 8th May and 22 June 2024.

[6] Daytime was defined as between sunrise and sunset times.

5.1.1 Effects category: physiological

During extraction (pump on, draghead down and loading the hopper), the TSHD *William Fraser* is not expected to induce TTS beyond 0.5m distance (Table 5), and no risk for auditory injury onset, including those leading to PTS, was found.

Table 5: Ranges (m) from the TSHD vessel actively extracting within which temporary threshold shift, TTS, may occur in the different marine mammal hearing groups (please refer to Table 4).

Functional hearing group	M-weighted source level (dB re 1 μPa)	TTS range (m)
Low Frequency	160.8	0.08
High Frequency	156.2	0.01
Otarrid Pinnipeds	155.0	0.01
Phocid Pinnipeds	157.5	0.06

5.1.2 Effects category: behavioural

Table 6: Distances at which some probability of an individual animal receiver responding to the noise from the TSHD may occur (as defined in Table 2). For pinnipeds, the distances represent the radius around the TSHD actively extracting within which low or medium level effects may begin occurring (i.e., onset) (see Table 3).

Animal Group	Behavioural Response Level equivalent to NZ regulatory frameworks (see Table 2)	Distances (m) at which some probability of an individual responding to the noise from the TSHD			
		75%	50%	25%	0%
Delphinids	Small	173	192	241	596
	Medium	130	141	164	227
Baleens	Small	540	660	774	1115
		Onset range (m)			
Pinnipeds	Small	700			
	Medium	203			

5.1.3 Effects category: auditory masking

Table 7: Distances at which 75, 50, 25 and 0% listening space reduction (LSR) occurs for each functional hearing group during the median noise conditions over the daytime.

Functional hearing group	Species	Distances (m) at which some percentage of an individual's active listening space is reduced by when the TSHD is actively extracting			
		75%	**50%**	**25%**	**0%**
Low Frequency	Bryde's, humpback, southern right, blue, sei, minke.	1431	2854	5524	16246
High Frequency	Common, bottlenose dolphins. Killer, LF pilot, false killer, Gray's beaked, sperm whales.	170	933	2500	8307
Phocid Pinnipeds	Leopard seals	1074	2664	5928	16174
Otariid Pinnipeds	New Zealand fur seals	319	2024	4493	15060

5.1.4 Effects category: audibility

Table 8: Distances within which audibility is possible during the median noise conditions over the daytime.

Functional hearing group	Species	Estimated Audibility Range (m)
Low Frequency	Bryde's, humpback, southern right, blue, sei, minke.	18000
High Frequency	Common, bottlenose dolphins. Killer, LF pilot, false killer, Gray's beaked, sperm whales.	10385
Phocid Pinnipeds	Leopard seals	18900
Otariid Pinnipeds	New Zealand fur seals	18684

5.2 Fishes and Invertebrates

This section presents a series of tables for the effects categories for fishes and invertebrates, based on the definitions outlined in Table 1, 2 and 3 above.

5.2.1 Effects category: auditory masking

Table 9: Distances at which 75, 50, 25 and 0% listening space reduction (LSR) occurs for fishes and invertebrates during the median noise conditions over the daytime.

Group	Proxy species (audiogram was based on)	Distances (m) at which some percentage of an individual's active listening space is reduced by when the TSHD is actively extracting			
		75%	**50%**	**25%**	**0%**
Fish	NZ Bigeye	205	607	1200	2573
Fish	Common triplefin	165	333	717	1100
Invertebrate	Decapod crabs / other crustaceans.	113	138	161	180
Invertebrate	Snapping shrimp	132	151	165	175

We note that the difference between the NZ bigeye and common triplefin in masking effects is because masking for those species was limited by the species' hearing thresholds (i.e., audiogram limited) rather than the ambient soundscape (see Figure 25 in Appendix F). This is why LSR varied more than previously reported in studies such as Wilson et al. (2023), who found little difference in the particle acceleration LSRs between NZ bigeye and common triplefin over a noisy reef (i.e., was ambient noise limited (Wilson et al. 2023)).

5.2.2 Effects category: audibility

Table 10: Distances within which audibility is possible during the median ambient sound levels over daytime hours.

Group	Proxy species (audiogram was based on)	Estimated Audibility Range (m)
Fish	NZ Bigeye	2800
Fish	Common triplefin	1230
Crustacean	Decapod crabs / other crustaceans	189
Crustacean	Snapping shrimp	184

5.3 Kororā/little penguins

This section presents a series of tables for the effects categories for kororā/little penguins, based on the definitions outlined in Table 1, 2 and 3 above.

5.3.1 Effects category: auditory masking

Table 11: Distances at which 75, 50, 25 and 0% listening space reduction (LSR) occurs for kororā/little penguins during the median noise conditions over the daytime.

Group	Species	Distances (m) at which some percentage of an individual's active listening space is reduced by when the TSHD is actively extracting			
		75%	**50%**	**25%**	**0%**
Little Penguin	Kororā	135	190	940	5621

5.3.2 Effects category: audibility

Table 12: Distances within which audibility is possible during the median noise conditions over the daytime.

Animal	Species	Estimated Audibility Range (m)
Little Penguin	Kororā.	5894

5.4 Sea turtles

This section presents a series of tables for the effects categories for sea turtles, based on the definitions outlined in Table 1, 2 and 3 above.

5.4.1 Effects category: auditory masking

Table 13: Distances at which 75, 50, 25 and 0% listening space reduction (LSR) occurs for sea turtles during the median noise conditions over the daytime.

	Distances (m) at which some percentage of an individual's active listening space is reduced by when the TSHD is actively extracting			
	75%	**50%**	**25%**	**0%**
Sea turtles	186	385	1162	3780

5.4.2 Effects category: audibility

Table 14: Distances within which audibility is possible during the median noise conditions over the daytime.

Animal Group	Estimated Audibility Range (m)
Sea turtles	4800

5.5 Changes to Te Ākau Bream Bay's Anthrophony/Soundscape

Long term changes to an ambient soundscape are a known contributor to avoidance behaviours in both terrestrial and marine species (see Kok et al. (2023) for a comprehensive review of wildlife responses to long-term noise exposure). Fishes, inverts, marine mammals, seabirds, and sea turtles can be impacted in similar ways from long-term noise exposure, including changes in predation rates, stress responses (Kok et al. 2023), habitat displacement or avoidance behaviours (Kok et al. 2023; Duarte et al. 2021; Pichegru et al. 2022). The amount of noise that is required to elicit avoidance behaviours is not well understood, and peer-reviewed studies on the ecological impact of soundscape changes over time are few. While not related to sand extraction, or vessel noise, and therefore not directly related to Te Ākau Bream Bay, increases of ~2 dB re 1 μPa have been suggested to cause changes to African penguins following the introduction of an offshore ship-to- ship bunkering facility (Pichergru et al. 2022).

Some regions around New Zealand have coastal policies that aim at protecting the natural character of certain environments, and therefore to avoid substantial changes to existing soundscapes in those areas (for example Policy NS 2 of the Bay of Plenty Regional Coastal Environmental Plan). From an animal's perspective, a useful measure of this is quantifying the potential increase to the existing anthropogenic noise levels from introducing the sand extraction activity and then assessing the change, after adding the measured ambient sound levels (**a soundscape change**).

Given the proposed sand extraction in Te Ākau Bream Bay is a new activity that is proposed to be present for up to 35 years in total, it can be considered as a new source of long-term anthropogenic noise. Consequently, the cumulative noise effects and potential soundscape changes must be assessed.

To achieve this, computational noise models that showed potential increases in the monthly anthropogenic noise levels, as well as monthly cumulative sound exposures, during the sand extraction were built (Appendix H). A total of 42 positions representing stationary 'measurement points' were systematically placed within and outside Te Ākau Bream Bay to assess the monthly soundscape changes in both the unweighted and M-weighted noise levels (please refer to Appendix D).

In summary, changes to soundscapes were assessed by:

- Generating extraction noise models using hypothetical tracks within the proposed extraction area and empirical noise data of the *William Fraser*, as well as real-world data on the vessel's speed and distance travelled while extracting[7].
- Changes were assessed for each of the two extraction volumes:
  - The extraction of up to 150,000m^3 volume over 3 years. 13 days (representing up to 13 trips) for each month were randomly selected and used in the cumulative extracting noise model.
  - The extraction of 250,000m^3 volume over 32 years. 22 days (representing up to 22 trips) for each month were randomly selected and used in the cumulative extracting noise model.
- Generating noise models of the AIS-traffic for the same days/months as the extraction activity but without the hypothetical extracting noise included. This was used to represent the existing anthrophony from vessels over three months (April, May and June 2024)[8].
- Changes to the **anthrophony** (i.e., the level of anthropogenic noise present over a month) were assessed by calculating the difference between the sand extraction noise models when added to the AIS-traffic models, which represented the contribution of noise from the TSHD *William Fraser* to the anthrophony of Te Ākau Bream Bay during each month (i.e., to the cumulative sound exposure levels over each month).
- Changes to the monthly ambient sound levels (i.e., the soundscape and assessed as a monthly average (L_{eq})) were assessed in a similar way, but by incorporating the measured ambient sound levels and the down-time between extraction times and the days when no extraction occurs. Soundscape changes could, therefore, be a better indication for cumulative effects from an animal's perspective, rather than only additional anthrophonic noise each month.
- The measured ambient sound levels were incorporated by adding the daytime averaged levels[9] to both the AIS-traffic and extracting models for each corresponding frequency band. Daytime[10] only levels were used because the extraction activity will not occur during the night. Days without the extraction activity were incorporated by omitting the corresponding extraction models for the remaining 18 or 9 days per month during the monthly L_{eq} calculations, leaving only the AIS-traffic models and/or background sound level for those days.

Changes to the existing anthrophony/soundscape are predicted throughout Te Ākau Bream Bay (Table 14 and Figures 19-24 in Appendix D). Very high changes (i.e., >7 dB re 1 μPa) are limited to the extraction area while smaller changes (<2 dB re 1 μPa) are predicted for

[7]Based on travel logs provided by MBL.

[8]This time period was chosen to investigate monthly variation in AIS traffic levels while covering the PAM survey period.

[9] From the PAM data obtained between 8 May and 22 June 2024.

[10] Defined as between sunrise and sunset.

outside the extraction area. This shows spatial-temporal variation in the predicted cumulative soundscape changes following the introduction of the sand extraction activity.

Of the marine mammal species assessed, pinnipeds and odontocete species can be expected to experience the largest soundscape change (Figures 19-24 in Appendix D). This is predominately due to the lower existing sound levels measured and modelled in their hearing ranges (see Table 4) compared to the empirical measurements from the *William Fraser* while in extraction mode (see Appendix H for a comprehensive breakdown of the added cumulative vessel noise to the existing anthrophony). Kororā/little penguins, fishes, invertebrates, and sea turtles will also experience elevated noise levels (represented by the unweighted noise levels in Table 14 and Figures 19-24 in Appendix D).

Table 15: Predicted increases to the ambient sound levels (soundscape change) within and outside the extraction area within Te Ākau Bream Bay.

Animal group	Inside extraction area (monthly L_{eq} dB re µPa)	Outside extraction area (monthly L_{eq} dB re µPa)
Mysticetes (Low Frequency)	3-37	0-2
Delphinids (High Frequency)	3-36	0-2
Phocids (PCW)	3-36	0-2
Otariids (OCW)	3-35	0-2
Fishes, Invertebrates	3-37	0-2
Penguins	3-37	0-2
Sea turtles	3-37	0-2

It is important to note that there are several fundamental assumptions that must be understood with these models. These are:

- The AIS-traffic models (that represent the existing vessel noise) are entirely based on AIS traffic that is underway. Therefore, the model is an underestimate of the true vessel activity in the area, as AIS does not include all vessels (especially recreational vessels). Recreational vessels can contribute significantly to the underwater soundscape of an area (see Pine et al., 2016, 2021). Consequently, the predicted soundscape changes can be considered conservative (i.e., worse case).

- The existing vessel noise model is based on the AIS traffic during the months of 2024 only. Data provided by the Harbourmaster show that vessel traffic (quantified as movements in and out of Whangārei Harbour, and therefore Te Ākau Bream Bay) during 2024 was lower than all previous years since 2014 (Goodchild, 2025).

Additionally, the modelling also does not consider potential increases in shipping traffic within Te Ākau Bream Bay, nor current or increasing usage of anchorage areas. Currently, there is an average of 12 ships per month[11] anchoring inside the anchorage which is located approximately a few hundred metres from the seaward side of the extraction area boundary. In a recent study, anchored bulk carriers were found to impact the underwater soundscape across a broad frequency range of 20-24,000 Hz, by increasing sound pressure levels by 2-8 dB re 1 μPa (Murchy et al. 2022). Murchy et al. (2022) also found that frequencies most impacted (i.e. >5dB re 1 μPa median increase) were below 100Hz and 1-5kHz (overlapping well with fishes, invertebrate, sea turtles, and marine mammal hearing ranges). Substantial increases in ambient sound levels have also been reported in some cruise ships at anchor (Ivanova et al. 2020). These studies provide evidence that the predicted anthrophony/soundscape changes in this assessment are conservative (i.e., worse-case), especially near the anchorage area within Te Ākau Bream Bay. Anchored vessels were present at a time (3 times) during the passive acoustic monitoring, and did increase the received sound pressure levels at the measurement hydrophone by several decibels (5-10 dB re 1 μPa). Those anchored vessels were therefore included in the ambient sound level used in the predicted soundscape changes.

As previously mentioned, this assessment has modelled the AIS-traffic based on three months during 2024. Given 2024 recorded a reduced number of ship movements through Te Ākau Bream Bay, the effect of changing ship movements between years was also assessed. Using the vessel classes modelled, port-related vessels in the AIS-traffic model that transit Te Ākau Bream Bay were containers, bulk carriers/bulkers, tankers and cruise ships (based on the JONOPANS-ECHO reference model classes (see Appendix C for more details)). The AIS-traffic noise model included 218 vessel movements/transits over the three months in 2024, which could be estimated as a total of 872 vessel movements for the complete year. This is very similar to the reported number of vessel movements by the Harbourmaster of 866. Assuming all else being equal[12], the level of soundscape change predicted in this assessment was adjusted for each year from 2014, based on the provided vessel movement counts from the Harbourmaster, using:

$$\Delta L_{!",\$} = L_{!"} - 10Log_{\%\&}\left(\frac{n_{\$}}{n_{\&}}\right) \quad (\text{Eq. 1})$$

Where $\Delta L_{!",\$}$ is the change in predicted monthly ambient sound level for year i, $L_{!"}$is is the predicted monthly ambient sound level provided in Table 13, $n_{\$}$ is the number of vessel movements in year i, and $n_{\&}$ is the reference number of vessels in the AIS noise model (set at 866 for 2024). Projected vessel traffic increases were also considered, based on a 10% increase to existing vessel movements in the next 10 years with the upgrading of Northport and the increased numbers of cruise and container ships (pers. comms Bruce Goodchild, NRC Harbourmaster).

[11] This was confirmed by the Harbourmaster, Bruce Goodchild, 29 Nov 2024.

[12] A reasonable assumption since AIS data for these vessel classes show the vessel movements are limited to the anchorages in the bay and shipping channel.

Table 16 shows the effect that changing shipping volumes (as quantified by vessel movements in and out of Whangārei Harbour) can have on the predicted level of soundscape changes in this assessment.

Pine et al. (2021) provided strong empirical evidence that vessel noise, especially from small boats (recreational vessels) can directly influence ambient sounds and have cumulative effects on the soundscape. The ambient sound levels presented included all vessel types, including commercial fishing, shipping, recreational vessels and passenger boats. The GLM-derived slope equations by Pine et al. (2021) provide an empirically-derived, simple method for preliminarily assessing median daily ambient sound level increases due to general vessel noise presence over a 24 hour period. While the TSHD *William Fraser* is not a typical vessel when extracting, the noise from the propulsion system (engine and propellor) and onboard pumps have similar spectral characteristics to typical vessel noise. Using slope equations derived from the generalised linear models (GLMs) by Pine et al. (2021), the daily median SPL on days when the sand extraction take place was approximately 1.7 dB re 1 μPa higher than days without the TSHD extracting (see Table 16 below). If extrapolated out over a month (13 days or 22 days of extracting with the remaining days being 0dB) would be 1.21 dB (if extracting 150,000m^3 per year) or 1.35 dB (250,000m^3 per year). These are slightly lower than the predicted soundscape change in the assessment, also suggesting the conservativeness of the soundscape change modelling.

Table 16: Predicted soundscape changes (increased monthly L_{eq}, dB re 1 μPa) based on previous vessel movement counts, as well as projected vessel movements over the next ?? years, assuming all else in the ship noise model being equal. Future vessel movement counts assume a 10% increase from the last 10-year average (2014-2024).

Note that 2024 reflected the predicted monthly L_{eq} increase in this assessment, and used as the reference point for which the other years were adjusted from (i.e., $n_{\&}$ eq. 1 above).

Year	Total Vessel Movements (in/out of Te Ākau Bream Bay)	Decibel difference to the predicted monthly L_{eq} increase.	Ambient sound level increase per month to existing anthrophony after sand extraction commences (from Eq. 1 above).		
			Outside the extraction area	Inside the extraction area	Outside the extraction area as derived from Pine et al. (2021)'s GLM.
2014	1408	-2.11	0	34.89	0
2015	1400	-2.09	0	34.91	0
2016	1278	-1.69	0.31	35.31	0
2017	1172	-1.31	0.69	35.69	0.04

Year	Total Vessel Movements (in/out of Te Ākau Bream Bay)	Decibel difference to the predicted monthly L_{eq} increase.	Ambient sound level increase per month to existing anthrophony after sand extraction commences (from Eq. 1 above).		
2018	1174	-1.32	0.68	35.68	0.03
2019	1202	-1.42	0.58	35.58	0
2020	1190	-1.38	0.62	35.62	0
2021	1068	-0.91	1.09	36.09	0.44
2022	1012	-0.68	1.32	36.32	0.67
2023	908	-0.21	1.79	36.79	1.14
2024	**866**	**0.00**	**2.00**	**37.00**	**1.35**
2025	876	-0.05	1.95	36.95	1.30
2026	887	-0.10	1.90	36.90	1.25
2027	897	-0.15	1.85	36.85	1.20
2028	908	-0.21	1.79	36.79	1.14
2029	918	-0.26	1.74	36.74	1.09
2030	929	-0.30	1.70	36.70	1.05
2031	939	-0.35	1.65	36.65	1.00
2032	950	-0.40	1.60	36.60	0.95
2033	960	-0.45	1.55	36.55	0.90
2034	971	-0.50	1.50	36.50	0.85
2035	981	-0.54	1.46	36.46	0.81

Table 17: Potential daily median sound pressure level increase within Te Ākau Bream Bay using slope equation derived from Pine et al. (2021) generalised linear regression model.

Sand extraction activity	Proportion of day extracting (%)	Increase median daily SPL (dB re 1 mPa) of Te Ākau Bream Bay	Monthly log average if extrapolated based on 13 days/month	Monthly log average if extrapolated based on 22 days/month
3.5 hours per day extracting	14.58	1.74	1.21	1.35

6.0 Conclusion

Styles Group has undertaken a comprehensive underwater noise assessment of the proposed sand extraction activity within Te Ākau Bream Bay and assessed the potential associated noise effects.

The proposed sand extraction activity will expose marine mammals, fish, invertebrates, kororā/little penguins, and sea turtles to acoustic-related disturbances. Notwithstanding, however, **no risk** of auditory injury was found in the modelling, and no temporary threshold shift beyond 0.5m from the *William Fraser* when it is actively extracting sand.

Generally, behavioural disturbances can generally be considered **Small/Minor** for all animal groups; occurring over the largest distances for baleen whales of 1115m. Small behavioural responses for delphinids could be possible within 596m, while pinnipeds may show small behavioural responses within 700m. **Medium/Moderate** behavioural responses occur far closer to the *William Fraser* for all species, for example within 203m and 227m, respectively, for delphinids and pinnipeds.

Small/Minor behavioural responses in fishes, invertebrates, kororā/little penguins, and sea turtles could not be robustly calculated like for the marine mammals, due to lack of technical guidance for continuous noise sources, such as vessels. However, they are unlikely to occur beyond 205m, which is the range at which auditory masking effects are likely too low (i.e., below 75% reduction in active listening space) for the onset of small behavioural responses.

Masking effects in marine mammals, fishes, invertebrates, kororā/little penguin, and sea turtles are also generally of **Small/Minor** magnitude when distant from the *William Fraser*. **Medium/Moderate** levels of masking begin occurring within 170m (delphinids) or 1431m (baleens) in marine mammals. In fishes, this was found to be between 165m and 205m, but 113m and 132m for invertebrate groups (for example, crustaceans). These ranges were also similar for kororā/little penguins (135m) and sea turtles (186m).

7.0 References

Caiger, P.E., Montgomery, J.C., & Radford, C.A. 2012. Chronic low-intensity noise exposure affects the hearing thresholds of juvenile snapper. *Marine Ecology Progress Series* 466: 225–232.

Clark, C.W., Ellison W.T., Southall B.L., et al. 2009. Acoustic masking in marine ecosystems: intuitions, analysis, and implication. *Marine Ecology Progress Series* 395: 201–222.

de Jong, C., Binnerts, B., Robinson, S., Wang, L. 2021. Guidelines for modelling ocean ambient noise. Report of the EU INTERREG Joint Monitoring Programme for Ambient Noise North Sea (Jomopans).

Duarte, C.M, Chapuis, L., Collin, S.P., et al. 2021. The soundscape of the Anthropocene ocean. *Science* 371: eaba4658.

Farcas, A., Powell, C.F., Brookes, K.L., Merchant, N.D. 2020. Validated shipping noise maps of the Northeast Atlantic. *Science of the Total Environment* 735: 139509.

Goodchild, B. 2025. Navigation Safety Assessment: William Fraser Sand Extraction in Bream Bay. Technical report produced for McCullum Bros Limited, Version 1.4, 21 February 2025.

Ivanova, S.V., S.T.Kessel, M. Espinoza, M., et al. 2020. Shipping alters the movement and behavior of Arctic cod (Boreogadus saida), a keystone fish in Arctic marine ecosystems. *Ecological Applications* 30(3): e02050

Joy R., Tollit D., Wood J. et al. 2019. Potential benefits of vessel slowdowns on endangered southern resident killer whales. *Frontiers in Marine Science* 6: 344.

Kok, A.C.M., Berkhout, B.W., Carlson, N.V., et al. 2023. How chronic anthropogenic noise can affect wildlife communities. *Frontiers in Ecology and Evolution* 11: 1130075.

MacGillivray, A., de Jong C. 2021. A reference spectrum model for estimating source levels of marine shipping based on automated identification system data. *Journal of Marine Science and Engineering* 9(4): 369.

Mensinger, A.F., Putland, R.L., Radford, C.A. 2018. The effect of motorboat sound on Australian snapper *Pagrus auratus* inside and outside a marine reserve. *Ecology and Evolution* 8(13): 6438–6448.

Murchy, K.A., Vagle, S., & Juanes, F. 2022. Anchored bulk carriers have substantial impacts on the underwater soundscape in Cowichan Bay, British Columbia. *Marine Pollution Bulletin* 182: 113921.

National Marine Fisheries Service (NMFS). 2024. Update to: Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (Version 3.0): Underwater and in-air criteria for onset of auditory injury and temporary threshold shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-xx, xxx p.

Pichegru, L., Vibert L., Thiebault A., et al. 2022. Maritime traffic trends around the southern tip of Africa – Did marine noise pollution contribute to the local penguins' collapse? *Science for the Total Environment* 849: 157878.

Pine, M.K., Jeffs, A.G., Wang, D., Radford, C.A. 2016. The potential for vessel noise to mask biologically important sounds within ecologically significant embayments. *Ocean & Coastal Management* 127: 63-73.

Pine M.K., Hannay D.E., Insley S.J. et al. 2018. Assessing vessel slowdown for reducing auditory masking for marine mammals and fish of the western Canadian Arctic. *Marine Pollution Bulletin* 135: 290-302.

Pine M.K., Nikolich K., Martin B., et al. 2020. Assessing auditory masking for management of underwater anthropogenic noise. *Journal of the Acoustical Society of America* 147(5): 3408-3417.

Pine M.K., Wilson L., Jeffs A.G., et al. 2021. A Gulf in lockdown: How an enforced ban on recreational vessels increased dolphin and fish communication ranges. *Global Change Biology* 27(19): 4839-4848.

Radford, C.A., Ghazali, S.M., Montgomery, J.C., Jeffs, A.G. 2016. Vocalisation Repertoire of Female Bluefin Gurnard (*Chelidonichthys kumu*) in Captivity: Sound Structure, Context and Vocal Activity. *PLoS ONE* 11(2): e0149338.

Radford, C.A., Montgomery, J.C., Caiger, P., Higgs, D. M. 2012. Pressure and particle motion detection thresholds in fish: a re-examination of salient auditory cues in teleosts. *The Journal of Experimental Biology* 215(19): 3429–3435.

Radford, C.A., Montgomery, J.C., Caiger, P., et al. 2013. A novel hearing specialization in the New Zealand bigeye, *Pempheris adspersa*. *Biology Letters* 9(4): 20130163.

Radford, C.A., Putland, R.L., Mensinger, A.F. 2018. Barking mad: The vocalisation of the John Dory, *Zeus faber*. *PLoS ONE* 13(10): e0204647.

SLR, 2025. Te Ākau Bream Bay Sand Extraction: Marine Mammal Environmental Impact Assessment. Report prepared by SLR Consulting New Zealand for McCallum Bros Limited. Dated April 2025.

Southall, B.L., Nowacek, D.P., Bowles, V.S., et al. 2021. Marine mammal noise exposure criteria: assessing the severity of marine mammal behavioral responses to human noise. *Aquatic Mammals* 47(5): 421-464.

Wei, C., Erbe, C. 2024. Sound reception and hearing capabilities in the Little Penguin (*Eudyptula minor*): first predicted in-air and underwater audiograms. *Royal Society Open Science* 11: 240593.

Weston, D.E. 1971. Intensity-range relations in oceanographic acoustics. *Journal of Sound and Vibration* 18: 271–287.

Wilson, L., Farcas, A., Pine, M.K., et al. 2023. Impact of small boat noise on crabs: Reduced listening space and behavioural changes. *Scientific Reports* 13(1): 7840.

Appendix A Glossary of Terms

Ambient sound	Ambient sound is the total of all noise within a given environment, comprising a composite of sounds from sources near and far.
Biologically important signal	An acoustic signal that, once detected and perceived, provides the receiving animal some information that is important to its survival and/or reproductive output.
Critical band	The frequency band of sound, contained within a broadband noise spectrum, that contains the energy equal to that of a pure tone centred in the critical band and just audible in the presence of broadband noise (Erbe et al. 2016).
Cumulative sound exposure level	Cumulative Sound Exposure Level (L_E/SELcum**)** is a measure of the total energy exposure to a sound event or series of sound events over a specified period.
dB (decibel)	The basic measurement unit of sound. The logarithmic unit used to describe the ratio between the measured sound pressure level and a reference level of 1 micropascals (0 dB) (or 20 micropascals for airborne sound).
Detector	A detector is a computer program that automatically detects the presence or absence of a particular signal that the algorithm is trained to detect.
Leq	Leq stands for equivalent continuous sound level. It is a measure of the continuous equivalent sound level that represents the time-averaged sound energy over a specified period.
Power spectral density (PSD)	The dB level of the power spectrum, presented every 1 Hz.
Permanent Threshold Shift (PTS)	An increase in the threshold of hearing (i.e. the minimum sound intensity required for the receiver to detect a signal) at a specific frequency that does not return to its pre-exposure level over time., i.e., it is permanently altered.
Sound pressure level (SPL)	The logarithmic unit used to describe the ratio between the measured sound pressure level and a reference level of 1 micropascals (0 dB) (or 20 micropascals for airborne sound). Unless stated otherwise, the SPL refers to the root-mean-square (rms) sound pressure.
Soundscape	Similar to ambient sound, the acoustic soundscape is the sum of multiple sound sources arriving at a receiver (whether animal or hydrophone).
SoundTrap (ST)	An autonomous underwater acoustic logger used in marine science research from Ocean Instruments New Zealand.
Sound exposure level	The dB level of the time integral of the squared pressure over the duration of the sound event, expressed as dB re 1 $\mu Pa^2 \cdot s$.
Source level	The sound pressure level transmitted by a point-like source that would be measured at 1 metre distance, and expressed as dB re 1 μPa @ 1m.
Temporary Threshold shift (TTS)	An increase in the threshold of hearing (i.e. the minimum sound intensity required for the receiver to detect a signal) at a specific frequency that returns to its pre-exposure level over time.

Appendix B Baseline passive acoustic monitoring

Marine animals depend on underwater sound for their survival. It plays a vital role in many life processes, such as (but not limited to) maintaining group cohesion while navigating turbid coastal waters, communication between group members, locating prey while foraging, mediating reproductive behaviours and avoiding predation or other dangers (Duarte et al. 2021). Their ability to communicate and perceive biologically important sounds is directly related to the surrounding acoustic environment as signals must be somewhat audible over the background soundscape within some critical bandwidth. Coastal activities, such as extracting sand or vessels underway etc, can cause ambient noise levels across a very wide frequency range to rise to the point where marine animals are unable to detect signals that are important to them. This masking effect can induce a range of impacts, from increased stress and behavioural responses to total habitat avoidance and exclusion (Southall et al. 2007, 2019; Nowacek et al. 2007; Duarte et al. 2021). Underwater noise pollution can therefore degrade marine habitats within and around sites where nearshore or offshore activities take place.

However, the degree/extent of habitat degradation is not equal between areas, environments, or regions because the physical environment changes. Generally, noise effects can only occur if the invading noise source is audible (audibility being a function of both the ambient soundscape and hearing thresholds of a listener). Therefore, to properly assess the maximum spatial extent of possible acoustic disturbance for marine mammals, the ambient soundscape must be understood and incorporated into assessments.

An autonomous recorder was therefore deployed within the proposed extraction area to provide data on the current soundscape in Te Ākau Bream Bay, including marine mammal presence.

Materials and Methods

A SoundTrap recorder (ST600HF, Ocean Instruments NZ) was deployed within the extraction area between 8 May and 22 June 2024 (Table 17). The recorder was programmed to record continuously at a 192kHz sampling rate and was bottom-mounted, 1m above the seafloor.

The hydrophone component of the SoundTrap recorders was calibrated by the manufacturer. Field-calibration checks before the initial deployment were undertaken using a calibrated piston phone (GRAS Type 42AA, SPL 114 dB re 20 µPa, nominal frequency range 250 Hz), and calibrated (using a Brüel & Kjaer Type 4231 Sound Calibrator) sound level meter (Brüel & Kjaer 2250 Type 1 SLM with a Brüel & Kjaer ½ inch condenser microphone Type 4189) and specialist acoustic software. Electronic calibration of the recorder component was undertaken at the start of every recording event by comparing a set of automated tones of known frequency and voltage amplitude to the full-scale response level provided by the manufacturer for the appropriate gain setting and verified using the piston phone.

Table 18: Metadata for the passive acoustic monitoring. NB: the marine mammal analysis is described in McConnell et al. (2024), and not repeated in this report.

Monitoring Site	Instrument	Period when data were collected	Data Analyses undertaken
Extraction Area (LAT/LON)	ST600HF	8/05/2024 – 22/06/2024	Soundscape (PSD, Decidecades). Marine Mammals (Delphinids/Mysticeti).

Ambient sound data were analysed following the methods in Pine et al. (2021) but summarised below.

Every 60 seconds of acoustic data was used to determine power spectral densities (PSDs, 1-sec FFT Hamming window sizes, 50% overlap, 60s averaging), producing a long-term spectral average (LTSA) spectrogram for each site. Broadband sound pressure levels (SPLs) (10Hz – 48 kHz), and decidecade bands were calculated from the LTSAs. This generated a single power spectrum, decidecade spectrum and SPL sample for every 60 seconds. Time-stamped hourly averages were then calculated. Daytime periods were defined as the time between sunrise and sunset times for each site.

Cetacean vocalisations were detected using a series of artificial neural networks that detect whistles, burst-pulses and buzzes from delphinid species and very low-frequency calls from baleen species. For odontocete species, detection events were defined as the time between the first and last detected vocalisation that was within 20 minutes of the previous vocalisation. For example, if a vocalisation was detected at 10:00hrs and another at 10:10hrs, that would count as the same detection event (lasting 10 minutes). However, if no whistles/burst-pulses/buzzes were detected within 20 minutes of the last (i.e., at 10:10hrs), then the detection event was concluded, and the duration would be 10 minutes. For baleens, detection events were not an output class, but instead individual calls per hour were quantified and plotted.

Results

The ambient soundscape within Te Ākau Bream Bay is complex with a range of sound sources occurring simultaneously at any given time (Figure 5). Wind, waves and tides (causing sediment entrainment) were the primary contributors to the bay's geophony, while fish, marine mammals and snapping shrimp formed the area's biophony. Vessels were the primary anthropogenic noise source. At the hydrophone, vessel noise was not found to be as prevalent as seen inside harbours or urbanised bays (such as around the Hauraki Gulf Marine Park or Whangarei Harbour). Instead, during May and June 2024, the Bay's soundscape was largely dominated by the geo- and biophony. The area was also relatively quiet with the 5th percentile sound level approximately 93dB re 1 μPa and a median level approximately 99 dB re 1 μPa (see Figures 6 through 9).

A total of 26,129 vocalisations were detected between May and June 2024 from odontocete species over 200 individual detection events (Figures 10, 11). A total of 336 whale vocalisations were also detected (Figure 12).

Specific detection event data are provided in tables at the end of this appendix**.**

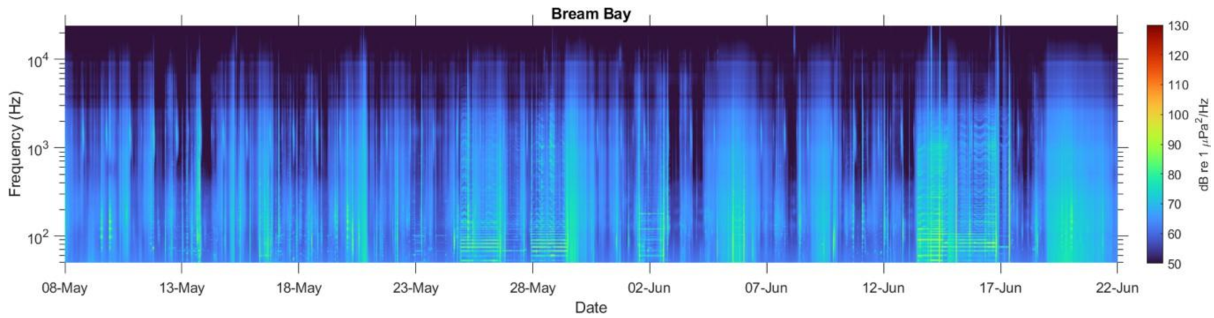

Figure 5: Long term spectral average (LTSA) of the power spectral density (*PSD*, dB re 1 μPa²/Hz) over the monitoring period.

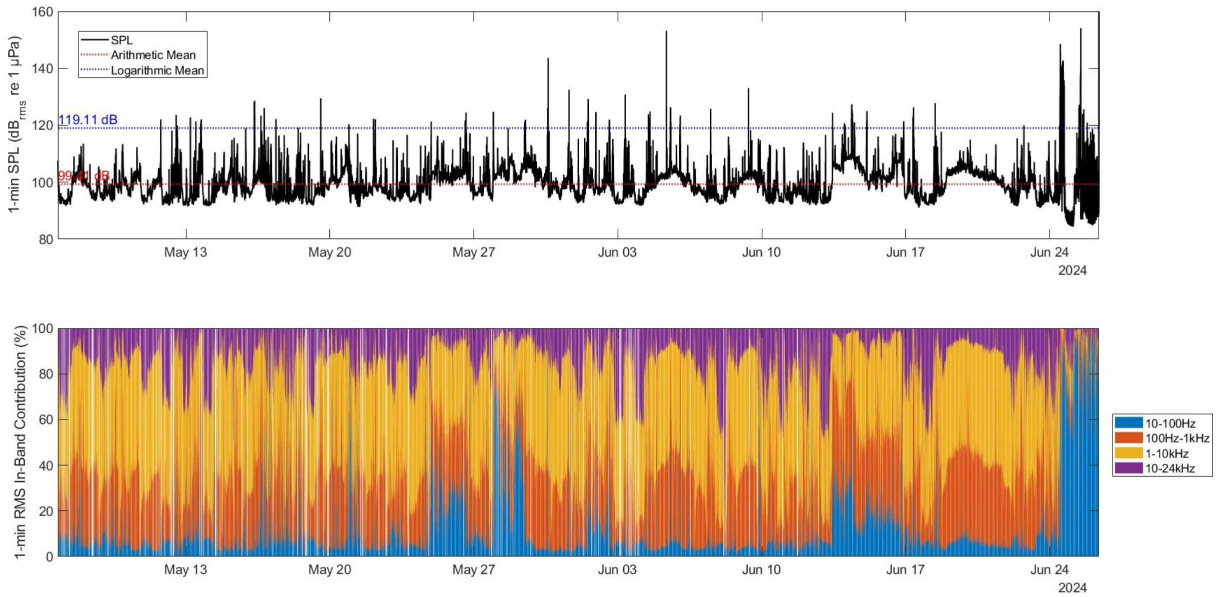

Figure 6: Broadband Sound Pressure Levels (averaged over 1-min) (dB_{rms} re 1 μPa) during May and June 2024 (top panel) and corresponding in-band energy contributions for different frequency bands (bottom panel).

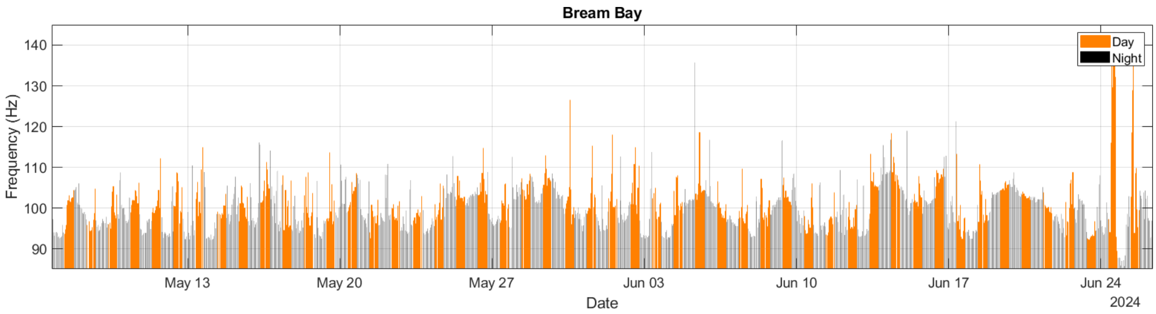

Figure 7: Hourly Leq (dB re 1 µPa) sound levels from each monitoring site.

The orange bars are during daylight hours (determined by sunset/sunrise times) and the black bars represent night time hours.

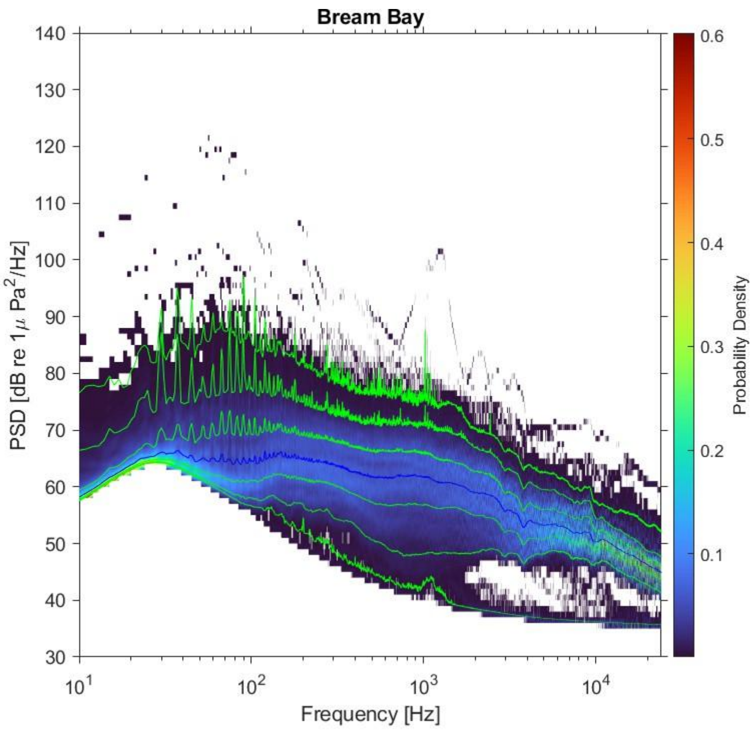

Figure 8: Power spectral densities and spectral probability densities from each monitoring site between 1st and 30th September 2022.

The blue line presents the medium (50th percentile) levels, while the green lines, starting at the top line, represent the 99th, 95th, 75th, 25th, 5th and 1st percentile levels. The colour bar presents the spectral probability density.

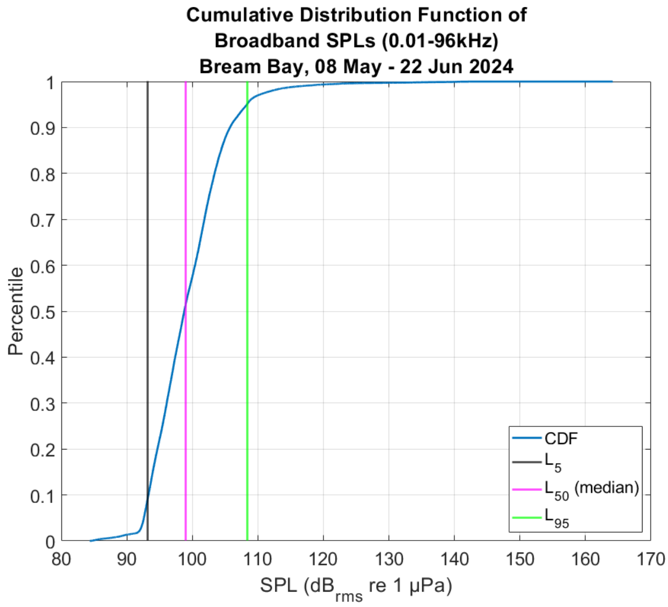

Figure 9: Descriptive statistics for the broadband ambient sound levels within Te Ākau Bream Bay.

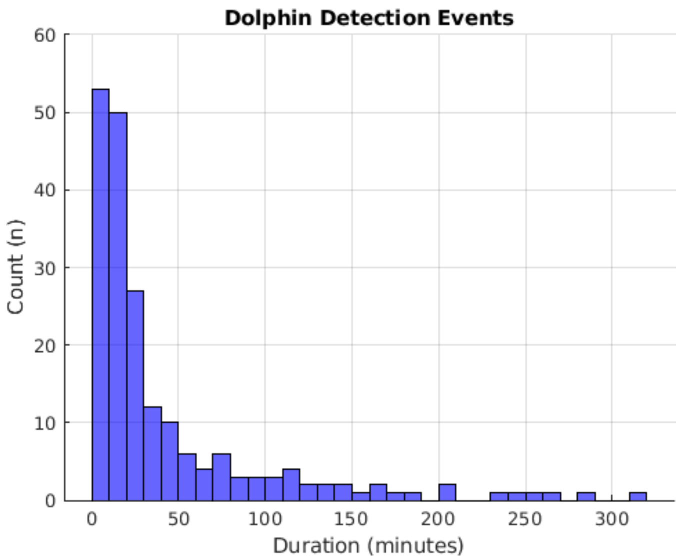

Figure 10: Distribution of delphinid detection event durations.

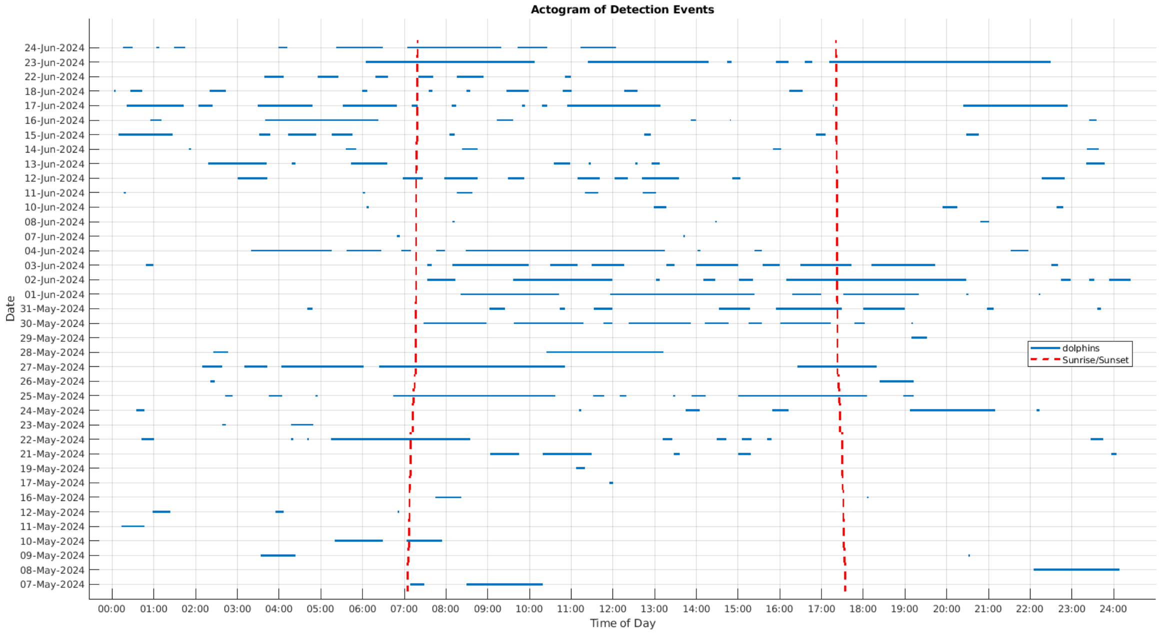

Figure 11: Actogram showing odontocete (output class Delphinidae/dolphins) vocal activity during the monitoring period.

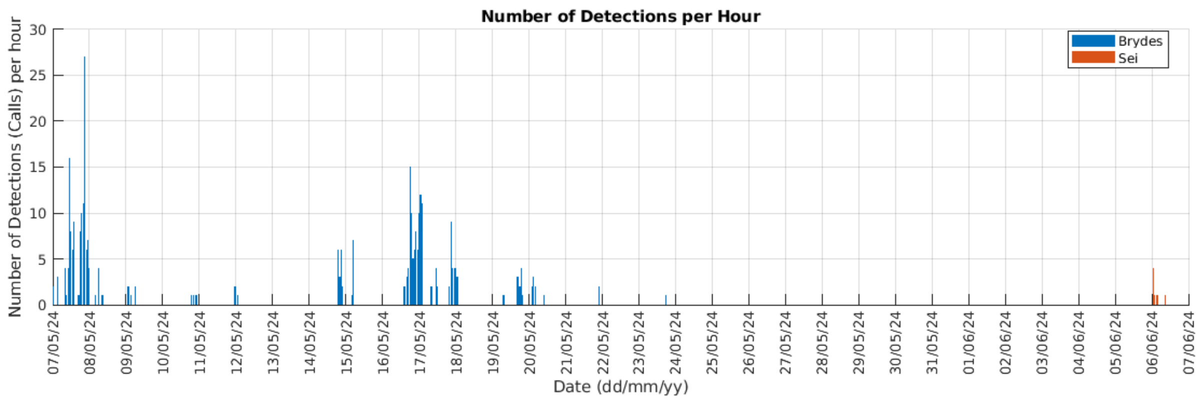

Figure 12: Detection counts per hour of baleen whale species during the monitoring period.

Odontocete detection events

Start	End	Duration (Detection Positive Minutes)
7/05/2024 7:09	7/05/2024 7:29	20
7/05/2024 8:30	7/05/2024 10:19	109
8/05/2024 22:05	9/05/2024 0:08	123
9/05/2024 3:33	9/05/2024 4:24	51
9/05/2024 20:31	9/05/2024 20:33	2
10/05/2024 5:20	10/05/2024 6:29	69
10/05/2024 7:03	10/05/2024 7:54	51
11/05/2024 0:13	11/05/2024 0:46	33
12/05/2024 0:58	12/05/2024 1:24	26
12/05/2024 3:55	12/05/2024 4:06	11
12/05/2024 6:51	12/05/2024 6:53	2
16/05/2024 7:45	16/05/2024 8:22	37
16/05/2024 18:05	16/05/2024 18:08	3
17/05/2024 11:55	17/05/2024 12:00	5
19/05/2024 11:07	19/05/2024 11:20	13
21/05/2024 9:04	21/05/2024 9:45	41
21/05/2024 10:19	21/05/2024 11:29	70
21/05/2024 13:28	21/05/2024 13:36	8
21/05/2024 15:00	21/05/2024 15:18	18
21/05/2024 23:57	22/05/2024 0:04	7
22/05/2024 0:42	22/05/2024 1:00	18
22/05/2024 4:17	22/05/2024 4:20	3
22/05/2024 4:41	22/05/2024 4:43	2
22/05/2024 5:15	22/05/2024 8:35	200
22/05/2024 13:12	22/05/2024 13:25	13
22/05/2024 14:29	22/05/2024 14:43	14
22/05/2024 15:05	22/05/2024 15:19	14
22/05/2024 15:42	22/05/2024 15:48	6
22/05/2024 23:27	22/05/2024 23:45	18
23/05/2024 2:38	23/05/2024 2:44	6
23/05/2024 4:17	23/05/2024 4:49	32
24/05/2024 0:35	24/05/2024 0:46	11
24/05/2024 11:11	24/05/2024 11:14	3
24/05/2024 13:45	24/05/2024 14:05	20
24/05/2024 15:49	24/05/2024 16:13	24
24/05/2024 19:07	24/05/2024 21:10	123
24/05/2024 22:09	24/05/2024 22:13	4
25/05/2024 2:42	25/05/2024 2:53	11
25/05/2024 3:45	25/05/2024 4:04	19
25/05/2024 4:52	25/05/2024 4:55	3

25/05/2024 6:44	25/05/2024 10:37	233
25/05/2024 11:32	25/05/2024 11:48	16
25/05/2024 12:10	25/05/2024 12:19	9
25/05/2024 13:26	25/05/2024 13:30	4
25/05/2024 13:53	25/05/2024 14:13	20
25/05/2024 15:00	25/05/2024 18:05	185
25/05/2024 18:58	25/05/2024 19:12	14
26/05/2024 2:21	26/05/2024 2:28	7
26/05/2024 18:23	26/05/2024 19:12	49
27/05/2024 2:09	27/05/2024 2:38	29
27/05/2024 3:10	27/05/2024 3:43	33
27/05/2024 4:03	27/05/2024 6:02	119
27/05/2024 6:24	27/05/2024 10:51	267
27/05/2024 16:25	27/05/2024 18:19	114
28/05/2024 2:25	28/05/2024 2:47	22
28/05/2024 10:24	28/05/2024 13:13	169
29/05/2024 19:09	29/05/2024 19:32	23
30/05/2024 7:28	30/05/2024 8:58	90
30/05/2024 9:38	30/05/2024 11:18	100
30/05/2024 11:46	30/05/2024 11:59	13
30/05/2024 12:23	30/05/2024 13:52	89
30/05/2024 14:12	30/05/2024 14:46	34
30/05/2024 15:15	30/05/2024 15:34	19
30/05/2024 16:01	30/05/2024 17:13	72
30/05/2024 17:47	30/05/2024 18:02	15
30/05/2024 19:09	30/05/2024 19:11	2
31/05/2024 4:41	31/05/2024 4:48	7
31/05/2024 9:02	31/05/2024 9:25	23
31/05/2024 10:44	31/05/2024 10:51	7
31/05/2024 11:33	31/05/2024 11:59	26
31/05/2024 14:33	31/05/2024 15:17	44
31/05/2024 15:54	31/05/2024 17:29	95
31/05/2024 18:00	31/05/2024 19:00	60
31/05/2024 20:58	31/05/2024 21:07	9
31/05/2024 23:36	31/05/2024 23:42	6
1/06/2024 8:21	1/06/2024 10:43	142
1/06/2024 11:56	1/06/2024 15:24	208
1/06/2024 16:18	1/06/2024 16:59	41
1/06/2024 17:31	1/06/2024 19:20	109
1/06/2024 20:28	1/06/2024 20:31	3
1/06/2024 22:12	1/06/2024 22:14	2
2/06/2024 7:33	2/06/2024 8:13	40
2/06/2024 9:37	2/06/2024 11:59	142

2/06/2024 13:02	2/06/2024 13:07	5
2/06/2024 14:10	2/06/2024 14:27	17
2/06/2024 15:01	2/06/2024 15:21	20
2/06/2024 16:09	2/06/2024 20:28	259
2/06/2024 22:44	2/06/2024 22:58	14
2/06/2024 23:25	2/06/2024 23:32	7
2/06/2024 23:54	3/06/2024 0:24	30
3/06/2024 0:49	3/06/2024 0:59	10
3/06/2024 7:33	3/06/2024 7:39	6
3/06/2024 8:09	3/06/2024 9:59	110
3/06/2024 10:30	3/06/2024 11:09	39
3/06/2024 11:29	3/06/2024 12:16	47
3/06/2024 13:17	3/06/2024 13:29	12
3/06/2024 14:00	3/06/2024 15:00	60
3/06/2024 15:35	3/06/2024 16:00	25
3/06/2024 16:30	3/06/2024 17:43	73
3/06/2024 18:12	3/06/2024 19:43	91
3/06/2024 22:30	3/06/2024 22:40	10
4/06/2024 3:20	4/06/2024 5:16	116
4/06/2024 5:37	4/06/2024 6:27	50
4/06/2024 6:56	4/06/2024 7:10	14
4/06/2024 7:46	4/06/2024 7:59	13
4/06/2024 8:28	4/06/2024 13:15	287
4/06/2024 14:02	4/06/2024 14:06	4
4/06/2024 15:24	4/06/2024 15:34	10
4/06/2024 21:32	4/06/2024 21:57	25
7/06/2024 6:49	7/06/2024 6:54	5
7/06/2024 13:41	7/06/2024 13:43	2
8/06/2024 8:09	8/06/2024 8:12	3
8/06/2024 14:27	8/06/2024 14:29	2
8/06/2024 20:48	8/06/2024 21:01	13
10/06/2024 6:06	10/06/2024 6:09	3
10/06/2024 12:59	10/06/2024 13:17	18
10/06/2024 19:54	10/06/2024 20:15	21
10/06/2024 22:38	10/06/2024 22:48	10
11/06/2024 0:17	11/06/2024 0:20	3
11/06/2024 6:00	11/06/2024 6:04	4
11/06/2024 8:16	11/06/2024 8:38	22
11/06/2024 11:20	11/06/2024 11:39	19
11/06/2024 12:43	11/06/2024 13:02	19
12/06/2024 3:01	12/06/2024 3:43	42
12/06/2024 6:58	12/06/2024 7:27	29
12/06/2024 7:58	12/06/2024 8:45	47

12/06/2024 9:29	12/06/2024 9:53	24
12/06/2024 11:09	12/06/2024 11:41	32
12/06/2024 12:02	12/06/2024 12:22	20
12/06/2024 12:42	12/06/2024 13:35	53
12/06/2024 14:52	12/06/2024 15:03	11
12/06/2024 22:17	12/06/2024 22:50	33
13/06/2024 2:18	13/06/2024 3:42	84
13/06/2024 4:18	13/06/2024 4:24	6
13/06/2024 5:43	13/06/2024 6:36	53
13/06/2024 10:35	13/06/2024 10:58	23
13/06/2024 11:25	13/06/2024 11:28	3
13/06/2024 12:32	13/06/2024 12:35	3
13/06/2024 12:56	13/06/2024 13:07	11
13/06/2024 23:21	13/06/2024 23:47	26
14/06/2024 1:50	14/06/2024 1:53	3
14/06/2024 5:36	14/06/2024 5:51	15
14/06/2024 8:23	14/06/2024 8:45	22
14/06/2024 15:50	14/06/2024 16:02	12
14/06/2024 23:22	14/06/2024 23:39	17
15/06/2024 0:09	15/06/2024 1:27	78
15/06/2024 3:31	15/06/2024 3:47	16
15/06/2024 4:13	15/06/2024 4:53	40
15/06/2024 5:16	15/06/2024 5:46	30
15/06/2024 8:05	15/06/2024 8:12	7
15/06/2024 12:45	15/06/2024 12:55	10
15/06/2024 16:52	15/06/2024 17:06	14
15/06/2024 20:28	15/06/2024 20:46	18
16/06/2024 0:55	16/06/2024 1:11	16
16/06/2024 3:40	16/06/2024 6:23	163
16/06/2024 9:13	16/06/2024 9:37	24
16/06/2024 13:52	16/06/2024 13:59	7
16/06/2024 14:48	16/06/2024 14:50	2
16/06/2024 23:25	16/06/2024 23:35	10
17/06/2024 0:21	17/06/2024 1:43	82
17/06/2024 2:04	17/06/2024 2:24	20
17/06/2024 3:29	17/06/2024 4:48	79
17/06/2024 5:32	17/06/2024 6:49	77
17/06/2024 7:11	17/06/2024 7:19	8
17/06/2024 8:08	17/06/2024 8:15	7
17/06/2024 9:49	17/06/2024 9:54	5
17/06/2024 10:18	17/06/2024 10:25	7
17/06/2024 10:54	17/06/2024 13:08	134
17/06/2024 17:16	17/06/2024 17:18	2

17/06/2024 20:24	17/06/2024 22:54	150
18/06/2024 0:03	18/06/2024 0:05	2
18/06/2024 0:26	18/06/2024 0:43	17
18/06/2024 2:20	18/06/2024 2:43	23
18/06/2024 5:59	18/06/2024 6:07	8
18/06/2024 7:35	18/06/2024 7:41	6
18/06/2024 8:30	18/06/2024 8:35	5
18/06/2024 9:27	18/06/2024 9:59	32
18/06/2024 10:48	18/06/2024 11:01	13
18/06/2024 12:16	18/06/2024 12:35	19
18/06/2024 16:14	18/06/2024 16:33	19
22/06/2024 3:39	22/06/2024 4:07	28
22/06/2024 4:56	22/06/2024 5:25	29
22/06/2024 6:19	22/06/2024 6:37	18
22/06/2024 7:20	22/06/2024 7:42	22
22/06/2024 8:16	22/06/2024 8:54	38
22/06/2024 10:51	22/06/2024 11:00	9
23/06/2024 6:05	23/06/2024 10:07	242
23/06/2024 11:24	23/06/2024 14:18	174
23/06/2024 14:44	23/06/2024 14:51	7
23/06/2024 15:54	23/06/2024 16:13	19
23/06/2024 16:36	23/06/2024 16:47	11
23/06/2024 17:11	23/06/2024 22:29	318
24/06/2024 0:15	24/06/2024 0:29	14
24/06/2024 1:03	24/06/2024 1:08	5
24/06/2024 1:29	24/06/2024 1:45	16
24/06/2024 3:59	24/06/2024 4:12	13
24/06/2024 5:22	24/06/2024 6:29	67
24/06/2024 7:04	24/06/2024 9:20	136
24/06/2024 9:43	24/06/2024 10:25	42
24/06/2024 11:13	24/06/2024 12:05	52

Baleen whale detection events

DateTime	Call Count per hour	Species
7/05/2024 0:00	2	Brydes
7/05/2024 3:00	3	Brydes
7/05/2024 8:00	4	Brydes
7/05/2024 9:00	1	Brydes
7/05/2024 10:00	4	Brydes
7/05/2024 11:00	16	Brydes
7/05/2024 12:00	8	Brydes
7/05/2024 13:00	6	Brydes
7/05/2024 14:00	9	Brydes

7/05/2024 17:00	1	Brydes
7/05/2024 18:00	8	Brydes
7/05/2024 19:00	10	Brydes
7/05/2024 20:00	11	Brydes
7/05/2024 21:00	27	Brydes
7/05/2024 22:00	6	Brydes
7/05/2024 23:00	7	Brydes
8/05/2024 0:00	4	Brydes
8/05/2024 4:00	1	Brydes
8/05/2024 6:00	4	Brydes
8/05/2024 8:00	1	Brydes
8/05/2024 9:00	1	Brydes
9/05/2024 1:00	2	Brydes
9/05/2024 2:00	2	Brydes
9/05/2024 3:00	1	Brydes
9/05/2024 6:00	2	Brydes
10/05/2024 19:00	1	Brydes
10/05/2024 20:00	1	Brydes
10/05/2024 22:00	1	Brydes
11/05/2024 23:00	2	Brydes
12/05/2024 0:00	2	Brydes
12/05/2024 1:00	1	Brydes
14/05/2024 19:00	6	Brydes
14/05/2024 20:00	3	Brydes
14/05/2024 21:00	6	Brydes
14/05/2024 22:00	2	Brydes
15/05/2024 4:00	1	Brydes
15/05/2024 5:00	7	Brydes
16/05/2024 14:00	2	Brydes
16/05/2024 15:00	2	Brydes
16/05/2024 16:00	3	Brydes
16/05/2024 17:00	4	Brydes
16/05/2024 18:00	15	Brydes
16/05/2024 19:00	10	Brydes
16/05/2024 20:00	5	Brydes
16/05/2024 21:00	6	Brydes
16/05/2024 22:00	8	Brydes
16/05/2024 23:00	6	Brydes
17/05/2024 0:00	10	Brydes
17/05/2024 1:00	12	Brydes
17/05/2024 2:00	11	Brydes
17/05/2024 8:00	2	Brydes
17/05/2024 11:00	4	Brydes

17/05/2024 12:00	2	Brydes
17/05/2024 20:00	2	Brydes
17/05/2024 21:00	9	Brydes
17/05/2024 22:00	4	Brydes
17/05/2024 23:00	4	Brydes
18/05/2024 0:00	4	Brydes
18/05/2024 1:00	3	Brydes
19/05/2024 7:00	1	Brydes
19/05/2024 8:00	1	Brydes
19/05/2024 16:00	3	Brydes
19/05/2024 17:00	3	Brydes
19/05/2024 18:00	2	Brydes
19/05/2024 19:00	4	Brydes
19/05/2024 20:00	1	Brydes
20/05/2024 2:00	2	Brydes
20/05/2024 3:00	3	Brydes
20/05/2024 4:00	2	Brydes
20/05/2024 10:00	1	Brydes
21/05/2024 22:00	2	Brydes
23/05/2024 18:00	1	Brydes
6/06/2024 1:00	4	Sei
6/06/2024 2:00	1	Sei
6/06/2024 3:00	1	Sei
6/06/2024 4:00	1	Sei
6/06/2024 9:00	1	Sei

References

Duarte, C.M., Chapuis, L., Collin, S.P., et al. 2021. The soundscape of the Anthropocene ocean. *Science* 371: eaba4658.

Merchant, N.D., Fristrup, K.M., Johnson, M.P., et al. 2015. Measuring acoustic habitats. *Methods in Ecology and Evolution* 6(3): 257-265.

Nowacek, D.P., Thorne, L.H., Johnston, D.W.., Tyack, P.L. 2007. Responses of cetaceans to anthropogenic noise. *Mammal Review* 37(2): 81-115.

Pine, M.K., Wilson, L., Jeffs, A.G., et al. 2021. A gulf in lockdown: how an enforced ban on recreational vessels increased dolphin and fish communication ranges. *Global Change Biology* 27: 4839-4848.

Southall, B.L., Bowles, A.E., Ellison, W.T., et al. 2007. Marine mammal noise exposure criteria: Initial scientific recommendations. *Aquatic Mammals* 33: 1-521.

Appendix C Cumulative ship noise modelling (AIS traffic)

Given vessel traffic is the primary source controlling the anthrophony of Te Ākau Bream Bay, vessel noise models were used to investigate the existing anthropogenic soundscape. Maps were made from noise models of individual vessels travelling through the harbour, using automatic identification system (AIS) data[13]. High resolution maps showing the overall noise levels for each month between April and June 2024 were generated, representing the cumulative sound exposure levels and average noise levels for each month. The maps also represented the existing anthropogenic noise levels within and outside Te Ākau Bream Bay.

Vessel position modelling

Vessel positions were taken from the overall AIS dataset that included a series of time-stamped waypoints (latitude and longitude coordinates) and associated data for each vessel class/type. Vessels classes were sorted according to those detailed in the reference spectrum model (RSM) (MacGillivray & de Jong (2021)), specifically:

- Bulk carriers
- Tanker
- Tug boats
- Passenger cruise vessels
- Recreational vessels
- Naval vessels
- Government research vessels, including icebreakers
- Fishing vessels

For each latitude and longitude waypoint, the associated data extracted for the modelling was speed over ground (SOG) and the vessel's International Maritime Organization (IMO) number.

AIS-based vessel source levels

The source spectrum of each vessel class for specific speeds and vessel sizes was estimated using the reference models by MacGillivray & de Jong (2021). The RSM is the most recent reference source level model based on empirical data from the Vancouver Fraser Port Authority's Enhancing Cetacean Habitat and Observation (ECHO) Program. For specific details on the RSM, please refer to MacGillivray & de Jong (2021).

[13] AIS dataset was obtained from Spire as a single CSV file. Note only vessels carrying AIS and transmitting were included in the model.

As the RSM provides spectra that are specific to a vessel's class, size and speed, those three parameters were required in the cumulative vessel noise model. While the speed and vessel type were available in the AIS dataset, the length of the vessel was found through a web search[14] of the MMSI number.

Propagation modelling

The propagation loss (N_{PL}) was modelled using an energy flux numerical model based on Western's Equations (Western 1971). These models have been used to model vessel noise in both New Zealand waters (for example, Wilson et al. 2023) and internationally (for example, Farcas et al. 2020).

The EF model demonstrates high computational efficiency over range-dependent scenarios and is suitable for high and low frequencies in shallow waters (de Jong et al. 2021). Consequently, high resolution models can be produced in relatively short-time frames. This was important for assessing how the sand extraction may impact the existing soundscape, because the vessel noise model contained 6,694 individual AIS-vessel tracks[15] for 31 decidecade bands (between 63Hz and 32kHz).

The EF model divides the noise propagation pathway into four regions at increasing distances from the source and are identified as regions *A, B, C* and *D* (Wood, 2016):

- Region A is a spherical spreading with frequency-dependent absorption out to half the water's depth from the source;
- Region B is a channel where shallower critical grazing angles are reflected from the seabed but absorbed at higher critical angles;
- Region C uses mode-stripping with high grazing angles or higher modes are attenuated; and
- Region D is single-mode propagation.

The EF model incorporates bathymetry (Figure 13), sound speed (Figure 14), seabed reflectivity and frequency. Bathymetry data was from NIWA (2016), which is based on multibeam and single beam sounding lines spaced 50-120m apart. Sound speeds were calculated as a depth-average from the Hauraki Gulf data (Zeldis 2013), while the seabed was assumed to be homogenous fine sand.

The input parameters are summarised in Table 18 below.

---

[14]The web search was done using a custom-written automated function that extracted the length of each vessel from the webpage's source code and loaded them directly into the cumulative noise model software.

[15]Individual vessel tracks that were included in the model were those when the vessel was underway and had more than 20 waypoints (ensuring reliable speed-dependent averages and sound exposure level calculations).

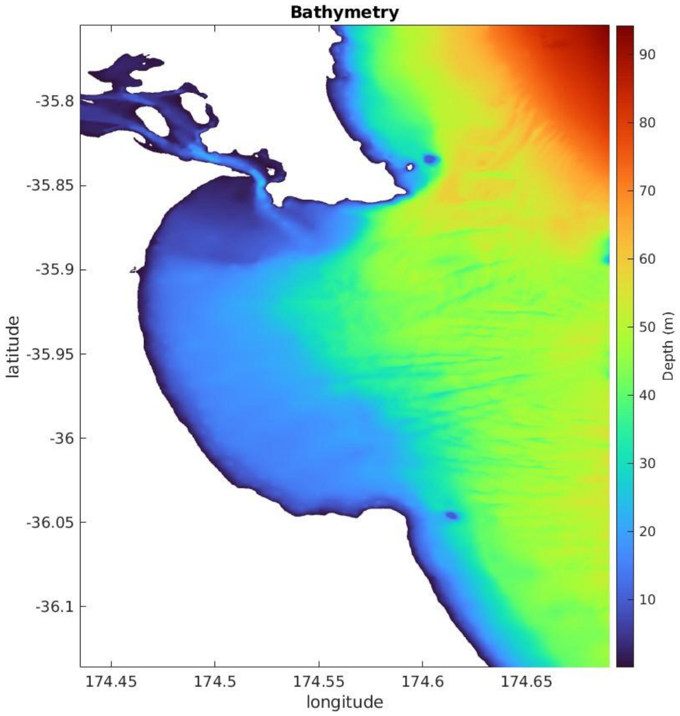

Figure 13: Bathymetry raster provided by NIWA.

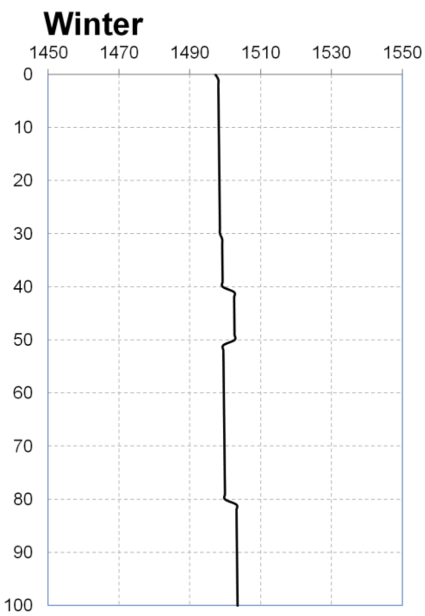

Figure 14: Sound speeds used in the modelling, based on data from Zeldis (2013). The winter sound speed profile was used in the modelling and applied as a depth-average speed.

For each vessel waypoint, the N_{PL} was calculated for 360 radials (1° bearings), with 100m range steps out to 40km range. For each calculation point, the corresponding bathymetry, seafloor reflectivity coefficients, and sound speeds were also extracted from the underlying raster. This resulted in a calculated N_{PL} value for each 25m along the radial, that together, formed a 3D array for each frequency. The frequency-dependent 3D arrays were then converted to a 2D map using linear interpolation and nearest neighbour extrapolation for each transect and waypoint. This resulted in a single N_{PL} map representing the decibel N_{PL} from an individual waypoint for each frequency.

Vessel noise maps

The instantaneous sound pressure levels were defined as:

$$L_{p,f}(R) = L_{s,f} - N_{PL,f}(R) \text{(eq.1)}$$

This equation was applied to each map, resulting in the instantaneous sound pressure level (L_p) map for each frequency (f), vessel and waypoint. The L_p maps were then used to generate the time-integrated models, such as the monthly cumulative sound exposure levels (L_E) and equivalent continuous sound pressure levels (Leq).

The Leq maps for each individual vessel track were produced by taking the log average of two successive waypoints, starting from the first waypoint in the AIS record. These two points represented the edges of a ‘cell’, while a new waypoint between them was the cell’s centre. This method meant that the cell sizes over which the Leq/L_E values were calculated were not equal but defined by the distance between waypoints, resulting in an automatic adjustment in the model’s spatial resolution that was directly related to a vessel’s SOG. The L_E of the same cell was then calculated using:

$$L_{E,i,f} = Leq_{i,f} + 10Log_{10}(T_i) \text{ (eq. 2),}$$

where i is the cell’s Leq at frequency f and T is the time taken to travel between the two waypoints at the cell’s boundaries. T was calculated using the averaged SOG, in km h^{-1}, between the two waypoints. This method of analysing per waypoint, instead of using a static grid, was to have the model automatically adjust for changing resolution requirements. For example, inside Whangarei harbour, the waterways are relatively narrow and a 5 km × 5 km grid cell would be too coarse to capture the SOG and bathymetric changes as the vessel approaches and then enters the harbour. However, smaller cell sizes increase the computational load in areas where lower spatial resolutions (therefore lower computational cost) would be appropriate, such as outside Te Ākau Bream Bay when SOG does not change often for large ships, and the N_{PL} coefficients are more stable. Furthermore, SOG changes in some vessel types, such as government or fishing vessels moving slower or changing heading/course a lot, would also be captured. This means the cumulative sound exposure maps would be more representative than when assuming constant travel and speed over larger ranges (such as through a 5 km × 5 km grid).

Table 19: Input parameters for the acoustic models.

Model independent variables	
Bathymetry	50-120m resolution ASCII raster.
Model independent variables	360 radials; 100km per radial; 100m range steps.
3D array to 2D grid conversion	Natural neighbour interpolation with nearest neighbour extrapolation.
Model dependent variables	
Weston's energy flux	3 frequencies either side of decidecade centre frequency (Fc). Fc = [25 31.6 40 50 63 80 120 125 160 200 250 315 400 500 630 800 1000 1200 1600 2000 2500 3200 4000 5000 6300 8000 10000 12500 16000 20000 25000 32000]
Sediments	
Sediment types	Gravel/Shell: ρ 2000kg/m^3, c_p 1800m/s, $α_p$ 0.6 dB/λ. Sand: ρ 1950kg/m^3, c_p 1725m/s, $α_p$ 0.8 dB/λ. Silt: ρ 1700kg/m^3, c_p 1650m/s, $α_p$ 1.0 dB/λ. Average of these sediment types applied, based on vibrocore data*)
Water column	
Sound speed	1500.19ms
Water density	1025 kg/m^3
Salinity	35 psu.

*Vibrocore data from the Geotechnical Factual Report from Tonkin & Taylor as part of the application.

References

de Jong, C., Binnerts, B., Robinson, S., Wang, L. 2021. Guidelines for modelling ocean ambient noise. Report of the EU INTERREG Joint Monitoring Programme for Ambient Noise North Sea (Jomopans).

Farcas, A., Powell, C.F., Brookes, K.L., Merchant, N.D. 2020. Validated shipping noise maps of the Northeast Atlantic. *Science of the Total Environment* 735: 139509.

MacGillivray, A., de Jong C. 2021. A reference spectrum model for estimating source levels of marine shipping based on automated identification system data. *Journal of Marine Science and Engineering* 9(4): 369.

National Marine Fisheries Service (NMFS). 2024. Update to: Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (Version 3.0): Underwater and in-air criteria for onset of auditory injury and temporary threshold shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-xx, xxx p.

NIWA (National Institute of Water and Atmospheric Research). 2016. New Zealand Bathymetry. www.niwa.co.nz/our-science/oceans/bathymetry.

Pine, M.K., Hannay, D.E., Insley, S.J., et al. 2018. Assessing vessel slowdown for reducing auditory masking for marine mammals and fish of the western Canadian Arctic. *Marine Pollution Bulletin* 135: 290-302.

Weston, D.E. (1971). Intensity-range relations in oceanographic acoustics. *Journal of Sound and Vibration* 18: 271–287.

Wilson, L., Constantine, R., Pine, M.K., et al. 2023. Impact of small boat sound on the listening space of *Pempheris adspersa, Forsterygion lapillum, Alpheus richardsoni* and *Ovalipes catharus*. *Scientific Reports* 13: 7007.

Wood, M.A. 2016. Modelling and preduction of acoustic disturbances from off-shore piling. Ph.D. Thesis, University of Southamptom.

Zeldis, J., Bind, J., Roulston, H., et al. 2013. Visualising nutrients and phytoplankton in the Hauraki Gulf Marine Park using GIS. Waikato Regional Council Technical Report 2013/50. Report number 2829462.

Appendix D Extraction noise modelling

Sound source: the TSHD *William Fraser*

The source spectrum used for the active extraction models was from empirical measurements of the *William Fraser* while in extraction mode off the Mangawhai-Pākiri coast in 2019 (see Appendix I for methods). The empirical source spectrum for the *William Fraser* in extraction mode is provided in Figure 15.

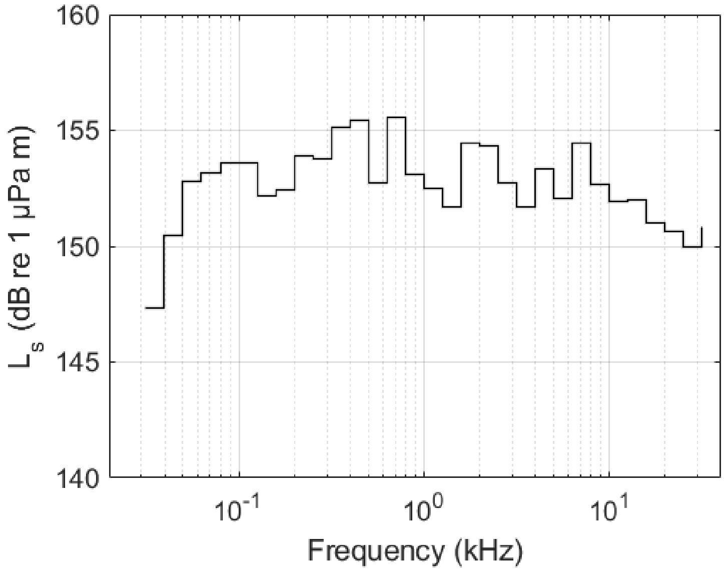

Figure 15: Source spectrum (decidecade) of the *William Fraser* measured in shallow (<30m) water.

Broadband source level = 167.85dB_{rms} re 1 µPa m

Modelling TSHD positions and extraction behaviours

A key objective of the extraction noise model was to assess the changes to the existing anthrophonic soundscape over each day of extraction. The *William Fraser* will typically be extracting transects within the extraction area, essentially combing the area until the hopper is filled. Once the hopper fills, the draghead is lifted and the vessel transits to Auckland, leaving Te Ākau Bream Bay.

The *William Fraser* is expected to operate inside Te Ākau Bream Bay over several days per week, for a maximum 3 hours and 30 minutes per day. When 150,000m^3 of sand per annum is to be extracted, the number of trips will be an average 3.1 trips per week. This will increase to approximately 5.2 trips per week (on average) to achieve the targeted 250,000m^3 of extracted sand per annum. Because sand extraction inside Te Ākau Bream Bay is not currently occurring, there were no real-world track data for the TSHD vessel available for our predictive modelling. We therefore randomly generated hypothetical tracks within the entire extraction area (Figure 16). Individual transects were spaced 100m apart, with assessment points also spaced 100m along the 7km long transect (the width of the extraction area, see Figure 1).

The AIS traffic data available for this assessment covered April through June 2024, and therefore the TSHD noise models covered the same period to allow for comparisons. Because the AIS traffic noise models are based on monthly cumulative sound exposures and averages, the same had to be applied to the TSHD models. To achieve this, daily tracks for the *William Fraser* were generated for each day of the month, that could be later recalled and pooled to represent each month (the same method as the for the AIS traffic models). The daily tracks were automatically generated by taking random start/end positions on any transect, then moving 2 knots along transects for 3 hours and 30 minutes (see Figure 17). These daily tracks were written to CSV files that could be read by the vessel noise model (detailed in Appendix C).

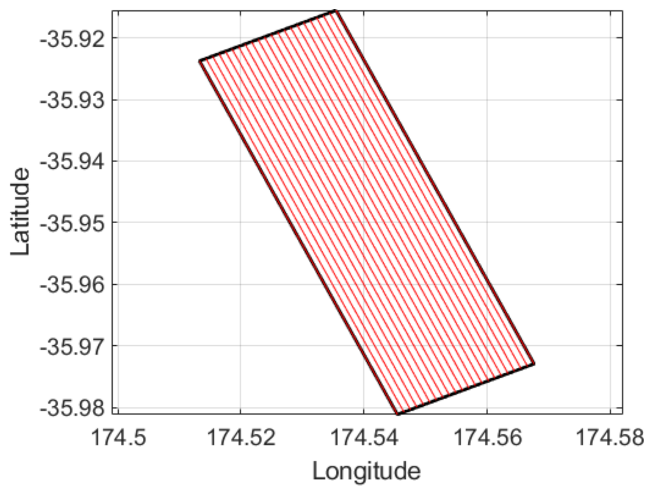

Figure 16: Polygon representing the extraction area and transects used in the TSHD noise model. The polygon was set using the corner coordinates Sa, Sb, Sc, Sd in **Figure 1**. Each 100m-spaced transect is made of 100m-spaced waypoints.

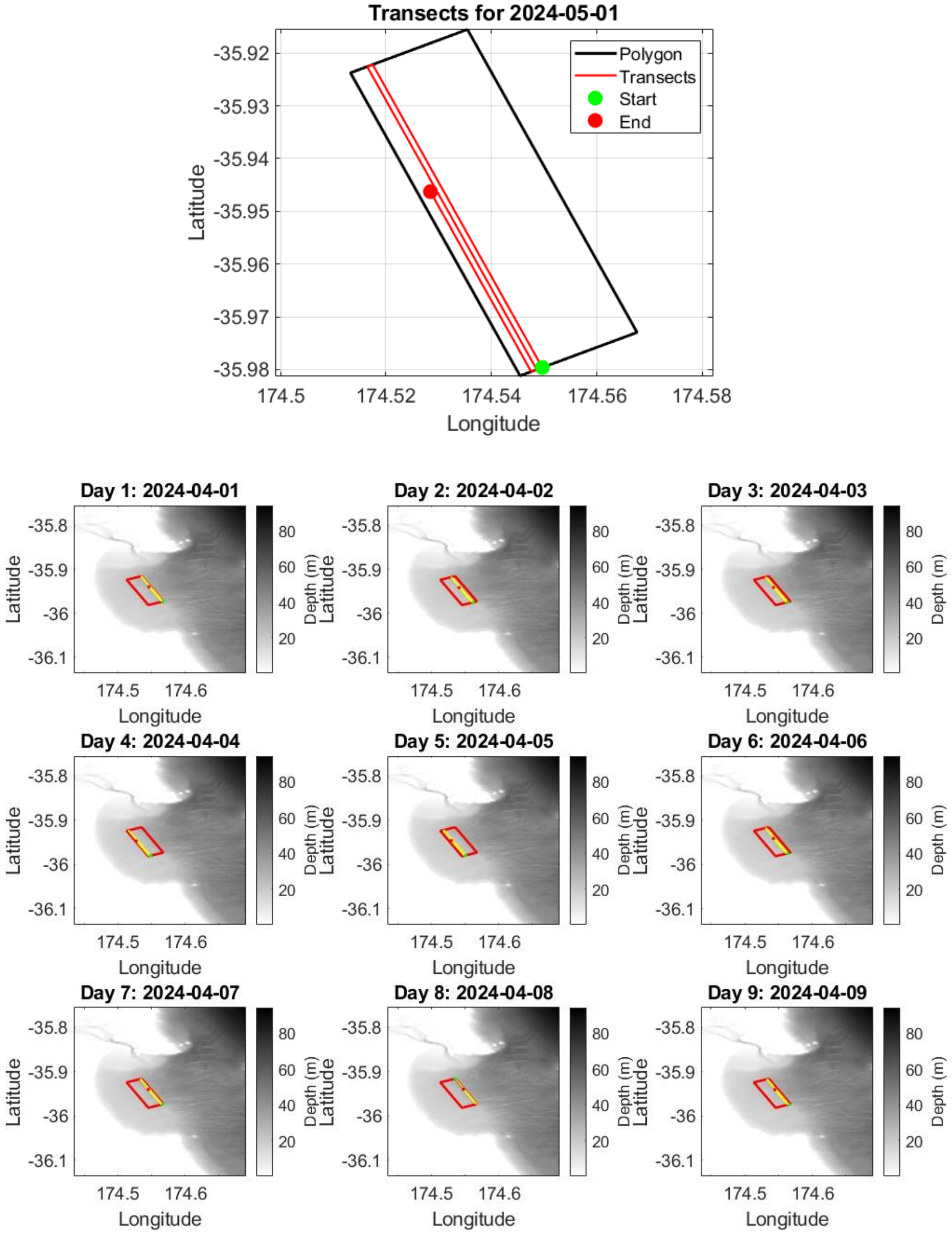

Figure 17: Examples of randomly generated daily transects used in the cumulative TSHD noise model. The top plot shows a single day, while the bottom subplot grid shows nine days plotted over the bathymetry. The red box represents the sand extraction area.

Assessing soundscape changes

The AIS dataset between April and June 2024 was used to produce noise maps of the existing monthly noise levels from concurrent vessel traffic. This allowed us to contextualise the cumulative extraction noise each month and calculate the additional noise to the existing anthrophony and soundscape that could be attributed to the proposed sand extraction activity. This method is likely to overstate reality because AIS records are known to exclude most recreational vessel activity (please refer to section 5.5 *Changes to Te Ākau Bream Bay's Anthrophony/Soundscape* above for more details).

In addition to assessing the overall difference in the cumulative noise energy, the differences in the average monthly Leq levels between the AIS traffic and extraction noise models[16] were also calculated at specific points ('measurement points') throughout Te Ākau Bream Bay. The specific locations are provided in Figure 18.

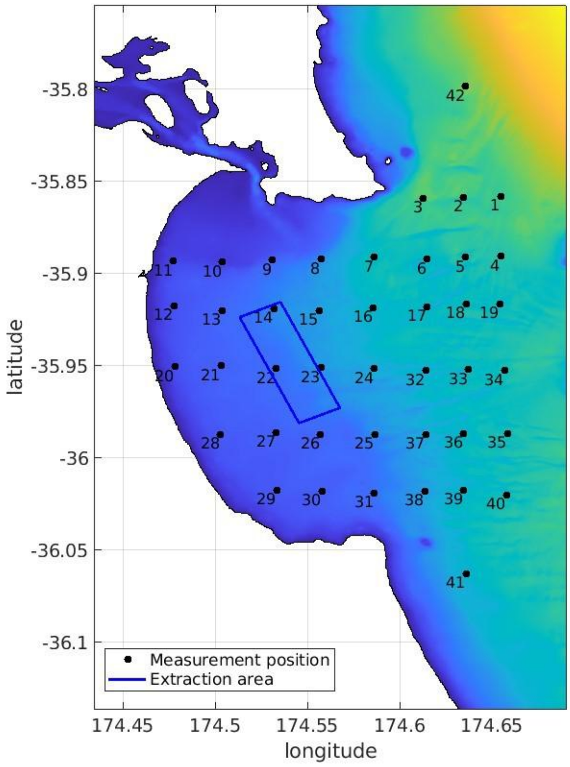

Figure 18: Map showing the positions of each 'measurement position' used to calculate the average soundscape changes from the proposed sand extraction activity within Te Ākau Bream Bay.

[16] Daytime Leq levels were averaged over each month and added to the models. The Leq noise models therefore included both the AIS traffic, sand extraction activity and ambient daytime noise level from the extraction area. Please note, that the extraction area was of a homogenous soft-sediment habitat, and therefore lower sound levels than over reefs.

Additional noise to the existing soundscape at each of those measurement points is provided in Figures 19 through 21 (for 150,000m^3) and Figures 22 through 24 (for 250,000m^3). It shows the representative spatial extent of potential soundscape changes from the sand extraction between April and June 2024.

150,000m^3 extracted annually

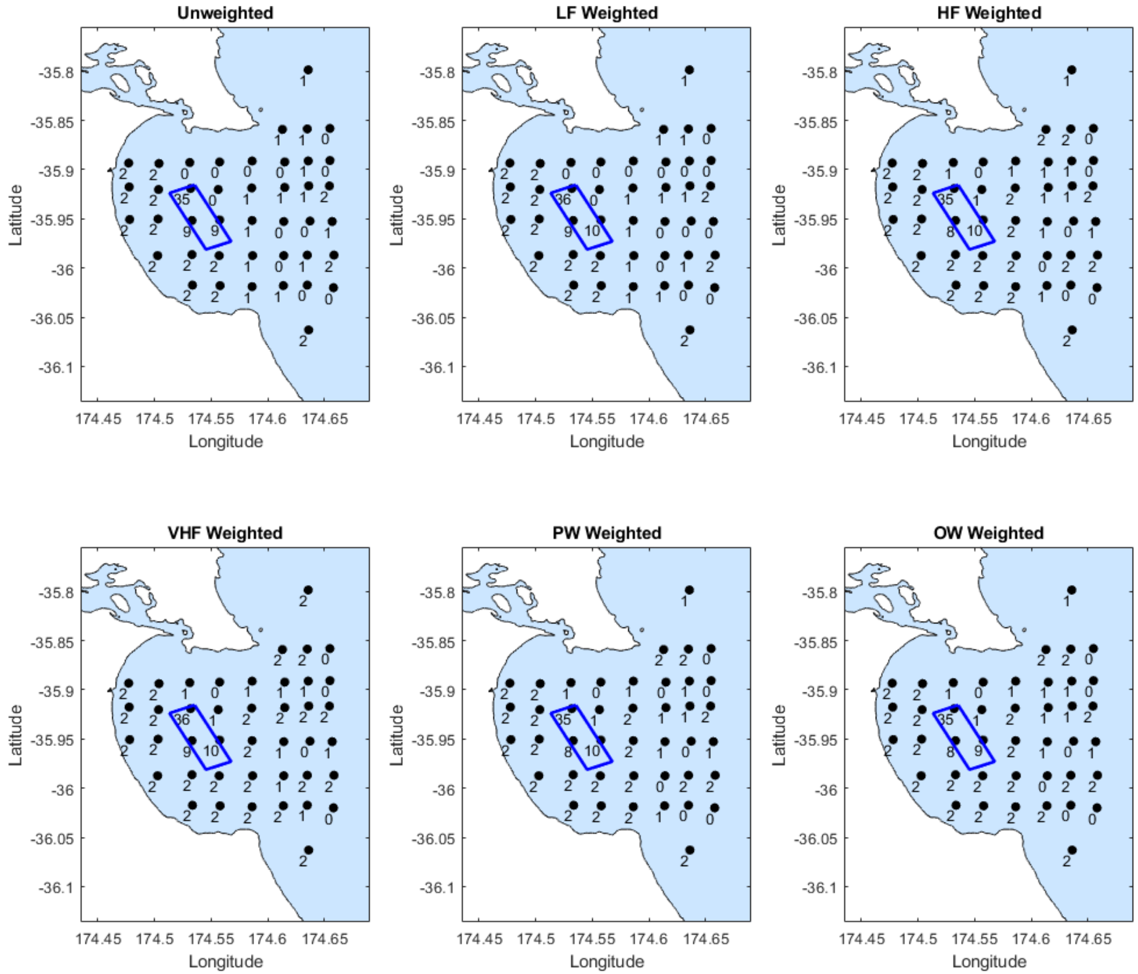

Figure 19: Plots showing the difference in the monthly Leq levels between the AIS traffic levels and sand extraction activity at each measurement point identified in **Figure 18**, during **April** 2024.

150,000m³ extracted annually

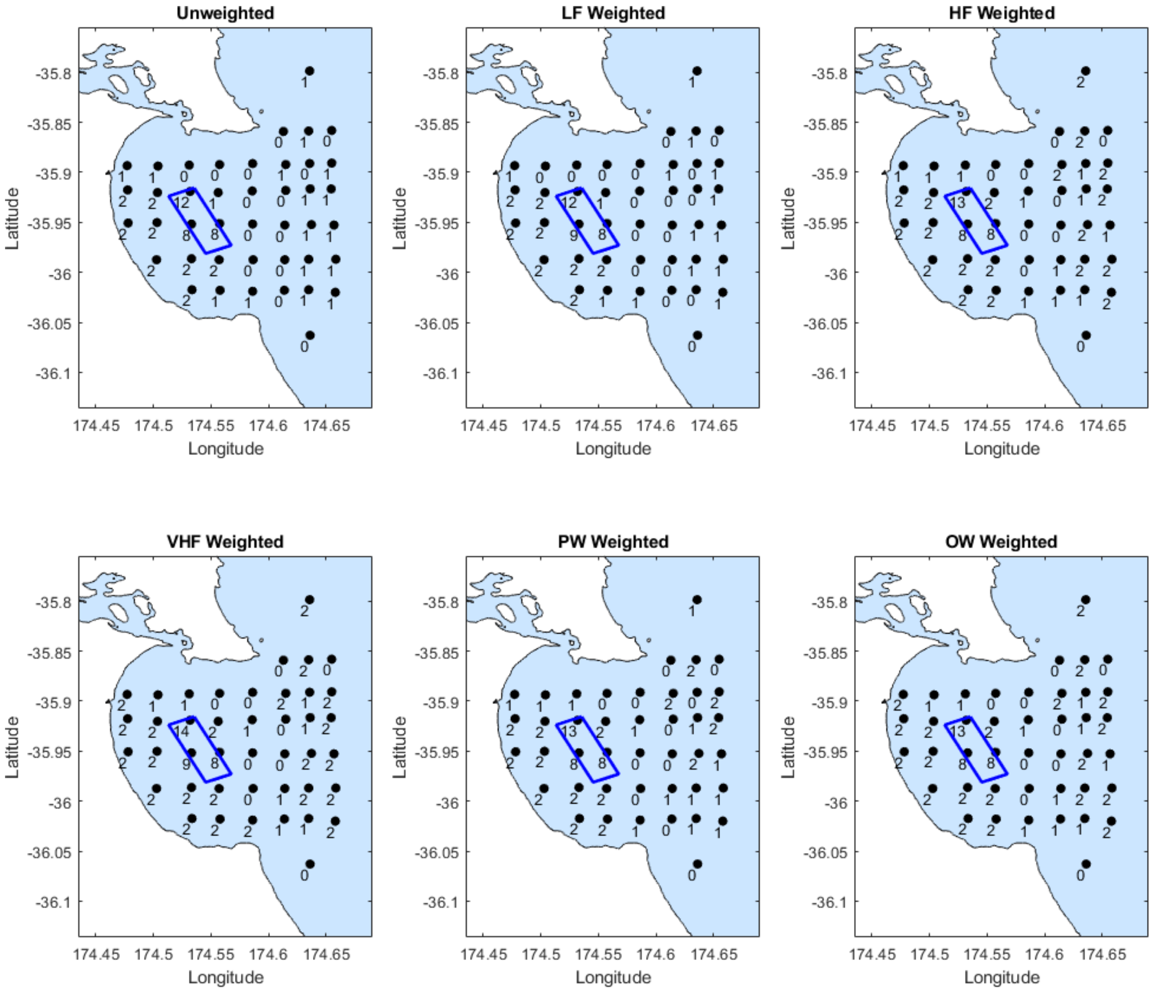

Figure 20: Plots showing the difference in the monthly Leq levels between the AIS traffic levels and sand extraction activity at each measurement point identified in **Figure 18**, during **May** 2024.

150,000m³ extracted annually

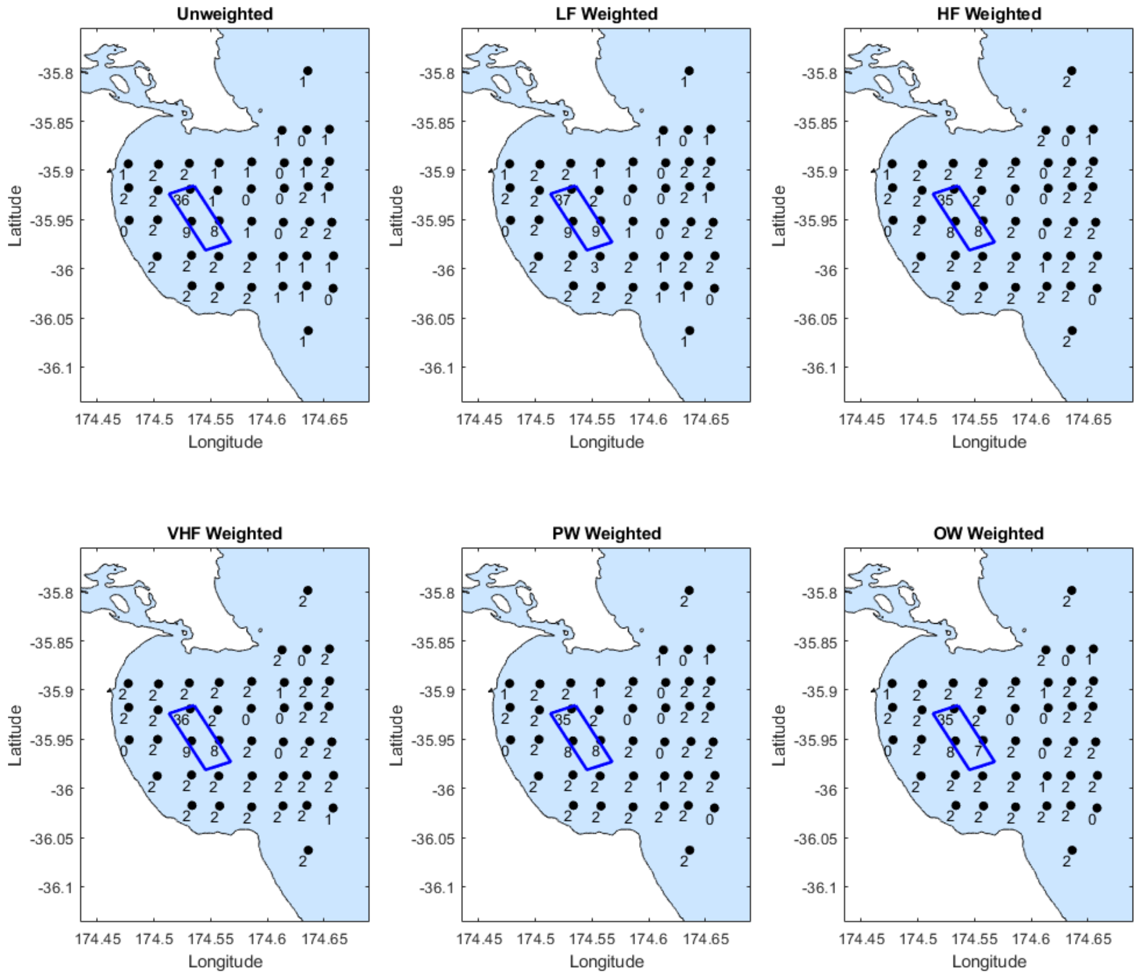

Figure 21: Plots showing the difference in the monthly Leq levels between the AIS traffic levels and sand extraction activity at each measurement point identified in **Figure 18**, during **June** 2024.

250,000m³ extracted annually

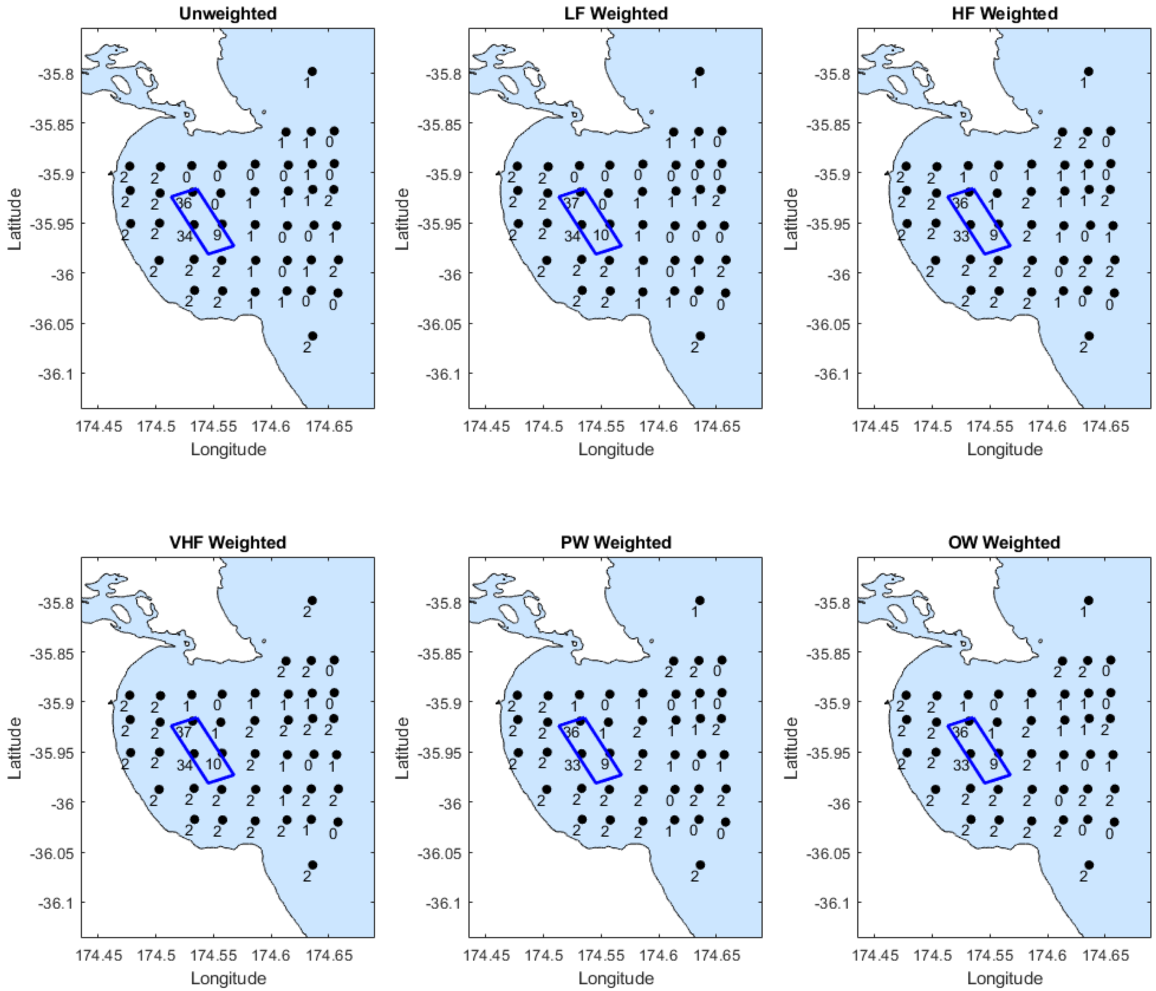

Figure 22: Plots showing the difference in the monthly Leq levels between the AIS traffic levels and sand extraction activity at each measurement point identified in **Figure 18**, during **April** 2024.

250,000m³ extracted annually

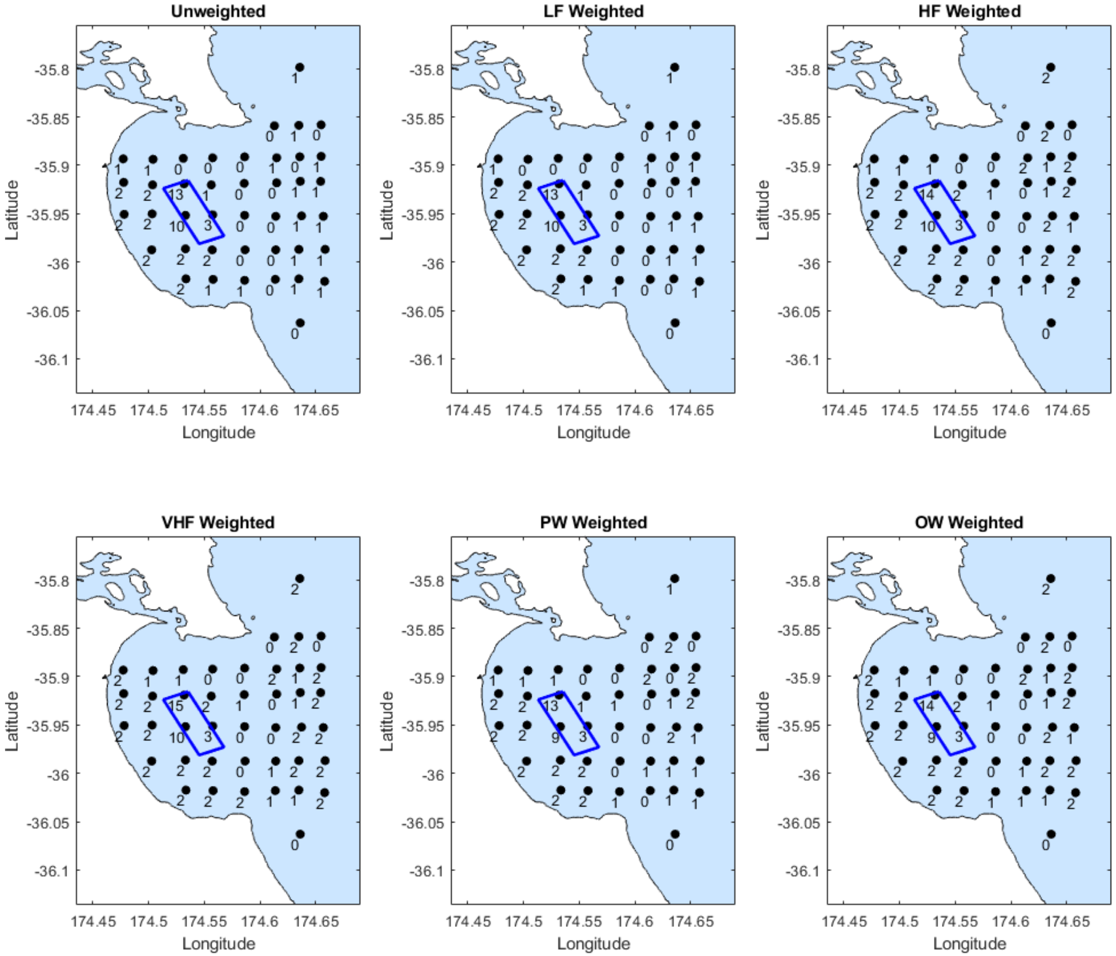

Figure 23: Plots showing the difference in the monthly Leq levels between the AIS traffic levels and sand extraction activity at each measurement point identified in **Figure 18**, during **May** 2024.

250,000m³ extracted annually

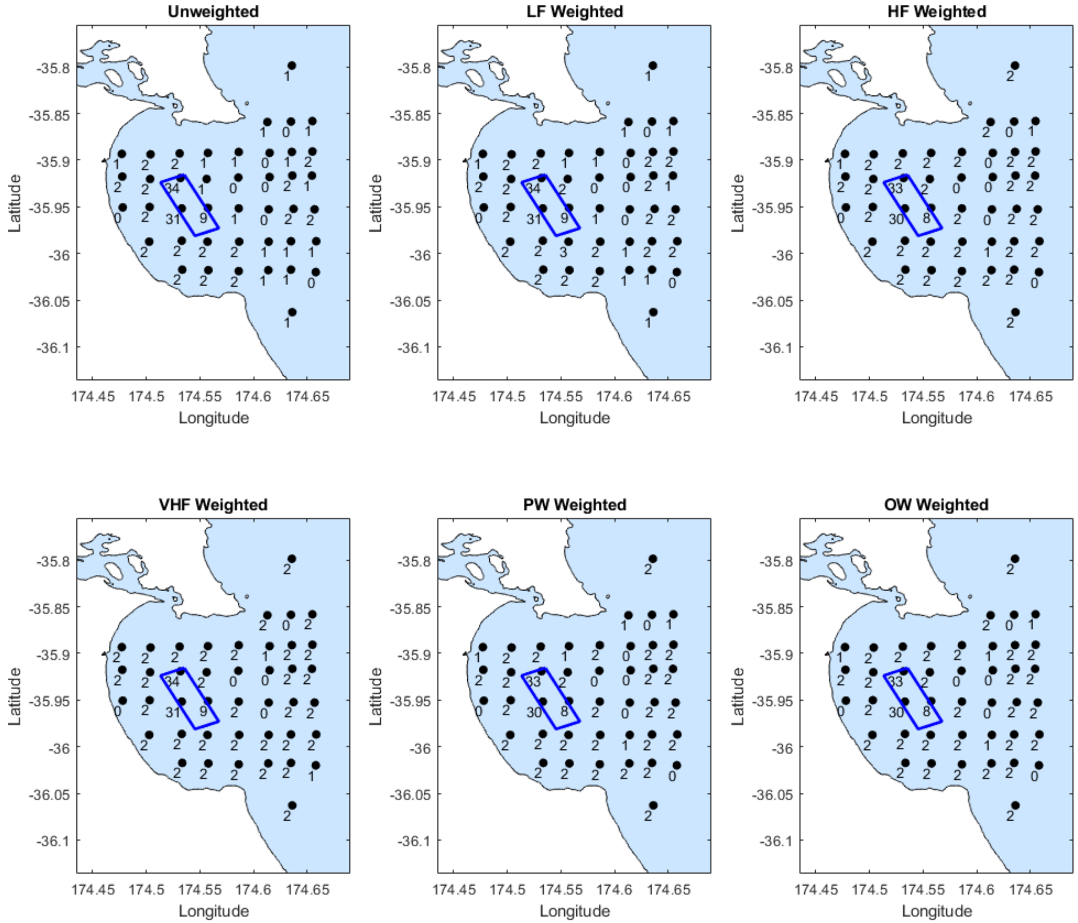

Figure 24: Plots showing the difference in the monthly Leq levels between the AIS traffic levels and sand extraction activity at each measurement point identified in **Figure 18**, during **June** 2024.

Appendix E Effects modelling for marine mammals, kororā/little penguin, sea turtles

The overall objective of the acoustic modelling is to provide the acoustic footprint of the noisiest activity to inform an assessment of the potential impacts on marine life. This section pertains to the animal groups/species with noise criteria that prescribe thresholds or discuss effects using sound pressure metrics. Fishes and invertebrates are therefore contained within Appendix F, since effects on them were assessed using particle acceleration metrics.

Please refer to Table 1 of the assessment report for details on which groups/species are specifically assessed for each effects category.

Physiological effects (marine mammals)

When a receiver is exposed to high noise levels over an extended period, the cells within the inner ear begin to fatigue and become less sensitive. Therefore, a change in the animal receiver's hearing threshold occurs, and the degree at which those thresholds change is referred to as a threshold shift. If hearing returns to normal after a certain time post-exposure, the threshold shift is temporary (termed temporary threshold shift, TTS), but if not, then it is referred to as permanent threshold shift (PTS)[17]. The type and amount of threshold shift depends on the duration of the noise, rise times, duty cycles, sound pressure levels within the listener's critical bandwidths (i.e., the spectral composition of the noise) and, of course, the overall energy.

Exposure guidelines for hearing effects (i.e., TTS or PTS) and continuous noises prescribe a cumulative sound exposure level (L_E) threshold which relates to the amount of time that the noise source is present for (after M-weighting the noise), as defined as:

$$L_E = L_p + 10\,log_{10}(duration\ of\ exposure) \quad \text{(eq. 3)},$$

where L_E is the cumulative sound exposure level, assuming a constant received L_p with no temporal variability over space and time (NMFS, 2024). However, if one were to assume a stationary (or very slow moving) animal receiver (i.e., a marine mammal) and a moving source at a constant speed and direction (typical of TSHDs actively extracting), then the actual exposure would vary over space and time (i.e., the rate at which sound exposure dose increases will be greatest when the receiver is closest to the TSHD and decreases with increasing range as either the TSHD or receiver moves away). Therefore, if the problem is addressed from the perspective of the marine mammal, then equation 3 does not reflect reality particularly well. In this case, the approach for assessing threshold shift risks on marine mammals was the *safe distance*, R_0, method[18]. This method "*allows one to determine the distance the receiver would have to remain in order to not exceed some predetermined*

[17] A type of Auditory Injury (AUD INJ) in NMFS (2024).

[18] First described by Sivle et al. (2014) and described in the 2018 Revisions to the Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2) from NOAA, April 2018.

exposure threshold" (NMFS 2018). The safe distance method accounts for the source velocity, spectrum, and duty cycle, and is independent of the exposure duration (i.e. suitable for moving sources, whether continuous or impulsive). The safe distance method was calculated using the same equation from Sivle et al. (2014), but expressed in a simpler manner:

$$R_{\&} = \frac{-}{,!-} SD \text{ (eq. 4)}$$

where S is the source factor, D is the duty cycle, v is the transit speed and E_0 is the exposure threshold[19] (NMFS 2024). A key assumption to this method is that the sound source is simple – i.e. the source moves at a constant speed and in a constant direction (such as that of a TSHD actively extracting along linear transects). Since the exposure thresholds for TTS are from the NMFS (2024) guidance, the empirical source levels of the TSHD were M-weighted. This was done for every 1 Hz and then recombined to generate the broadband source level used for the threshold shift zone calculations (see NMFS (2024) for the weighting functions).

The noise criteria used for the establishment of PTS and TTS radii were from NMFS (2024). Consequently, the various hearing groups are named VHF, HF, LF cetaceans and PW, OW for pinnipeds in water in this report. These are effectively reclassified functional hearing groups, essentially shifting MF to HF, and HF to a new group, VHF (very high frequency) (Table 19). The 2024 update to the NMFS guidance also includes new M-weighting functions, revised TTS/PTS thresholds and refers to Auditory Injury (AUD INJ) which can include PTS (Table 20).

Because these updated functions, classes and thresholds are based on the latest science, we have adopted those functional hearing groups and thresholds in our assessment.

Table 20: Nomenclature of functional hearing groups between NMFS (2018) and NMFS (2024).

NMFS (2018)	NMFS (2024)	Species
High-frequency (HF) cetaceans	Very high-frequency (VHF) cetaceans.	NBHF odontocetes: Hector's dolphins, porpoises.
Mid-frequency (MF) cetaceans	High-frequency (HF) cetaceans. .	General odontocetes not NBHF: Killer whales, bottlenose dolphins, common dolphins, dusky dolphins.
Low-frequency (LF) cetaceans	Low-frequency (LF) cetaceans.	Baleen whales.
Phocid pinnipeds (PW) underwater	Phocid carnivores (PW) in water.	True seals.
Otariid pinnipeds (OW) underwater	Other marine carnivores (OW) in water.	Sea lions & fur seals.

[19]As a pressure value of the NMFS (2024) thresholds.

Table 21: NMFS (2024) auditory threshold criteria for a non-impulsive noise source.

Functional hearing group	TTS threshold	AUD-INJ threshold
LF	177	197
HF	181	201
VHF	161	181
OCW	179	199
PCW	175	195

Behavioural responses (marine mammals)

There is a substantial amount of literature on the behavioural effects of noise on marine mammals – either direct evidence-based studies, opportunistic studies, or observations – that have been summarised in several reviews (for example Richardson et al. 1995; Hildebrand 2005; NRC 2005; MMC 2007; Nowacek et al. 2007; Weilgart 2007; NAS 2017). Behavioural effects are highly varied and may include changes in swimming behaviours (directions and speeds), diving behaviours (durations, depths, surface intervals), time spent on the surface, respiration rates, fleeing the noise source and changes to vocalisations. Predicting the zones within which behavioural effects may be seen is the most difficult noise effect to quantify due to their dependency on the context, species and location (see Ellison et al. 2012; Gomez et al. 2016 for reviews on the issue of context dependency on marine mammal behaviour).

Consequently, there is no widely accepted regulatory guidance on behavioural effects currently in existence as it is still a research problem. The only interim guidance for behavioural responses is a single unweighted decibel value of 120 dB re 1 µPa for continuous noise sources (applicable to TSHD vessels) from NOAA (the National Oceanic and Atmospheric Administration in the US). However, for many noise sources, such as continuous extraction noise, they have not had a great uptake (Gomez et al. 2016). One of the issues of using a single noise threshold for behavioural responses is that the data currently available are not very comparable (Nowacek et al. 2007; Southall et al. 2007; Eillison et al 2012; Gomez et al 2016). There is a limited relationship between the severity of the behavioural response and the received level of underwater noise (Gomez et al 2016).

Some underwater noise assessments in New Zealand still consider the 120 dB re 1 µPa contour, stating the reason being it is the only threshold for the onset of some behavioural response. However, because of the uncertainty in assessing the risk of behavioural effects within and between species (based on the highly contextual nature of behavioural effects), the application of a simplistic noise threshold for behaviours should be avoided (Faulker et al. 2018).

Recent studies assess behavioural zones based on the probability of occurrence using dose-response curves specific to the species of interest (Joy et al. 2019). Dose-response curves show the relationship between the probability of a behavioural effect occurring at a given level of noise exposure (Joy et al. 2019). The dose-response formulas have been used by the U.S. Navy (US Navy 2008, 2012) and the scientific community for several years, primarily for sonar, among other transducers, or explosions.

Recent studies provide a specific dose-response function and thresholds for southern resident killer whales exposed to continuous noise sources (Joy et al. 2019). The thresholds make use of the most up-to-date data for killer whales and behavioural effects (specifically those effects classed as low[20] or moderate[21](respectively, a Southall severity score of 2-3 and 4-6 (see Joy et al. 2019). We note that these response severity scores were maintained in this assessment because Southall et al. (2021) do not provide general response scores but scores for the three vital tracks (survival, foraging, reproduction). Briefly explained, Joy et al. (2019) took empirical studies on killer whales and noise (42 studies in total) and correlated the estimated received sound pressure levels with the behavioural response type (i.e. the Southall severity scores) to get a regression curve (linear relationship). From there, two received levels that corresponded to the 50% probability of either a low or moderate behavioural response occurring were calculated. Dose-response curves for killer whales were then generated from those received levels.

The dose-response curve used in this assessment was calculated using:

$$R = \frac{\%/0^{\frac{"\#\$}{\%}}1^{\#\&}}{\%/\,0^{\frac{"\#\$}{\%}}1^{\#'\&}} \text{ (eq. 5)}$$

where *R* was the risk from 0 to 1 (i.e. the probability of an effect occurring) at the noise level *L*, *B* was the basement received sound pressure level (L_p) at which the risk of an effect occurring is so low it does not warrant calculating, *K* was the L_p increment above *B* at which there is 50% risk and *A* was a transition sharpness parameter (Joy et al. 2019).The *RL* at which there was a 50% risk of an effect was set at 129.5 (for a low response (Southall severity 2)) and 137.2 dB re 1 μPa (for a moderate response (Southall severity 5)) (Joy et al. 2019).

Since this method is based on more accurate data (and on killer whales, which is a species that may be present within Te Ākau Bream Bay, with hearing biology similar to other delphinids), we applied the same method and assumptions to our data. However, for this assessment, we altered the basement received level, *B*, to be the averaged 1-min L_p of ambient noise over our monitoring period (between May and June 2024). This provided a conservative

[20]Low behavioural responses are defined as minor changes in respiration rates, swimming speeds and direction (Joy et al. 2019).

[21] Moderate behavioural responses are defined as moderate to extensive changes in swimming speeds, direction and/or diving behaviours, moderate or prolonged cessation of vocalisations, and/or avoidance (Joy et al. 2019).

baseline level specifically related to Te Ākau Bream Bay that is more useful than the unweighted threshold level for continuous noises of 120 dB_{rms} re 1 μPa for all marine mammals.

For larger mystecete species, such as humpback whales, the L_p at which 50% risk of behavioural response occurring was set at 120 dB_{rms} re 1 μPa (Southall et al. 2007, 2019), which is also the threshold for likely behavioural effects from continuous noise (Level B Harrassment) (NOAA, 2005). This was because that level is the lowest level at which bowhead whales, another mystecete species and one of the only whales with estimated levels of exposure (from continuous noise), has been linked to a certain behavioural response (Southall et al. 2007, 2019). This is conservative. No assessment for moderate behavioural effects for mystecetes was made because we do not know what such a threshold would look like and is therefore too speculative to be meaningful. The same basement levels and transition sharpness values were applied.

Dose-response functions were not used for pinnipeds due to data deficiencies. Required data inputs for leopard seals and fur seals (the two seal species considered in this assessment) are not available and therefore a step function approach was used and applied to both species. We note care is needed when interpreting the results using step functions due to the underlying assumptions around the set thresholds. Southall et al. (2007, 2019) review studies showing pinnipeds responding to continuous noise, with individuals shown to react above 120 dB_{rms} μPa (Southall severity score 3[22]). Above 130 dB_{rms} re 1 μPa, the behavioural responses reviewed by Southall et al. (2007, 2019) are more moderate[23]. These unweighted thresholds were used to determine the potential onset for low and moderate severity behavioural responses in this assessment.

Auditory masking (marine mammals, kororā/little penguins, sea turtles)

Marine mammals, fishes, invertebrates, seabirds and turtles are all capable of perceiving low-frequency anthropogenic noise, with many species having hearing ranges that overlap with anthropogenic noise. For example, bottlenose dolphins (*Tursiops truncates*) and common dolphins (*Delphinus delphis*) have shown hearing sensitivities to signals as low as 100 Hz, while killer whales (*Orcinus orca*) show sensitivity down to 500 Hz (Hall & Johnson 1972; Popov & Klishin 1998; Szymanski et al. 1999). Fishes, invertebrates, sea turtles and little penguins all have hearing sensitivities that extend to the low frequencies (below 2kHz) where anthropogenic noise dominates (Duarte et al. 2021). Therefore, auditory masking – the interference of a biologically important signal (such as vocalisations from conspecifics or predator/prey etc) by an unimportant noise that prevents the listener from properly perceiving the signal (Erbe 2008) – is expected to occur (Pine et al. 2019). Extraction noise (along with other anthropogenic noise sources commonly seen in coastal waters) has the potential to

[22] Such as alert behaviours, minor changes to swimming speeds, dive profiles or directions, changes to respiration rates, or minor cessation or modification of vocalisations (Southall et al. 2017, Table 4).

[23] Such as prolonged changes to swimming speeds, dive profiles, or directions, moderate shifts in distributions, prolonged cessation or modification of vocalisations (Southall et al. 2017, Table 4).

interfere with an animal's ability to perceive their natural acoustic environment (Erbe et al. 2016; Popov & Klishin 1998). The inclusion of auditory masking in underwater noise effects assessments is best practice because behavioural effects generally occur at moderate levels of masking and therefore understanding the spatial limits of masking is important (Pine et al. 2019).

We assessed auditory masking for each animal group (including fishes and invertebrates in Appendix F**)** by quantifying the reduction in an animal's listening space. An animal's listening space is the immediate area (volume of ocean) surrounding it within which it can detect and perceive a biologically important signal. The listening space method was used instead of sonar equations in this case because the call structures of all the species of interest at the source are not well understood, while the listening space method is more sensitive to changes in the existing sound environment (Pine et al. 2018, 2020).

As an animal receiver moves around an area when development activities are underway, such as extraction, the animal's listening space will decrease to a new, smaller listening space. The difference between the original and the smaller listening space under masking conditions is termed the listening space reduction (**LSR**).

The method for calculating the LSR is fully described by Pine et al. (2018) who define the LSR as:

$$LSR = 100 * 1 - 10^{/3^{\underline{\Delta}}}), \text{ (eq. 6)}$$

where N is the frequency-dependent N_{PL} slope coefficient and Δ is the difference between the perceived ambient noise level NL_1 and anthropogenic noise level NL_2 at a given distance (NL_2 was the modelled sound pressure levels of the TSHD vessel actively extracting, as described above). The ambient noise levels were taken from the passive acoustic monitoring (as described in Appendix B). It is important to note that NL_1, being the perceived ambient noise level, is the maximum of the listener's hearing threshold (audiogram value) and the ambient level inside a critical band (please refer to Table 21).

Table 22: Summary of critical bandwidth estimates used in the listening space reduction calculations.

Animal group	Critical bandwidth estimates in this assessment	Rationale
Marine mammals	1/3 octave bands between 32 Hz and 32 kHz	Commonly used in quantitative masking studies.

Animal group	Critical bandwidth estimates in this assessment	Rationale
Kororā/little penguin	1/3 octave bands between 32 Hz and 32 kHz	Critical ratios and bandwidths for seabirds, including penguins, are not known, so unable to robustly assess audibility/masking. However, • Little penguins (*E. minor*) have a broad hearing range of ~200-6000Hz, similar to other diving seabirds (Wei et al. 2024). • 1/3 octave bands have finer frequency scales, so provide more detail on noise content. Given these factors, it might be possible that 1/3 octave bands might better reflect the critical bandwidths of little penguins than 1/1 octaves. Note that without specific studies on critical bandwidths (or even critical ratios), this is somewhat speculative.
Sea turtles	1/1 octave bands between 63 Hz and 1 kHz.	While several studies have been published on the hearing abilities of sea turtles (specifically loggerhead (Martin et al., 2012; Lavender et al. 2014), green (Piniak et al., 2016) and leatherback turtles (Dow Piniak et al. 2012)), no studies exist that specifically investigate turtle psychoacoustics or quantified masking using audiograms. Consequently, robust estimation of their critical bandwidths is not possible. However, • Sea turtles have a relatively narrow hearing range compared to other taxa, of between 50-1600Hz with a maximum sensitivity between 100-400Hz (Lavender et al. 2014; Dow Piniak et al., 2012; Piniak et al., 2016). • Their auditory systems appear less sophisticated than those of other taxa, such as fishes – especially fishes with specialised hearing structures. This could suggest their frequency resolution perception may be wider than that of fishes (Lavender et al. 2014; Piniak et al. 2016). • They have a relatively simpler hearing structure. Given these factors, and the lack of targeted psychoacoustic studies, it is possible that sea turtles have critical bandwidths that are wider than 1/1 octave bands. Notwithstanding, however, since the masking noise from the TSHD is wider than 1/1 octaves, the LSR assessment is not overly sensitive to estimates of

Animal group	Critical bandwidth estimates in this assessment	Rationale
		critical bandwidths (Pine et al. 2020). 1/1 octave bands were therefore used for masking effects for sea turtles.
Fishes/Invertebrates	1/1 octave bands (see Appendix F)	Commonly used in quantitative masking studies.

Audiogram values for kororā/little penguins were taken from Wei & Erbe (2024), while the various marine mammal species in and around Te Ākau Bream Bay were based on composite audiograms (see NMFS (2024) for details). For sea turtles, a behavioural audiogram was used (Martin et al. 2012; Lavender et al. 2014) and was selected over an AEP audiogram because behavioural audiograms generally present lower thresholds (Martin et al. 2012; Lavender et al. 2014; Popper et al. 2014; Piniak et al. 2016). Composite audiograms for each 1 Hz over the complete modelled bandwidth were calculated using:

$$T(f) = T_0 + A\,Log_{10}\left(1 + \frac{F_1}{f}\right) + \left(\frac{f}{F_2}\right)^B \quad \text{(eq. 7)}$$

where $T(f)$ is the auditory threshold at frequency f, and T_0, F_1, F_2, A, and B are fitting parameters provided by NMFS (2024).

The N_{PL} slope coefficient was calculated by curve fitting the empirical N_{PL} of each relevant octave band (see Table 21) over a distance that represented the listener's maximum listening range under natural sound conditions. This was done using a simplified sonar equation without signal gain (to increase conservativeness):

$$\Delta L_{SE} = SL - PL - NL_1 - \Delta L_{DT} \quad \text{(eq. 8)}$$

where signal excess (ΔL_{SE}) is set to zero to indicate detection onset, NL_1 was the 50th percentile ambient noise level and ΔL_{DT} was the detection threshold (conservatively set at 10 dB for (Clark et al. 2009; Kastelein et al. 2013; Putland et al. 2017; Pine et al. 2018; Pine et al 2019)). This was done because the N_{PL} slope can have some range-dependence. Equation 8 was also used for simple audibility range calculations, where NL_1 was 5th percentile daytime ambient level.

The empirical source levels, ambient levels and composite audiograms are provided in Figure 25.

The LSR was then calculated for each frequency band at each range step – resulting in an LSR map for each band. Those maps were then overlaid on top of each other (forming a 3D matrix) and averaged through layers to provide an overall 2D LSR map for the project area (Pine et al. 2018).

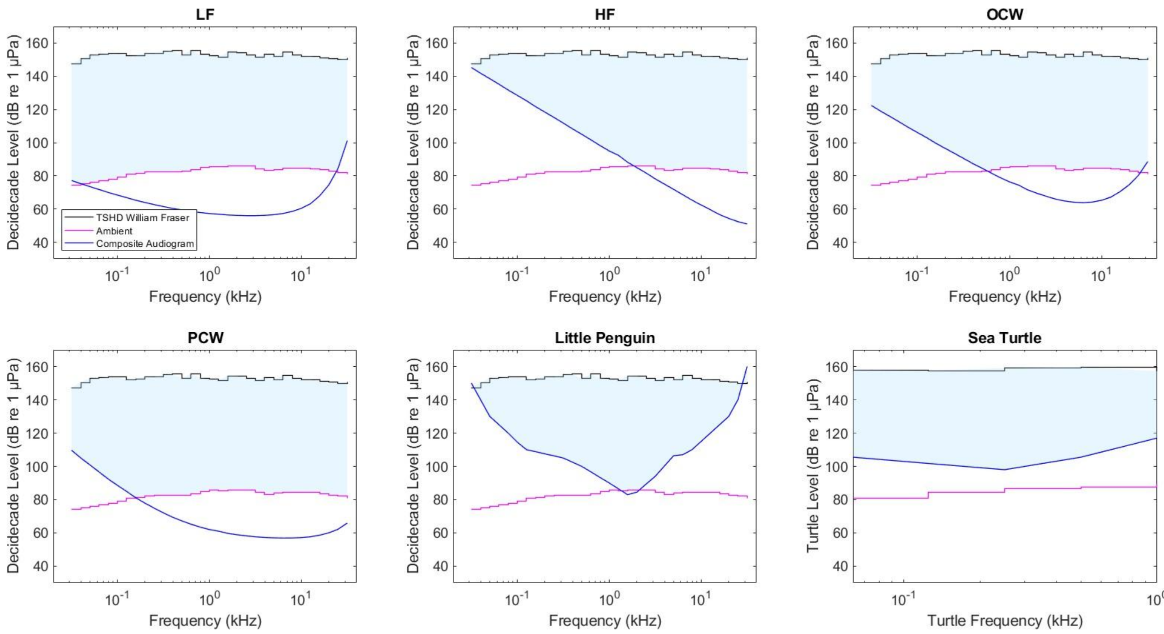

Figure 25: Decidecade source levels for the *William Fraser* actively extracting, 50th percentile decidecade daytime ambient sound levels within Te Ākau Bream Bay (May-June2024) and NMFS (2024) audiograms for each group.The blue shading represents the area used as NL1 in the LSR equation and the larger the area, the more susceptible a listener is to masking effects.

Note the change in axes for sea turtles, which are limited to below 1kHz and are 1/1 octaves.

It is important to note the three important assumptions applied to the auditory masking model: (1) the listener exhibits omnidirectional hearing; (2) the sound propagation field is omnidirectional; and (3) no masking release mechanisms occurred.

Marine fauna have evolved in naturally noisy environments, with many natural sources (such as waves and conspecific or heterospecific vocalisations etc) acting as effective maskers (Radford et al. 2014). It therefore stands to reason that they have evolved to counteract naturally occurring maskers, ensuring their vocalisations can be detected by a listener over the ambient noise level. Anti-masking strategies by the sender are predominately altering the call's characteristics, such as increasing call amplitude (Lombard effects), changing the spectral characteristics of the call (such as lowering or raising the fundamental or peak frequencies) to reduce spectral overlap, or altering the temporal dynamics of the call, such as increasing call rates or repetition (Radford et al. 2014; Erbe et al. 2016). There may also be repeating information at multiple frequencies within a call's harmonics (such as in some fish calls, graded structures in dolphin vocalisations and whale calls). In addition, masking release at the listener may occur when the call and masking noise are coming from different direction (termed spatial release from masking) or when the masking noise is amplitude modulated over a bandwidth much wider than the critical band of the listener (termed comodulation masking release) (Erbe et al. 2016). All these masking release mechanisms have been documented in marine mammals and fish, giving way to the importance of this assumption.

Audibility ranges (marine mammals, kororā/little penguins

For any noise effect to occur, the noise has to first be audible to a receiver. It is important to note, however, that simply detecting a noise source does not equate to an effect occurring. Notwithstanding, the limits of audibility do provide us a maximum area within which the risk of any effect occurring is theoretically greater than 1% during the median daytime ambient sound levels. By calculating the limits of audibility for each of the species of concern, it allows decision makers to better understand the acoustic footprint of the proposed extraction.

A conservative approach was taken – detection thresholds, auditory gain functions and directivity of hearing sensitivities have been left out of the calculations because they are unknown for the species of concern. Masking release mechanisms have also been left out for the same reason. The key assumption, therefore, is that detectability of the anthropogenic noise is omnidirectional[24] and directly relates to the difference between the ambient sound, the anthropogenic noise and hearing thresholds at each critical band.

References

Clark, C.W., Ellison, W.T., Southall, B.L., et al. 2009. Acoustic masking in marine ecosystems: intuitions, analysis, and implication. *Marine Ecology Progress Series* 395: 201–222.

Cranford, T.W., Krysl, P. 2015. Fin whale sound reception mechanisms: skull vibration enables low-frequency hearing. *PLoS One* 10: 1–18.

Dow Piniak, W.E., Eckert, S.A., Harms, C.A., Stringer, E.M. 2012. Underwater hearing sensitivity of the leatherback sea turtle (*Dermochelys coriacea*): Assessing the potential effect of anthropogenic noise. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Headquarters, Herndon, VA. OCS Study BOEM 2012-01156. 35pp.

Duarte, C.M., Chapuis, L., Collin, S.P., et al. 2021. The soundscape of the Anthropocene ocean. *Science* 371: eaba4658.

Ellison, W.T., Southall, B.L., Clark, C.W., Frankel, A.S. 2012. A new context-based approach to assess marine mammal behavioral responses to anthropogenic sounds. *Conservation Biology* 26: 21−28

Erbe, C. 2008. Critical ratios of beluga whales (*Delphinapterus leucas*) and masked signal duration. *Journal of the Acoustical Society of America* 124(4): 2216-2223.

Erbe, C., Reichmuth, C., Cunningham, K., et al. 2016. Communication masking in marine mammals: a review and research strategy. *Marine Pollution Bulletin* 103: 15–38.

[24]Also assumed in peer reviewed scientific publications, such as Pine et al. 2016; Pine et al. 2018; Pine et al. 2019; Putland et al. 2017; Stanley et al. 2018.

Faulkner, R.C., Farcas, A., Merchant, N.D. 2018. Guiding principles for assessing the impact of underwater noise. *Journal of Applied Ecology* 55: 2531-2536.

Gomez, C., Lawson, J.W., Wright, A.J., et al. 2016. A systematic review on the behavioural responses of wild marine mammals to noise: the disparity between science and policy. *Canadian Journal of Zoology* 94: 801-819.

Hall, J.D., Johnson, S.C. 1972. Auditory thresholds of a killer whale *Orcinus orca*. *Journal of the Acoustical Society of America* 51: 515.

Hildebrand, J.A. 2005. Impacts of anthropogenic sound. In: Reynolds JE III, Perrin WF, Reeves RR, et al (eds) Marine Mammal Research: Conservation Beyond Crisis. Johns Hopkins University Press, Baltimore, Md. pp 101-124.

Joy, R., Tollit, D., Wood, J. et al. 2019. Potential benefits of vessel slowdowns on endangered southern resident killer whales. *Frontiers in Marine Science* 6: 344.

Kastelein, R.A., van Heerden, D., Gransier, R., Hoek, L., 2013. Behavioral responses of a harbor porpoise (*Phocoena phocoena*) to playbacks of broadband pile driving sounds. *Marine Environmental Research* 92: 206–214.

Lavender, A.L., Bartol, S.M., & Bartol, I.K. 2014. Ontogenetic investigation of underwater hearing capabilities in loggerhead sea turtles (*Caretta caretta*) using a dual testing approach. *The Journal of Experimental Biology* 217: 2587-2596.

Martin, K.J., Alessi, S.C., Gaspard, J.C., et al. 2012. Underwater hearing in the loggerhead sea turtles (*Caretta caretta*): A comparison of behavioural and auditory evoked potential audiograms. *Journal of Experimental Biology* 215(17): 3001-3009.

MMC (Marine Mammal Commission). 2007. Marine Mammals and Noise: A Sound Approach to Research and Management. MMC. (12 December 2011).

NAS (National Academy of Sciences). 2017. Approaches to understanding the cumulative effects of stressors on marine mammals. Washington, DC: The National Academies Press.

National Marine Fisheries Service (NMFS). 2024. Update to: Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (Version 3.0): Underwater and in-air criteria for onset of auditory injury and temporary threshold shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-xx, xxx p.

National Marine Fisheries Service (NMFS). 2018. 2018 Revision to: Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (Version 2.0): underwater thresholds for onset of permanent and temporary thresholds shifts. U.S. Dept. of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-59.

NOAA (National Oceanic and Atmospheric Administration). 2005. Endangered Fish and Wildlife; Notice of Intent to Prepare an Environmental Impact Statement. Federal Register 70: 1871-1875.

Nowacek, D.P., Thorne, L.H,, Johnston, D.W., Tyack, P.L. 2007. Responses of cetaceans to anthropogenic noise. *Mammal Review* 37(2): 81-115.

NRC (National Research Council). 2005. Marine mammal populations and ocean noise: determining when noise causes biologically significant events. National Academy Press, Washington, DC.

Pine, M.K., Hannay, D.E., Insley, S.J., Halliday, W.D. 2018. Assessing vessel slowdown for reducing auditory masking for marine mammals and fish of the western Canadian Arctic. *Marine Pollution Bulletin* 135: 290-302.

Pine, M.K., Schmitt, P., Culloch, R.M., et al. 2019. Providing ecological context to anthropogenic subsea noise: assessing listening space reductions of marine mammals from tidal energy devices. *Renewable and Sustainable Energy Reviews* 103: 49-57.

Pine, M.K., Nikolich, K., Martin, B., et al. 2020. Assessing auditory masking for management of underwater anthropogenic noise. *Journal of the Acoustical Society of America* 147(5): 3408-3417.

Piniak, W.E.D., Mann, D.A., Harms, C.A., et al. 2016. Hearing in the Juvenile Green Sea Turtle (*Chelonia mydas*): A Comparison of Underwater and Aerial Hearing Using Auditory Evoked Potentials. *PLoS ONE* 11(10): e0159711.

Popper, A.N., Hawkins, A.D., Fay, R.R. et al. 2014. Sound exposure guidelines for fishes and sea turtles. A technical report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. Report No. ASA S3/SC1.4 TR-2014.

Popov, V.V., Klishin, V.O. 1998. EEG study of hearing in the common dolphin, *Delphinus delphis*. *Aquatic Mammals* 24:13–20.

Putland, R.L., Merchant, N.D., Farcas, A., Radford CA. 2017. Vessel noise cuts down communication space for vocalizing fish and marine mammals. *Global Change Biology* 24: 1708-1721.

Radford, C.A., Montgomery, J.C., Caiger, P., Higgs, D. M. 2012. Pressure and particle motion detection thresholds in fish: a re-examination of salient auditory cues in teleosts. *The Journal of Experimental Biology* 215(19): 3429–3435.

Radford, A.N., Kerridge, E., Simpson, S.D. 2014. Acoustic communication in a noisy world: Can fish compete with anthropogenic noise? *Behavioural Ecology* 25: 1022–1030.

Reine, K.J., Clarke, D., Dickerson, C. 2014. Characterization of underwater sounds produced by hydraulic and mechanical dredging operations. *Journal of the Acoustical Society of America* 135(6): 3280-3294.

Richardson, W.J., Greene, C.R., Jr, Malme, C.I., et al. 1995. Marine mammals and noise. Academic Press, San Diego, CA. 576 pp.

Robinson, S.P. 2015 Dredging Sound Measurements. WODA Workshop presentation. 26 March 2015, Paris.

Szymanski, M.D., Bain, D.E., Kiehl, K., et al. 1999. Killer whale (*Orcinus orca*) hearing: auditory brainstem response and behavioral audiograms. *Journal of the Acoustical Society of America* 106: 1134–41.

Tonkin & Taylor Ltd. 2016. Marsden Point Refinery - Crude Freight Project. April 2016, report number 30488.1000.

US Navy. 2008. Southern California Range Complex Environmental Impact Statement/Overseas Environmental Impact Statement. Washington, DC: United States Department of the Navy.

US Navy. 2012. Atlantic Fleet Training and Testing EIR/OEIS: Draft Version. Washington, DC: United States Department of the Navy.

Wei, C., Erbe, C. 2024. Sound reception and hearing capabilities in the Little Penguin (*Eudyptula minor*): first predicted in-air and underwater audiograms. *Royal Society Open Science* 11: 240593.

Weilgart, L.S. 2007. The impacts of anthropogenic ocean noise on cetaceans and implications for management. *Canadian Journal of Zoology* 85: 1091-1116.

Wood, J., Southall, B.L. Tollit, D.J. 2012. PG&E offshore 3-D Seismic Survey Project EIR – Marine Mammal Technical Draft Report. SMRU Ltd.

Appendix F Noise effects on fish and invertebrates

This Appendix pertains to the animal groups/species with noise criteria that prescribe thresholds or discuss effects using sound acceleration metrics. Marine mammals (all cetaceans, pinnipeds), kororā/little penguins, sea turtles are therefore contained within Appendix E, since effects on them are done using sound pressure metrics.

Please refer to Table 2 of the assessment report for details on which groups/species are specifically assessed for each effects category.

Fish and invertebrates can be negatively impacted by anthropogenic noise, just as marine mammals. However, unlike marine mammals who have statutory protections in several countries, noise exposure criteria for fish are far more varied in their usefulness (Hawkins & Popper 2017). Data that establishes the expected severity of a certain effect following the exposure to some pressure levels are scarce. One of the only peer-reviewed guidance for the potential onset of noise effects on fishes that has experienced some uptake internationally is the ANSI-accredited guidance from Popper et al. (2014). That guidance does provide useful guidelines (within the limitations and constraints) in gauging the spatial extent of potential impact. For percussive pile-driving, for example, the criteria for various fish-groups are provided as decibel ranges. However, no criteria are provided for vessel noise, or underwater extraction activities.

While thresholds are a good starting point, noise criteria for fishes should consider the biological significance of sound exposure (Hawkins et al. 2020). The biological significance of the sound exposure relates to whether the animal experiences an adverse effect in its life, i.e., is the invasive noise likely to cause significant physical, chemical or biological responses that have real consequences for the net fitness of the individual or population (Hawkins et al. 2020). The only effect that can currently be directly linked to such an impact is mortality or severe injury that eventually may be fatal. Other biologically significant effects include PTS, TTS, sub-lethal injuries, behavioural and auditory masking but the relationship between the severity of those effects and exposure to noise is data deficient and still a research question (Hawkins et al. 2020). Notwithstanding, hearing loss (either permanent or temporary) is an impact that can impact an individual's net fitness because their perception of predators can be inhibited. Some sublethal effects can also lead to detrimental impacts on fish and invertebrate communities. This can particularly be the case for newly introduced long-term noise exposures, and because many species of fish lack the mobility to move large distances to evade stressors (Wilson et al. 2023).

Like marine mammals, auditory masking effects for fish and invertebrates occur over greater ranges than other impacts. And, because behavioural impacts occur at the higher end of masking, they can be a useful proxy for the potential onset of higher level effect sizes (i.e., impact). However, unlike marine mammals, fish and invertebrates predominately perceive the particle motion (vibration) component of sound, rather than sound pressure. Particle motion is the oscillatory movement of particles in a sound field, critical for underwater hearing in fish and invertebrates. Unlike sound pressure, which has magnitude alone, particle motion is a vector with both magnitude and direction (Jones et al. 2023). Sound propagates as vibrating particles transmit energy, comprised of a pressure wave and oscillating particles (or water) (Cook 2017). Most fish primarily detect particle motion using the otolith in their inner ear and, as a secondary mechanism, the lateral line system (Fay & Popper, 2000). The otolith, denser than surrounding tissues, moves differently in response to sound waves, stimulating sensory hair cells. The lateral line system detects vibration and pressure changes at short ranges, sensitive to low frequencies. Invertebrates, lacking accessory hearing structures, rely solely on particle motion detection (Davis et al. 2024). They utilize superficial surface receptors, internal statocysts, and chordontal organs to sense particle motion (Cook, 2017; Davis et al. 2024).

While many fishes are capable for detecting both sound modalities, this assessment considers masking and audibility using particle acceleration. While the NZ bigeye (*Pempheris adspersa)* has unique hearing structures that make them more sensitive to sound pressure than other fish species, we have assessed masking based on particle acceleration only. This was because a recent study found listening space reductions in fish was slightly greater for particle acceleration than sound pressure (Wilson et al. 2023). Additionally, particle acceleration is more relevant for fish species within Te Ākau Bream Bay, and since NZ bigeyes have similar acceleration thresholds to other fishes, including the common triplefin, *Forsterygian lappillum* (Radford et al. 2012), are more relevant if assessed using particle acceleration.

Under ideal conditions, sound pressure and particle velocity correlate. However, the sound propagation is highly site (and signal) specific, and the pressure vs velocity correlation is not always met, especially in coastal areas. In shallow water or near the *William Fraser*'s draghead, particle motion attenuates more rapidly than sound pressure due to reflections and near-field effects. Therefore, direct measurement is the most reliable method for determining particle motion levels in these environments.

Despite the difficulties in measuring particle motion directly in open-water environments, studies have used pressure measurements from hydrophone arrays to estimate particle acceleration (Chapuis et al. 2019, Nedelec et al. 2021, Wilson et al. 2023, Jones et al. 2023). By converting the modelled sound pressure level data to particle motion, we can apply the same LSR equations (following Wilson et al. 2023). Wilson et al. (2023) quantified auditory masking in terms of LSR in two different fish and crustacean species when a small recreational-type vessel passed overhead. The researchers used hydrophone data and converted modelled sound pressure levels to estimate particle acceleration.

Following Wilson et al. (2023)'s methods, assumptions and environmental and hearing sensitivity data[25] (Figure 26), we modelled the potential masking effects from the TSHD *William*

---

[25] Data were taken from an Auckland University repository: Wilson, Louise; Constantine, Rochelle; K. Pine, Matthew; Farcas, Adrian; Radford, Craig (2023). Impact of small boat sound on the listening space of *Pempheris adspersa*, *Forsterygion lapillum*, *Alpheus richardsoni* and *Ovalipes catharus*.. The University of Auckland. Collection. https://doi.org/10.17608/k6.auckland.c.6203761.v4

Fraser while actively extracting based on the propagation of particle acceleration (dB re 1 μm s^{-2}). LSRs were modelled for the NZ bigeye (*Pempheris adspersa*), common triplefin (*Forsterygion lapillum*), NZ paddle crab (*Ovalipes catharus*), and snapping shrimp (*Alpheus richardsoni*). Selected for their vocal nature and/or dependence on underwater sound, these species are common around Northern New Zealand (Wilson et al. 2023), including reef habitats around Te Ākau Bream Bay.

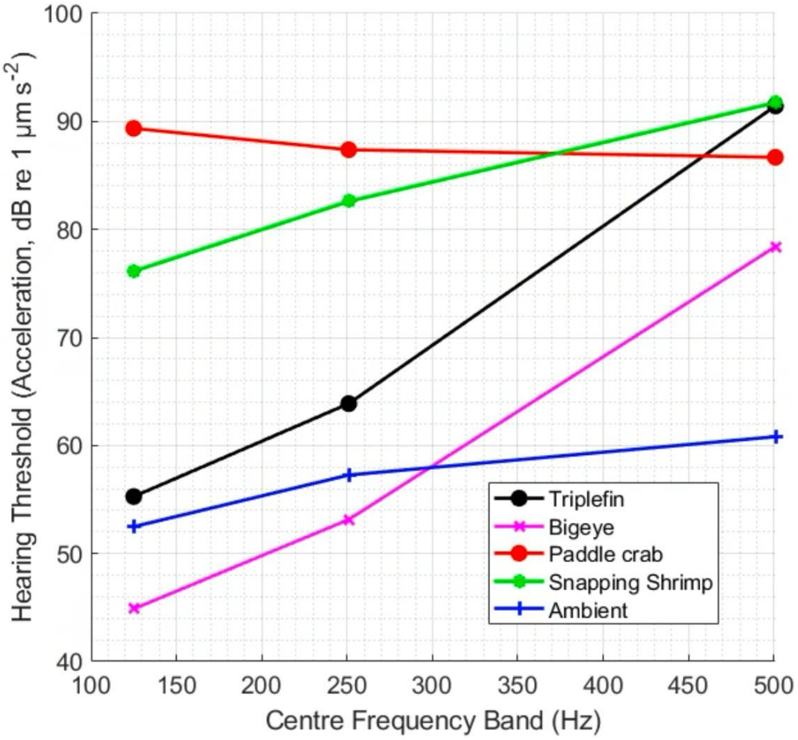

Figure 26: Particle acceleration hearing thresholds for the NZ bigeye, common triplefin, NZ paddle crab and snapping shrimp, as well as the 50th percentile daytime ambient sound levels within Te Ākau Bream Bay (May-June2024) from Wilson et al. (2023).

As for the marine mammals, the LSR was defined using equation 6. However, for NL_1, the hearing threshold data for particle acceleration was used and were the same as those used by Wilson et al. (2023). Masking was therefore considered for bands below 2kHz only (the most sensitive region of hearing). The propagation loss modelling used was the same as described in Appendix C, however pressure levels were converted to acceleration (dB re 1 μm s^{-2}) using:

$$\delta_{<!=>/(\$!?@} = \frac{\cdot}{3\text{-}(AB} Q1 + G\frac{C}{3\text{-}>} \overset{*}{3} H\ R \quad \text{(eq. 9)}$$

$$\delta_{(=>/(\$!?@} = \frac{\cdot}{3\text{-}(AB} \quad \text{(eq. 10)}$$

$$\lambda = \frac{B}{(} \quad \text{(eq. 11)}$$

$$a = \delta 2\pi r^3 \quad \text{(eq. 12)}$$

where δ = displacement (m), p = pressure (Pa), f = frequency (Hz), ρ = density of sea water (kg m^{-3}), c = speed of sound in sea water (ms^{-1}), λ = wavelength (m), r = distance from receiver position to source position (m) and α = acceleration (ms^{-2}) (taken from Wilson et al. 2023). The distinction between the near- and far-field was based on the receiver's distance from the source, where if the receiver was 2/∴ from the source, it would be considered near- field (Montgomery et al. 2006; Wilson et al. 2023). The source level of the *William Fraser*, however, was treated as if in the far-field only (similar to the ambient soundscape levels). This was because the measurements of the *William Fraser* were along a single plane, and therefore it was impossible to convert the measurements to a vector norm. However, given the propagation model's range-step was set at 100m, this was well beyond 2/∴ distance for the frequencies modelled.

References

Cook, G. 2017. Discussion paper on particle motion. Technical report for Inch Cape Wind Farm. IFS No. 1152864.

Chapuis, L., Kerr, C.C., Collin, S.P., et al. 2019. Underwater hearing in sea snakes (*Hydrophiinae*): First evidence of auditory evoked potential thresholds. *Journal of Experimental Biology* 222(14): 198184.

Davis, H.L., Cox, K.D., Murchy, K.A., et al. 2024. Marine and freshwater sounds impact invertebrate behaviour and physiology: a meta-analysis. *Global Change Biology* 30: e17593.

Fay R.R., Popper A.N. 2000. Evolution of hearing in vertebrates: the inner ears and processing. *Hearing Research* 149: 1-10.

Hawkins, A.D., Popper, A.N. 2017. A sound approach to assessing the impact of underwater noise on marine fishes and invertebrates. *ICES Journal of Marine Science* 74(3): 634-651.

Hawkins, A.N., Johnson, C., Popper, A.N. 2020. How to set sound exposure criteria for fishes. *The Journal of the Acoustical Society of America* 147(3): 1762-1777.

Jones, I.T., Martin, B., Miksis-Olds, J.L. 2023. Incorporating particle motion in fish communication and listening space models. In: Popper, A.N. et al. (eds). The effects of noise on aquatic life. Springer Nature, Switzerland.

Montgomery, J.C., Jeffs, A.G., Simpson, S.D., et al. 2006. Sound as an orientation cue for the pelagic larvae of reef fishes and decapod crustaceans. *Advances in Marine Biology* 51:143–196.

Nedelec, S.L., Ainslie, M.A., Andersson, M.H., et al. 2021. Best practice guide for measurement of underwater particle motion for biological applications. Exeter, UK:

University of Exeter for the IOGP Marine Sound and Life Joint Industry Programme, 89pp. & Appendices.

Popper, A.N., Hawkins, A.D., Fay, R.R. et al. 2014. Sound exposure guidelines for fishes and sea turtles. A technical report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. Report No. ASA S3/SC1.4 TR-2014.

Radford, C.A., Montgomery, J.C., Caiger, P., Higgs, D.M. 2012. Pressure and particle motion detection thresholds in fish: a re-examination of salient auditory cues in teleosts. *The Journal of Experimental Biology* 215(19): 3429–3435.

Sole, M., Kaifu, K., Mooney, T.A., et al. 2023. Marine invertebrates and noise. *Frontiers in Marine Science* 10: 1129057.

Wilson, L., Constantine, R., Pine, M.K., et al. 2023. Impact of small boat sound on the listening space of *Pempheris adspersa*, *Forsterygion lapillum*, *Alpheus richardsoni* and *Ovalipes catharus*. *Scientific Reports* 13: 7007.

Appendix G Noise effects maps

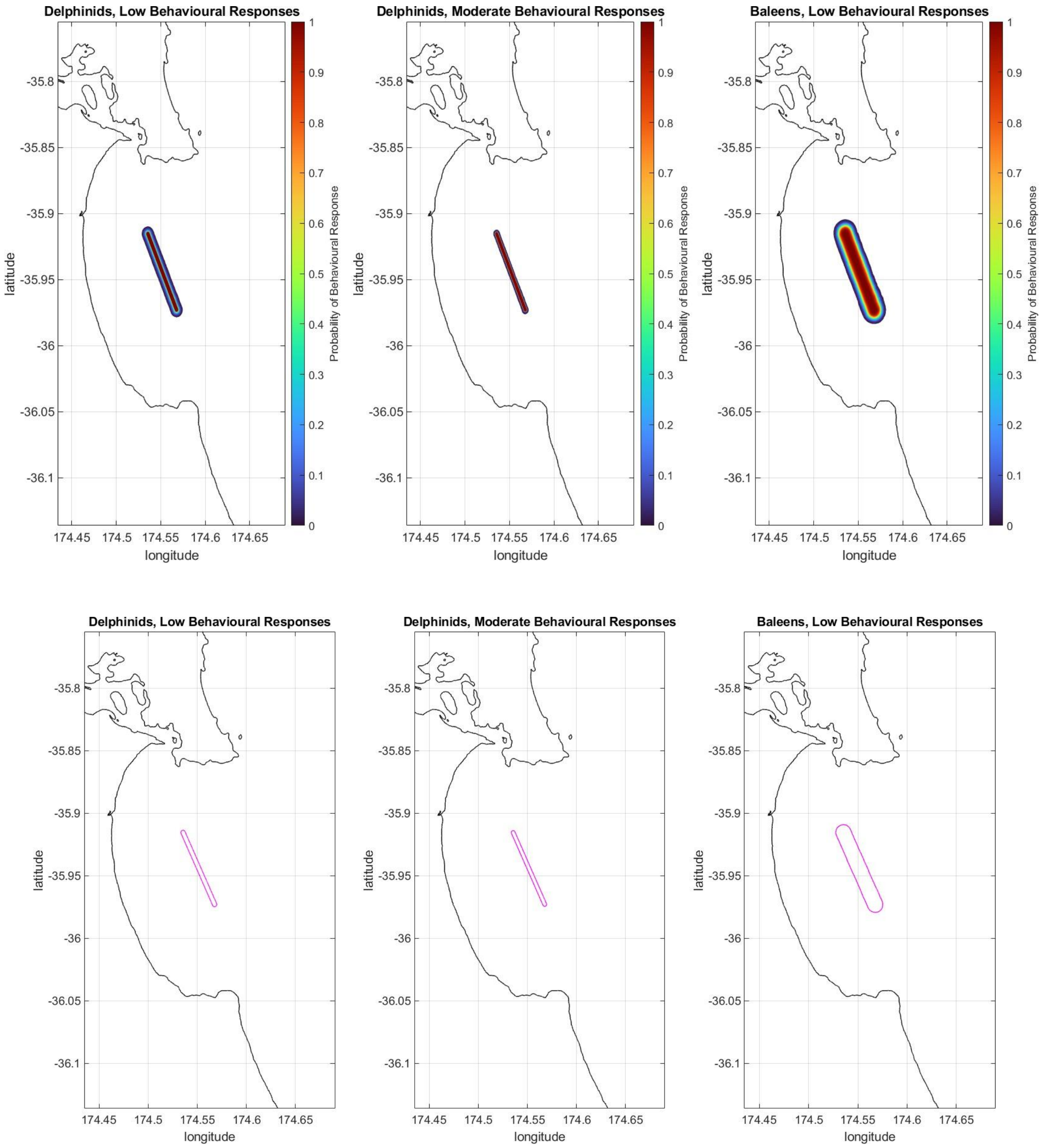

Figure 27: Low and moderate behavioural response risk for dolphin species (Delphinidae) (left and centre panels) and baleen whales (right panel) from the *William Fraser* actively extracting. The three bottom plots present the 50% probability of response.

Note the plots show the area over a single transect and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

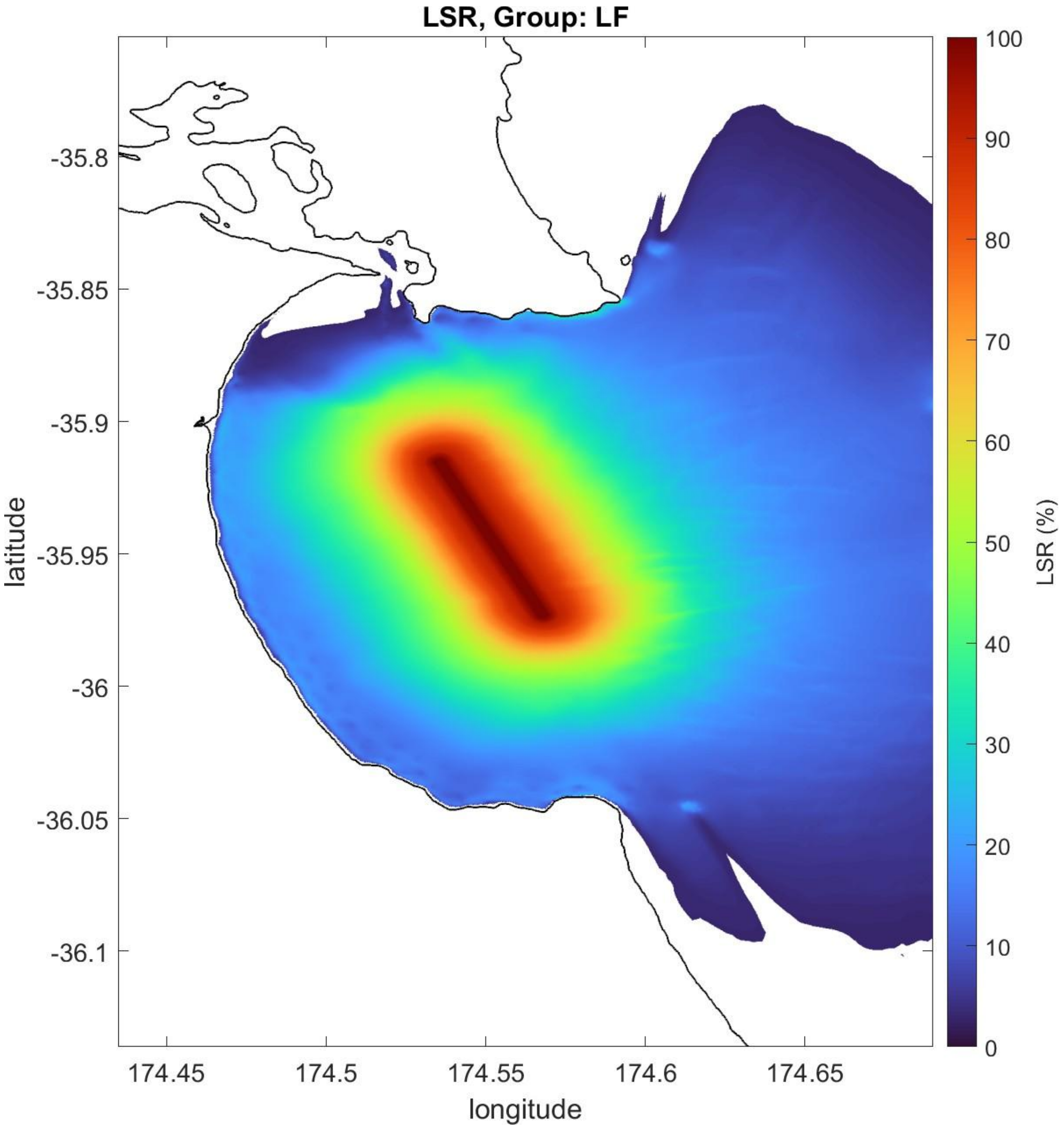

Figure 28: Map showing the spatial extent of listening space reductions for baleen whales (NMFS 2024 function hearing group LF) from the *William Fraser* actively extracting.

Note the plot shows the area over a single transect and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

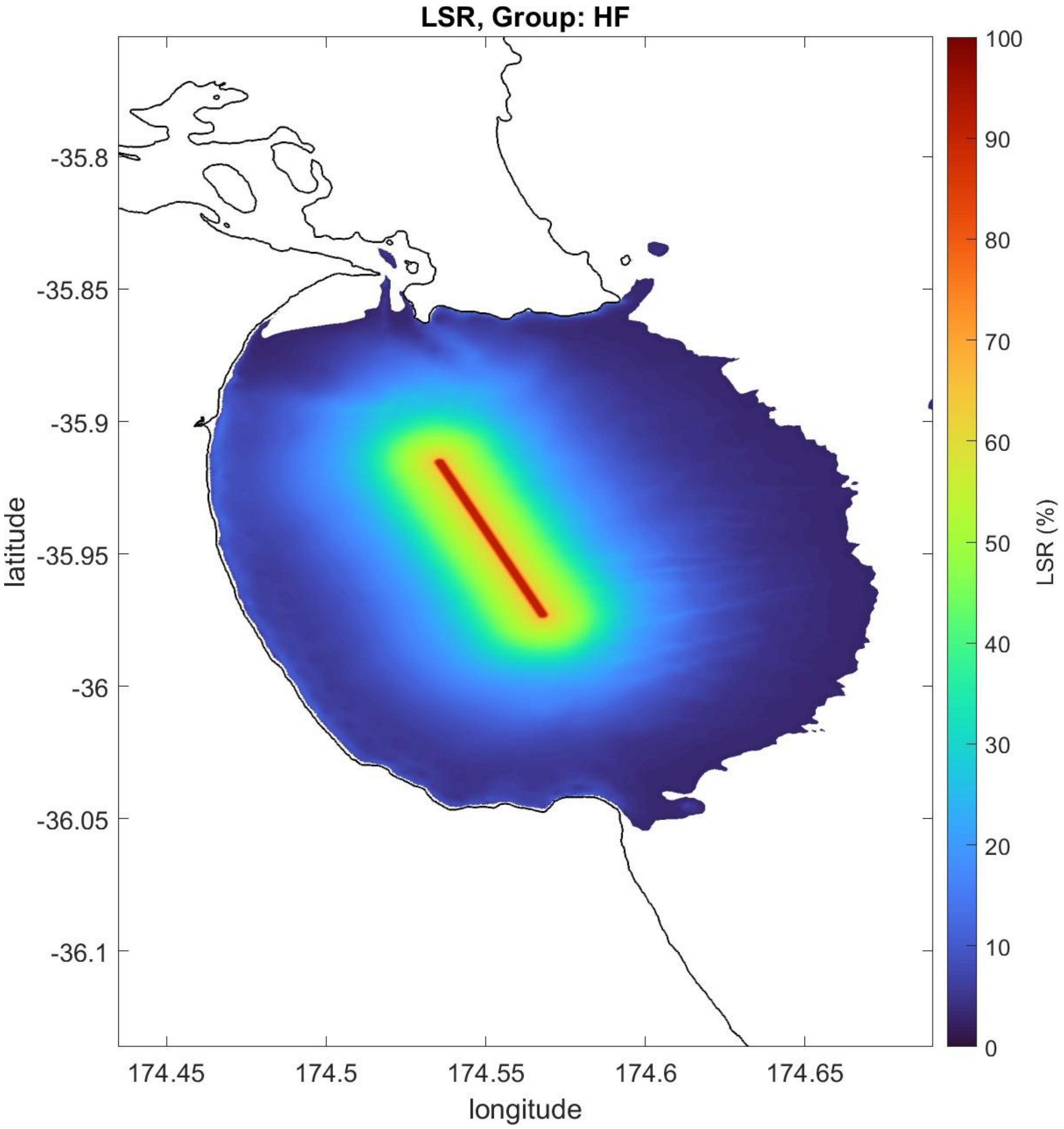

Figure 29: Map showing the spatial extent of listening space reductions for odontocete species (NMFS 2024 function hearing group HF) from the *William Fraser* actively extracting.

Note the plot shows the area over a single transect and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

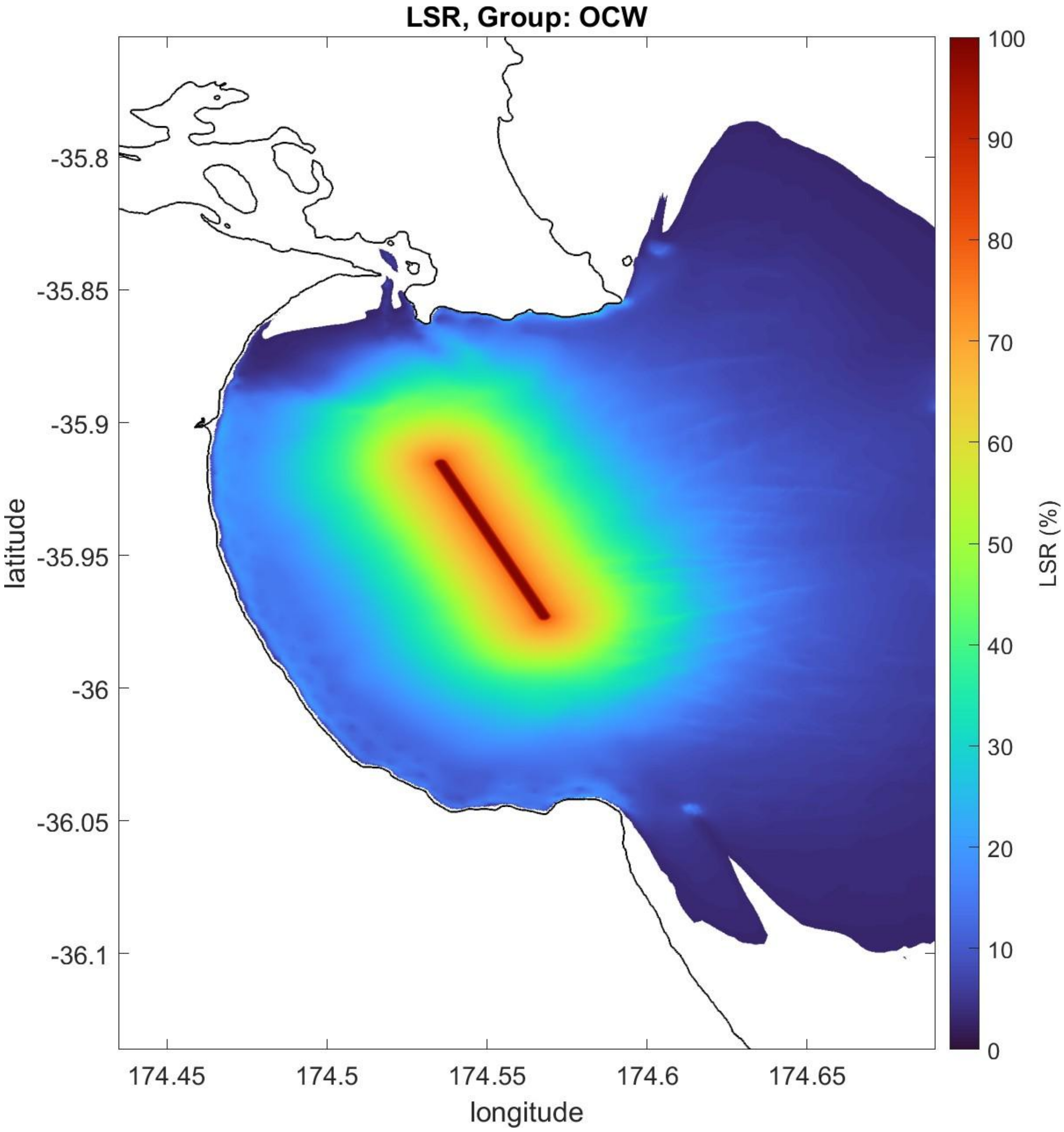

Figure 30: Map showing the spatial extent of listening space reductions for otariid pinnipeds (NMFS 2024 function hearing group OCW) from the *William Fraser* actively extracting.

Note the plot shows the area over a single transect and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

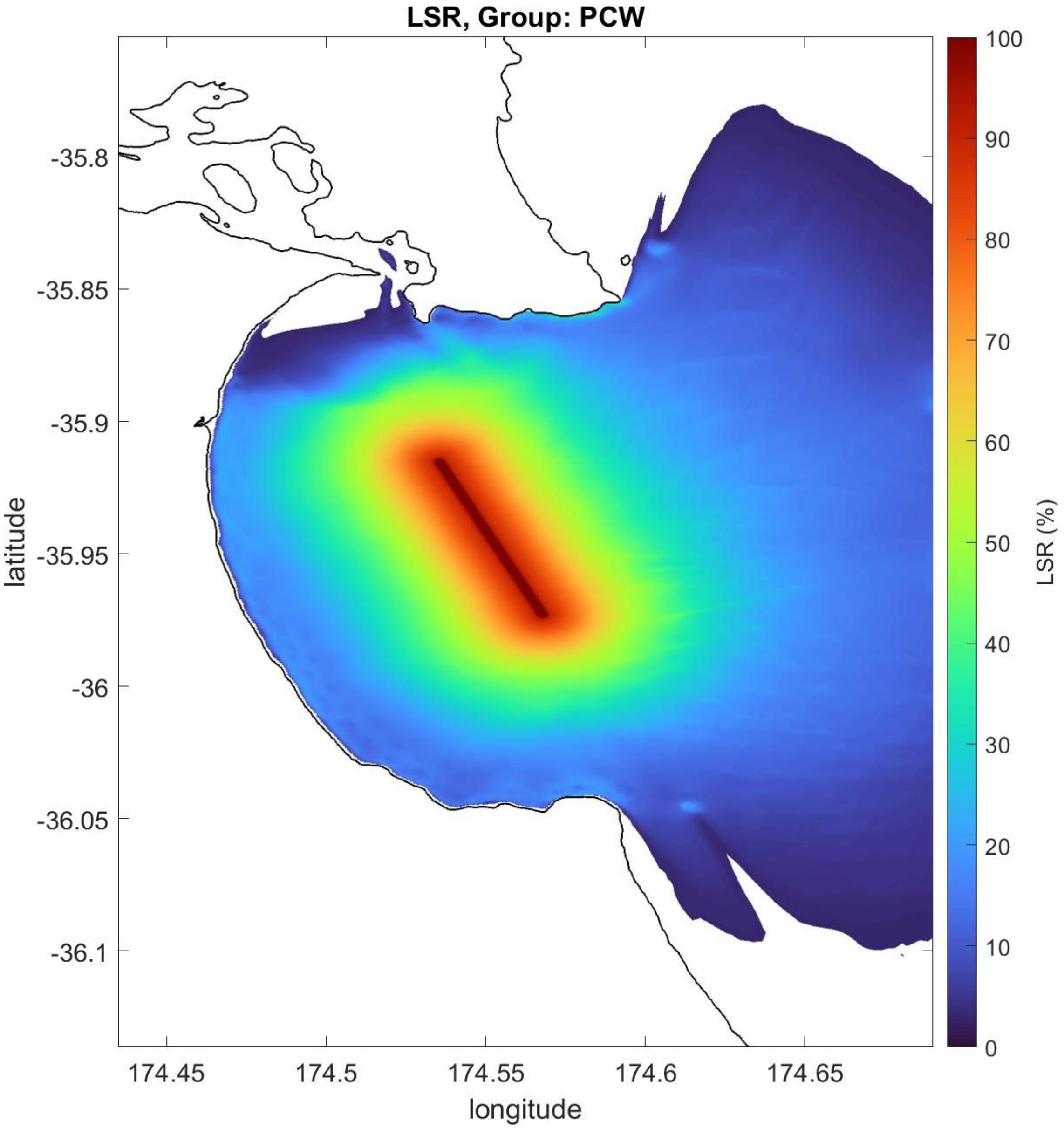

Figure 31: Map showing the spatial extent of listening space reductions for phocid pinnipeds (NMFS 2024 function hearing group PCW) from the *William Fraser* actively extracting.

Note the plot shows the area over a single transect and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

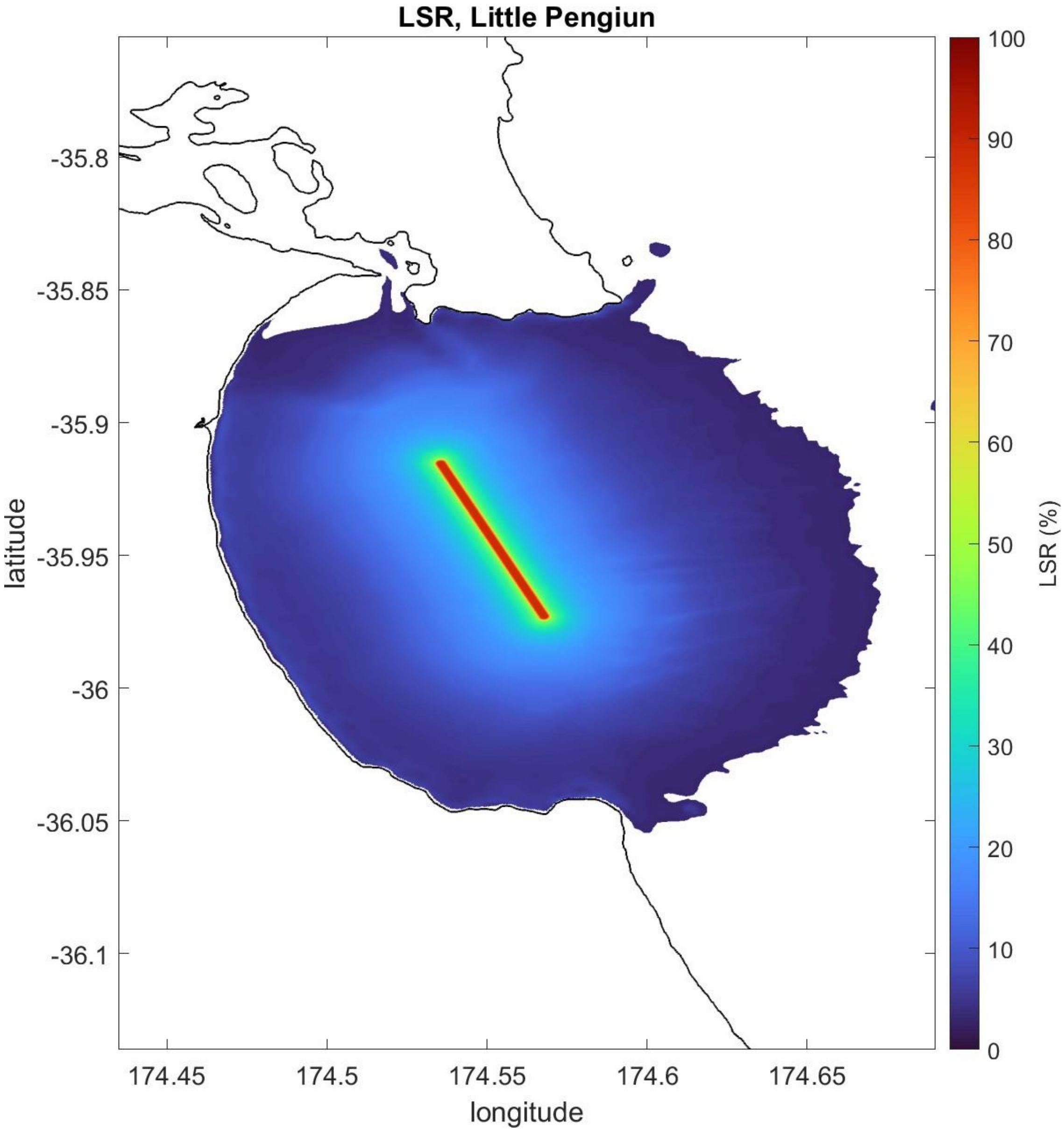

Figure 32: Map showing the spatial extent of listening space reductions for Kororā while the *William Fraser* is actively extracting.

Note the plot shows the area over a single transect and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

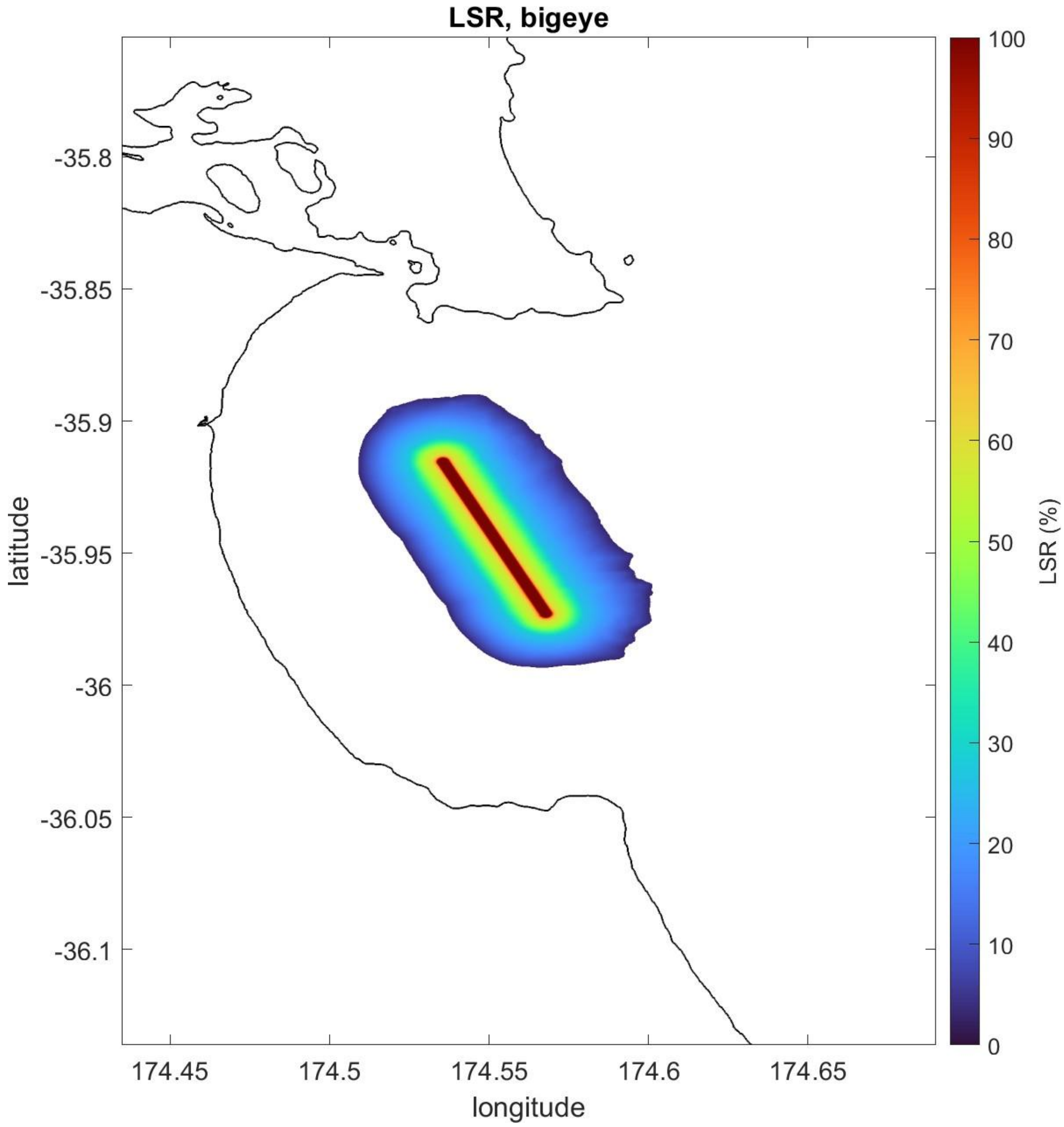

Figure 33: Map showing the spatial extent of listening space reductions for bigeye while the *William Fraser* is actively extracting.

Note the plot shows the area over a single transect and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

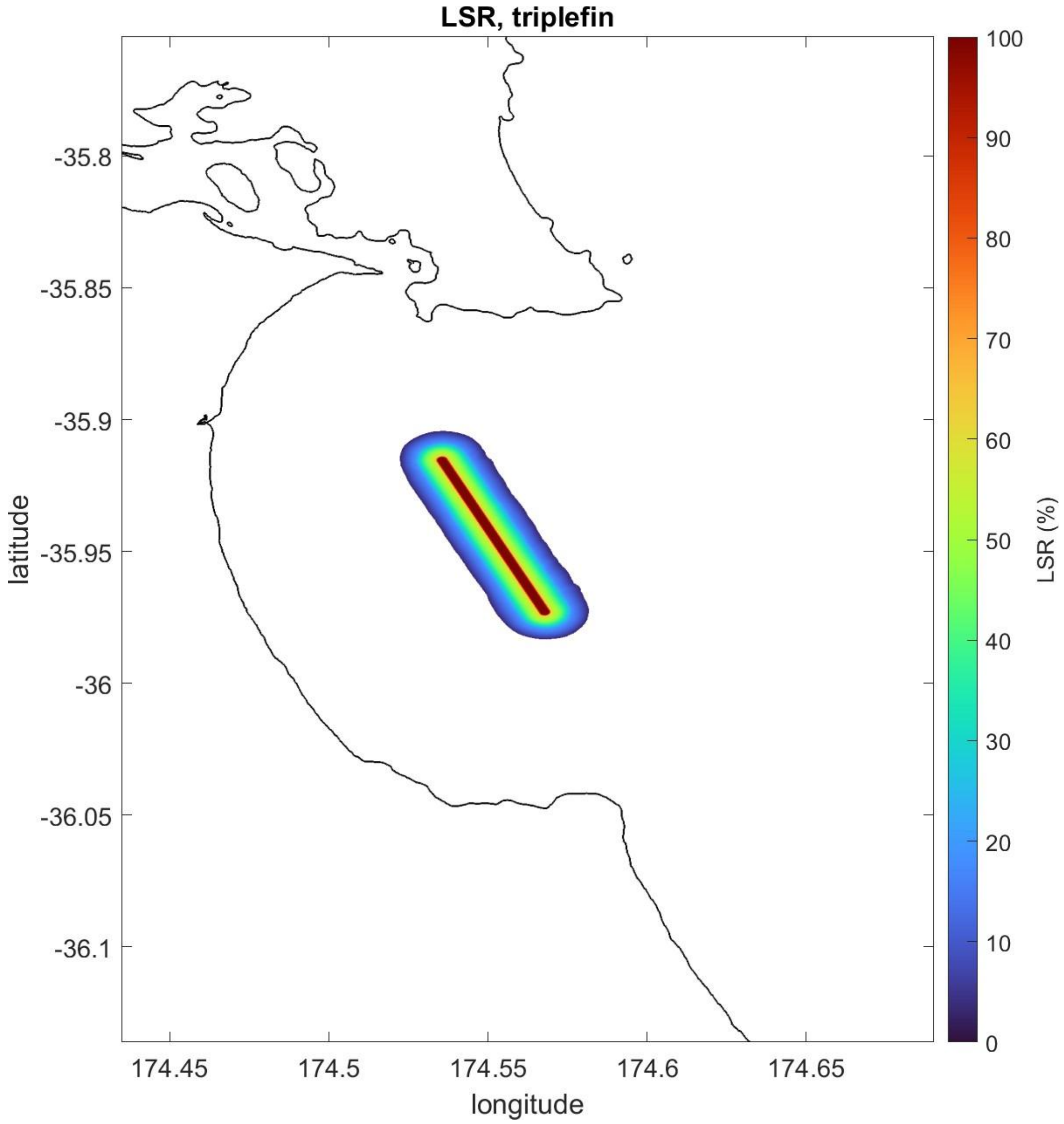

Figure 34: Map showing the spatial extent of listening space reductions for the common triplefin while the *William Fraser* is actively extracting.

Note the plot shows the area over a single transect and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

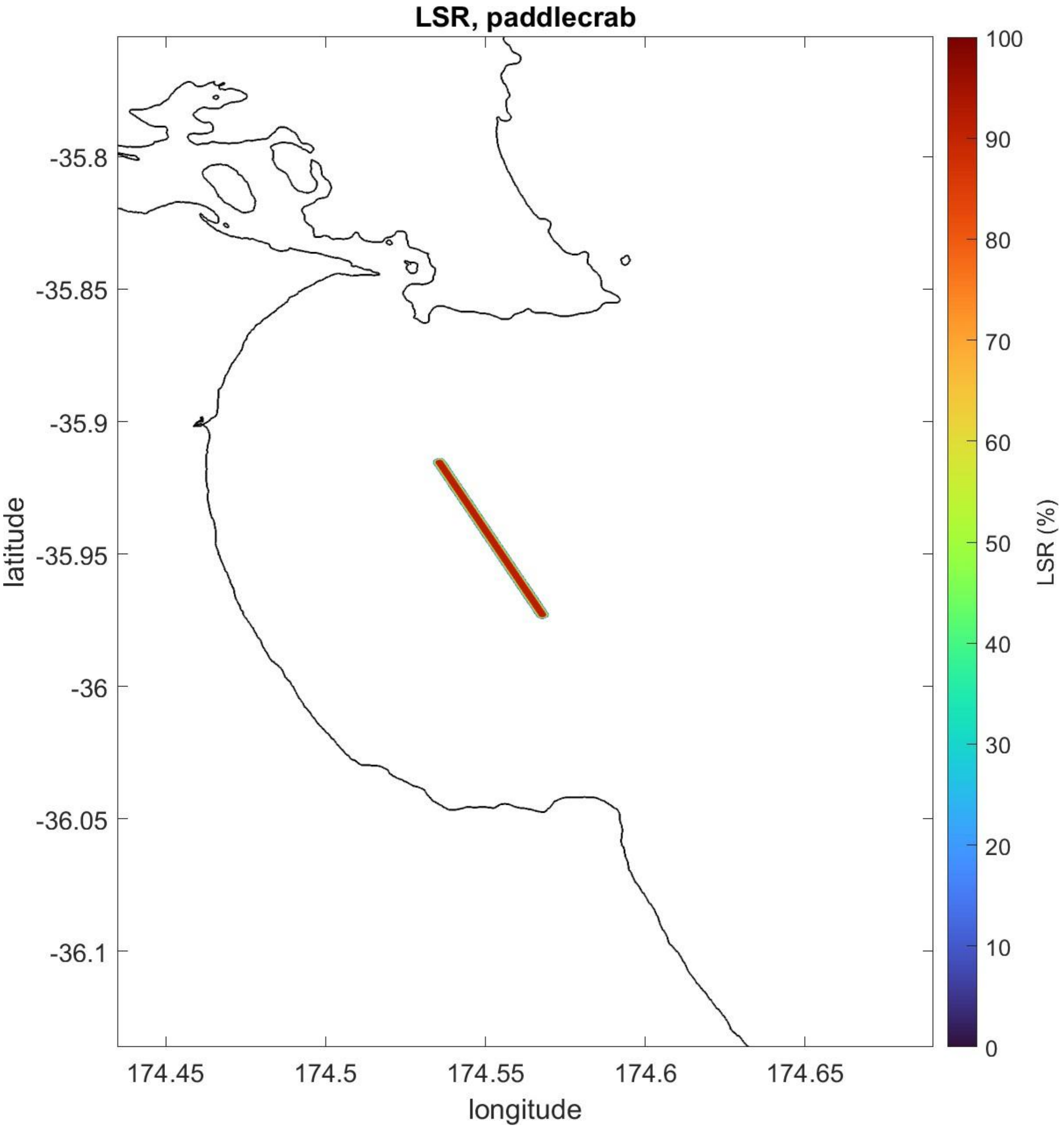

Figure 35: Map showing the spatial extent of listening space reductions for paddle crab while the *William Fraser* is actively extracting.

Note the plot shows the area over a single transect and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

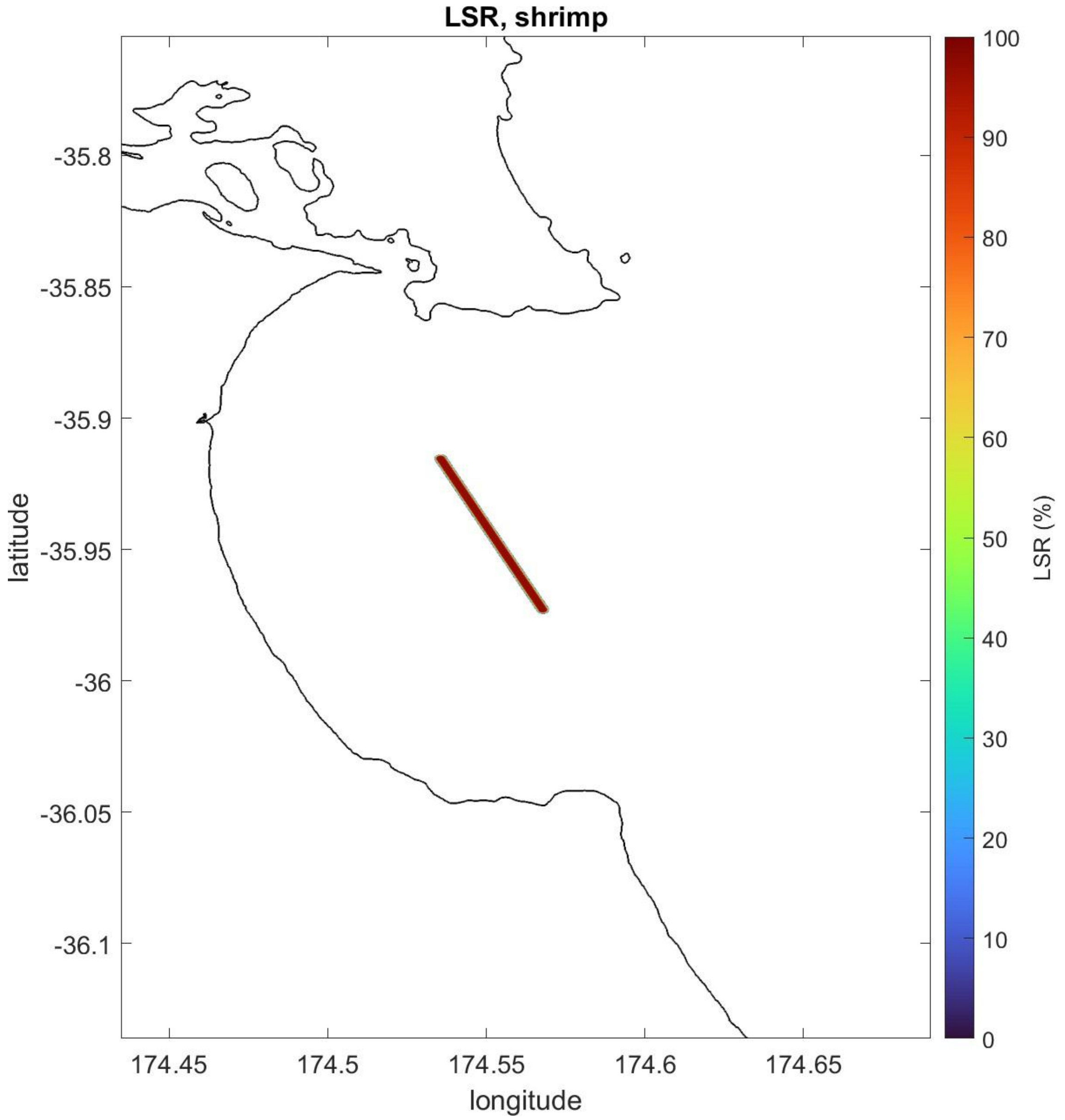

Figure 36: Map showing the spatial extent of listening space reductions for snapping shrimp while the *William Fraser* is actively extracting.

Note the plot shows the area over a single transect and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

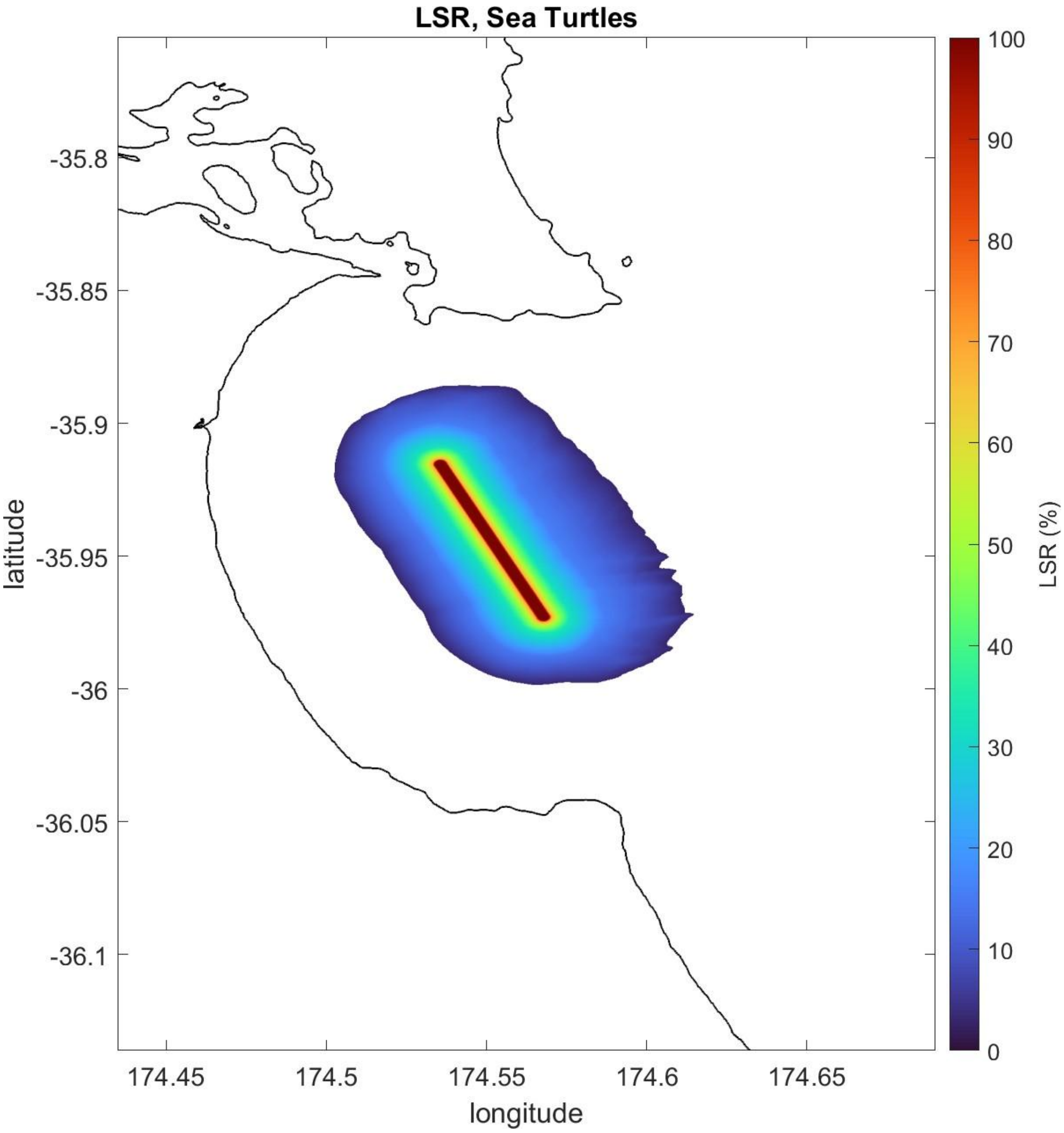

Figure 37: Map showing the spatial extent of listening space reductions for sea turtles while the *William Fraser* is actively extracting.

Note the plot shows the area over a single transect and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

Appendix H Vessel and extraction noise models

Model validation

To establish the appropriateness of the propagation loss model in this assessment, the model output was compared with measurements of the *William Fraser* actively extracting in approximately 30m of water off the Mangawhai-Pākiri coastline (see Appendix I for more details).

A single point was selected from the extraction noise model, and the received levels at each waypoint along 360 radials were extracted (Figure 38). The results (Figure 39) could then be compared with the measured received levels with range (Figure 40).

The results demonstrated that the propagation loss model used in this assessment can be considered appropriate and not overly conservative.

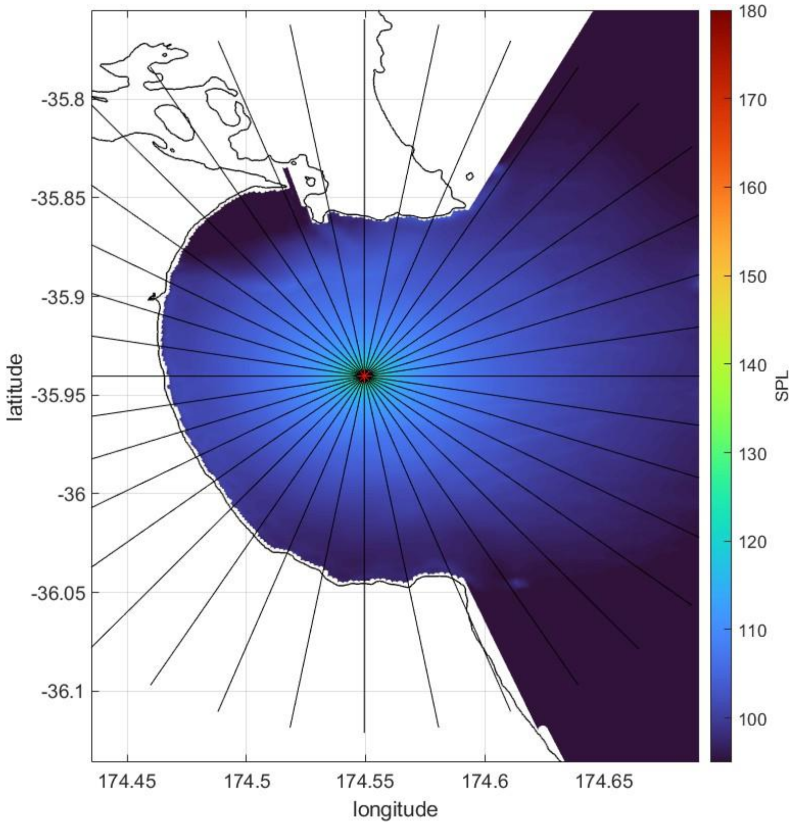

Figure 38: Single modelled point of the *William Fraser* while active extracting. The black lines represent the transects used to establish the propagation loss with range to compare with measurements.

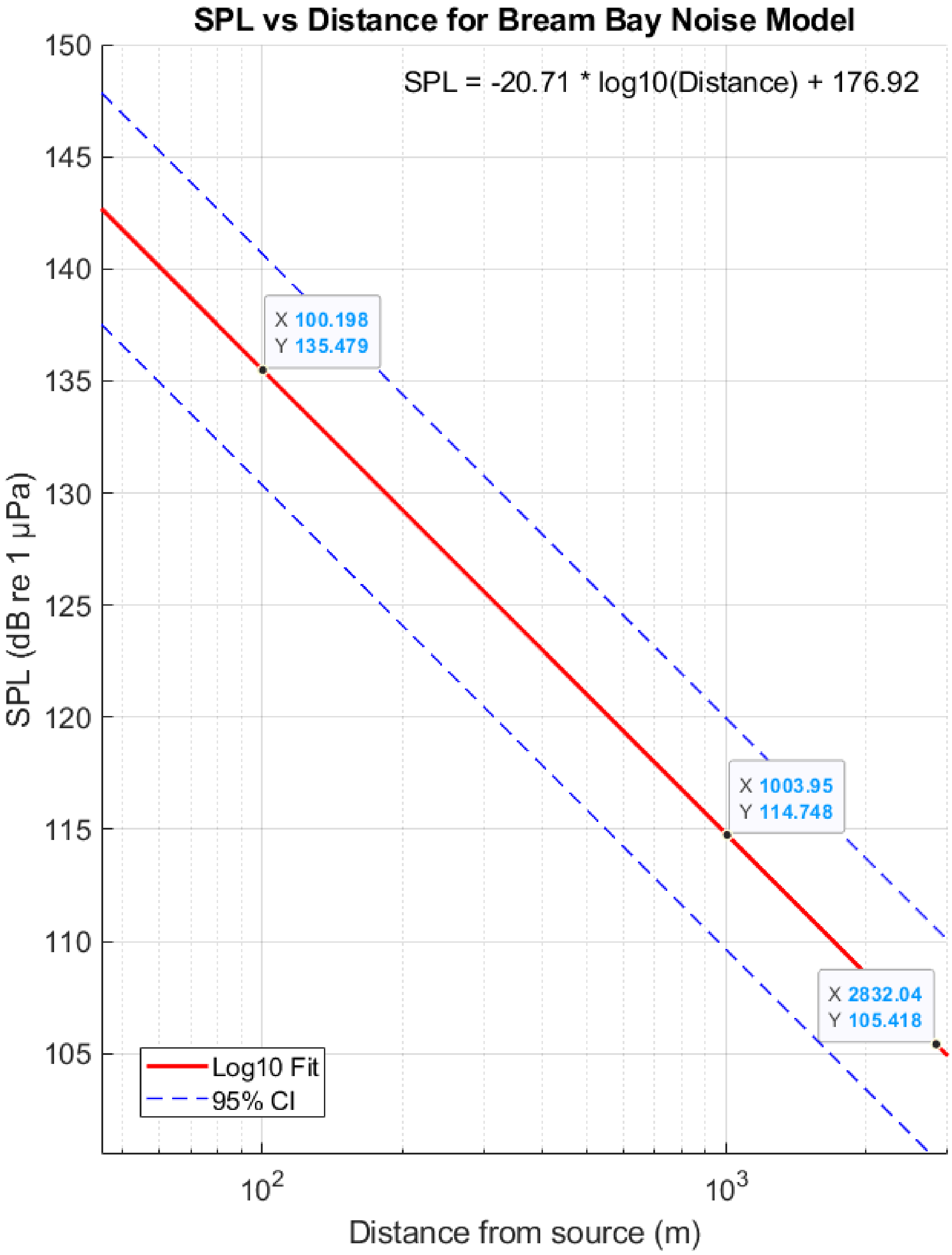

Figure 39: Curve-fitted modelled propagation loss (broadband) from all transects shown in Figure 38. Data tips show the modelled sound pressure level (Y) at different ranges (X) for comparison against the measured slope in Figure 40.

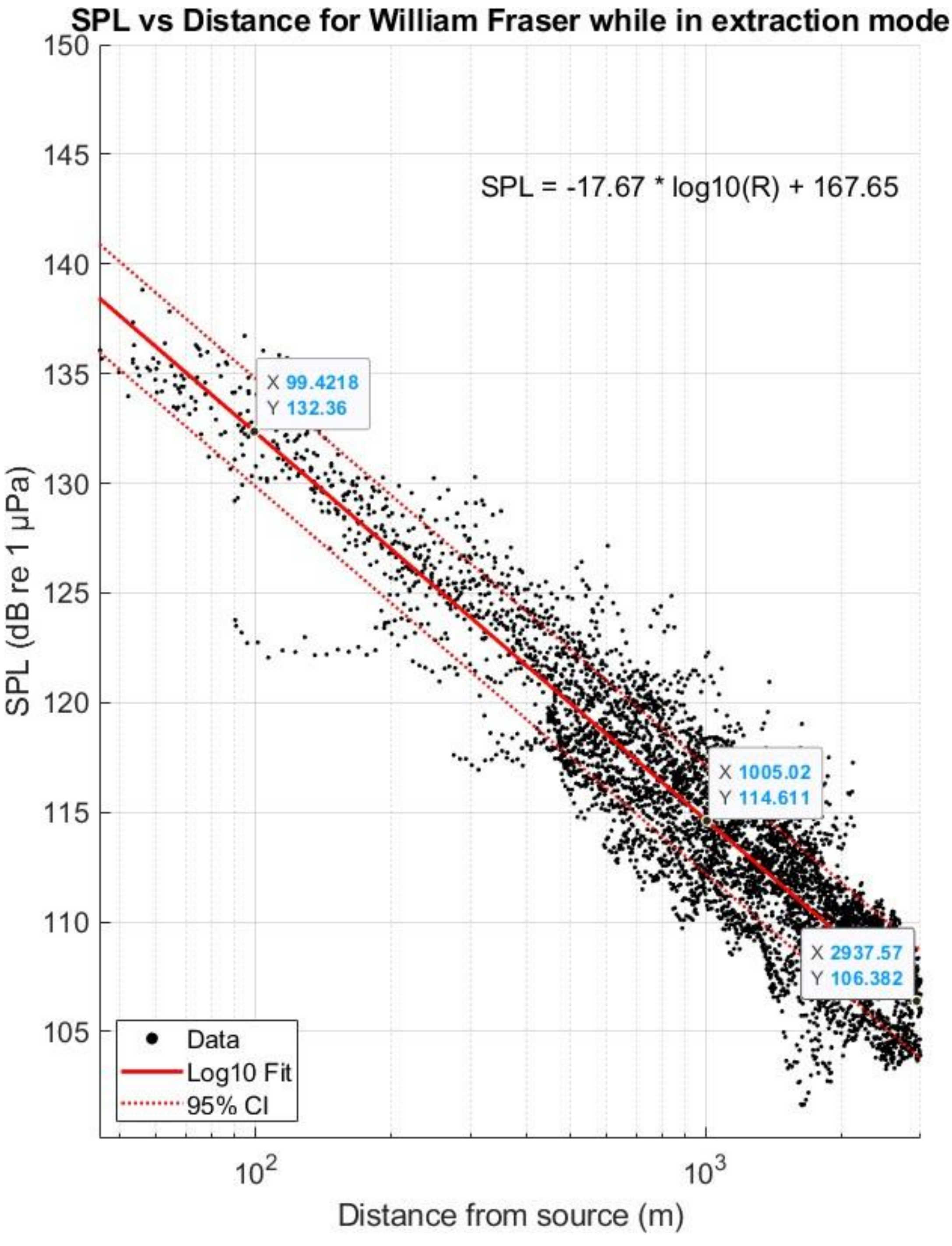

Figure 40: Curve-fitted propagation loss (broadband) from empirical measurements of the *William Fraser* extracting off the Mangawhai-Pākiri coast in 2019. Data tips show the measured sound pressure level (Y) at different ranges (X) for comparison against the modelled PL slope in Figure 39.

AIS Traffic

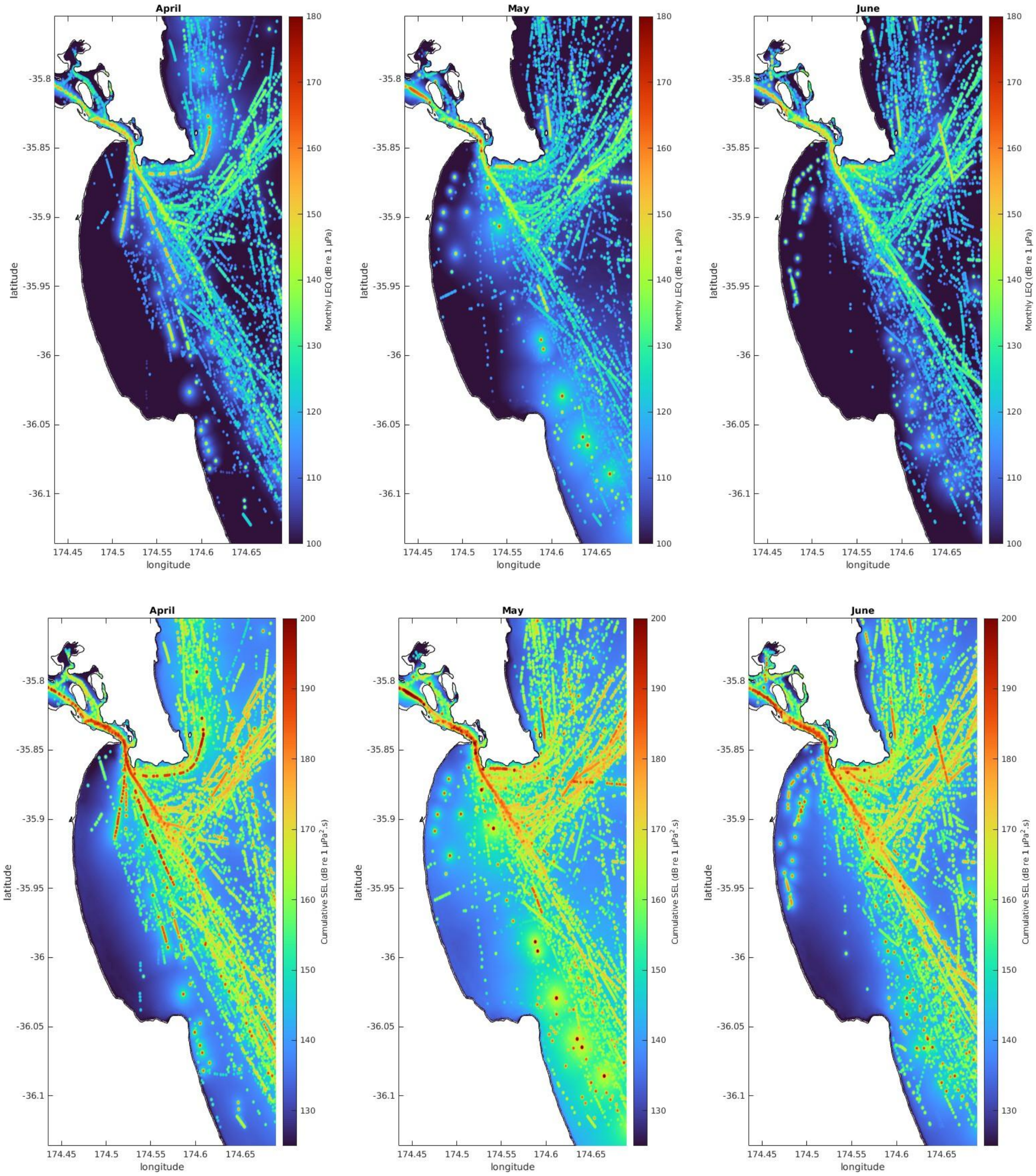

Figure 41: Monthly Leq (dB re 1 μPa, top panel) and cumulative sound exposure level (L_E, bottom panel) map of all AIS vessels for each month modelled in 2024, representing the minimal existing anthrophonic noise levels in the area.

TSHD William Fraser extracting

150,000m^3

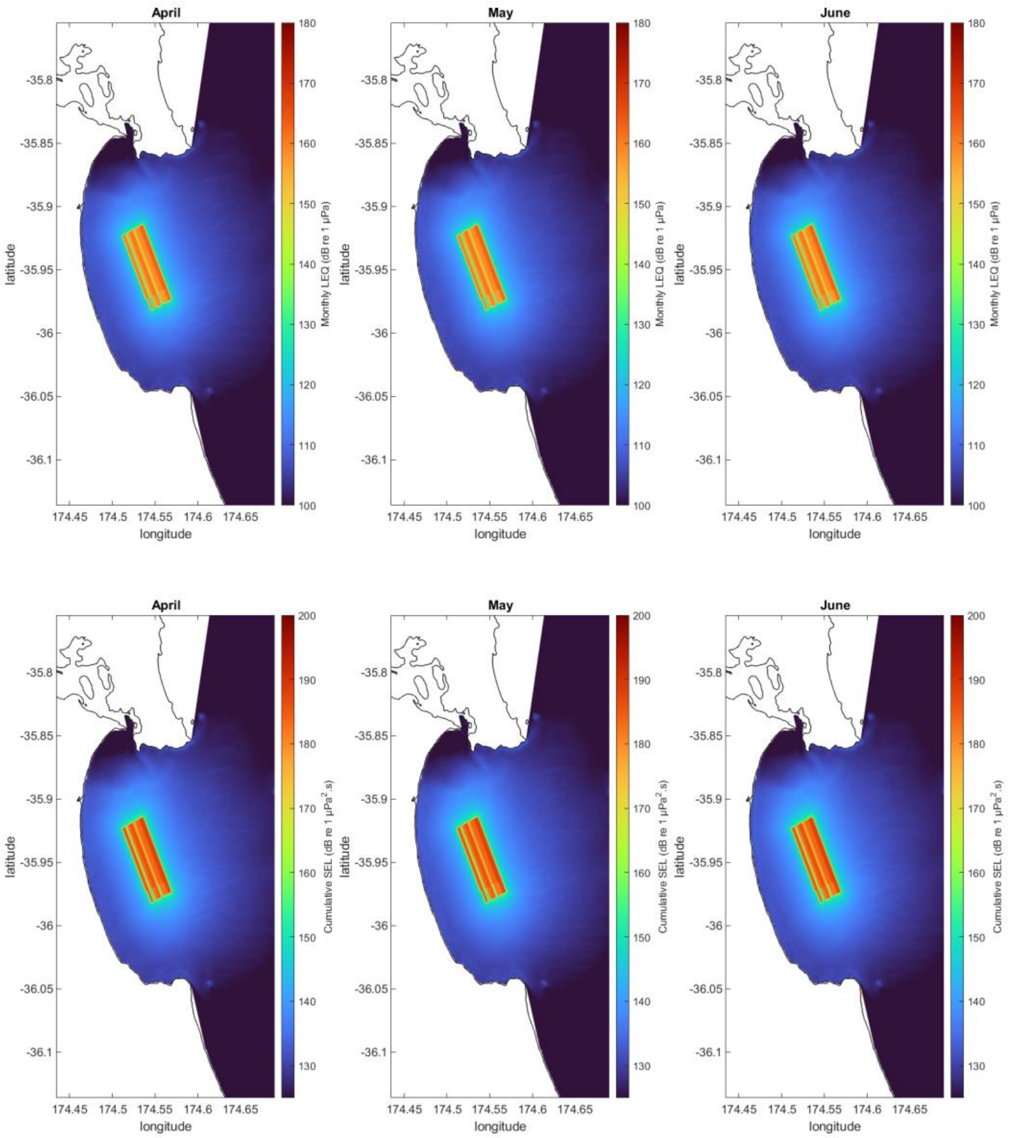

Figure 42: Monthly Leq (dB re 1 µPa, top panel) and cumulative sound exposure level (L_E, bottom panel) map of the *William Fraser* for each month modelled in 2024.

250,000m^3

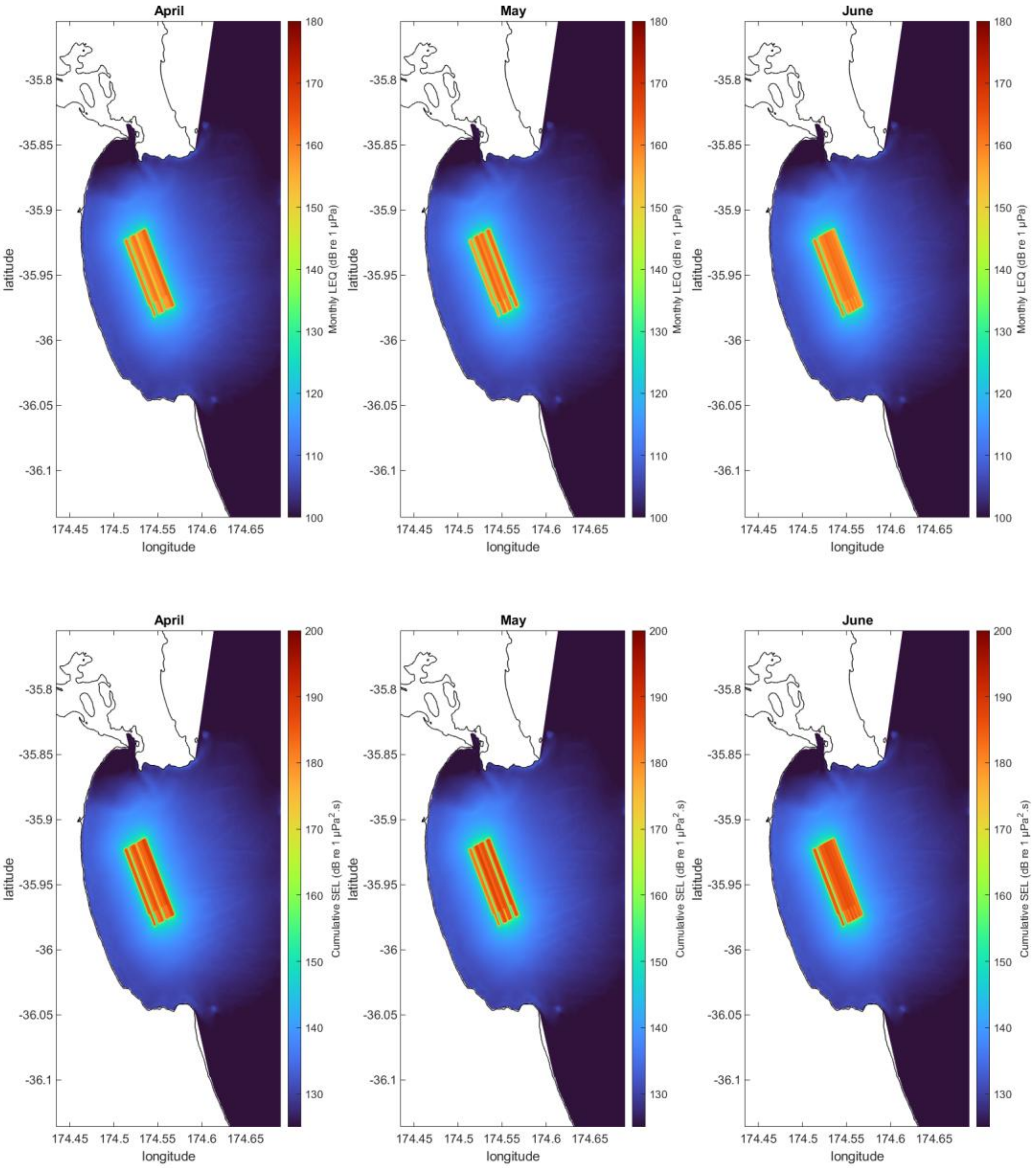

Figure 43: Monthly Leq (dB re 1 μPa, top panel) and cumulative sound exposure level (L_E, bottom panel) map of the *William Fraser* for each month modelled in 2024.

Cumulative noise models

<< This page has been deliberately left blank >>

150,000m^3

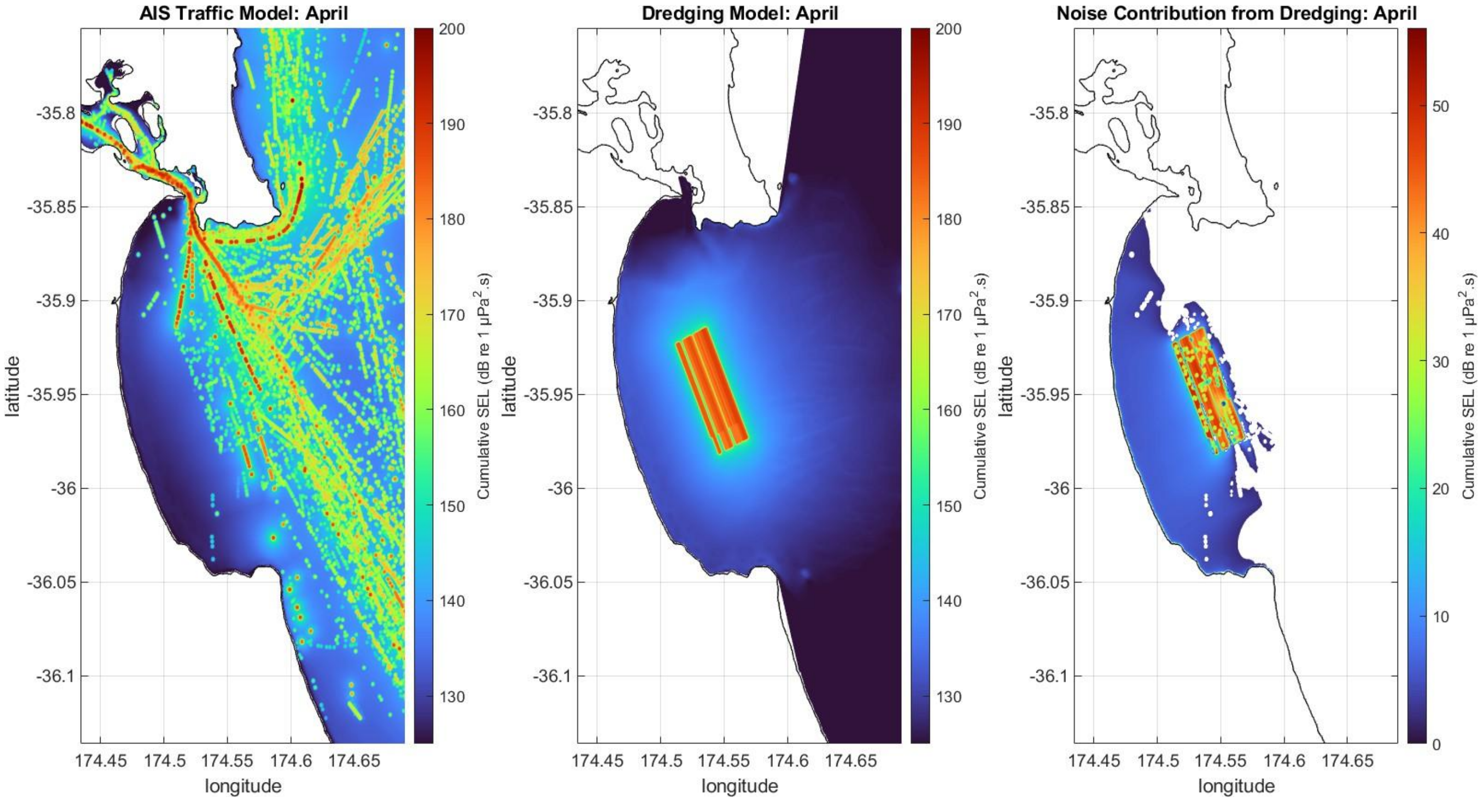

Figure 44: Monthly cumulative sound exposure levels (dB re 1 µPa^2•s) for April 2024 from the AIS traffic only (left panel), the TSHD actively extracting during the same time (centre panel) and the difference between the two (right panel).

150,000m^3

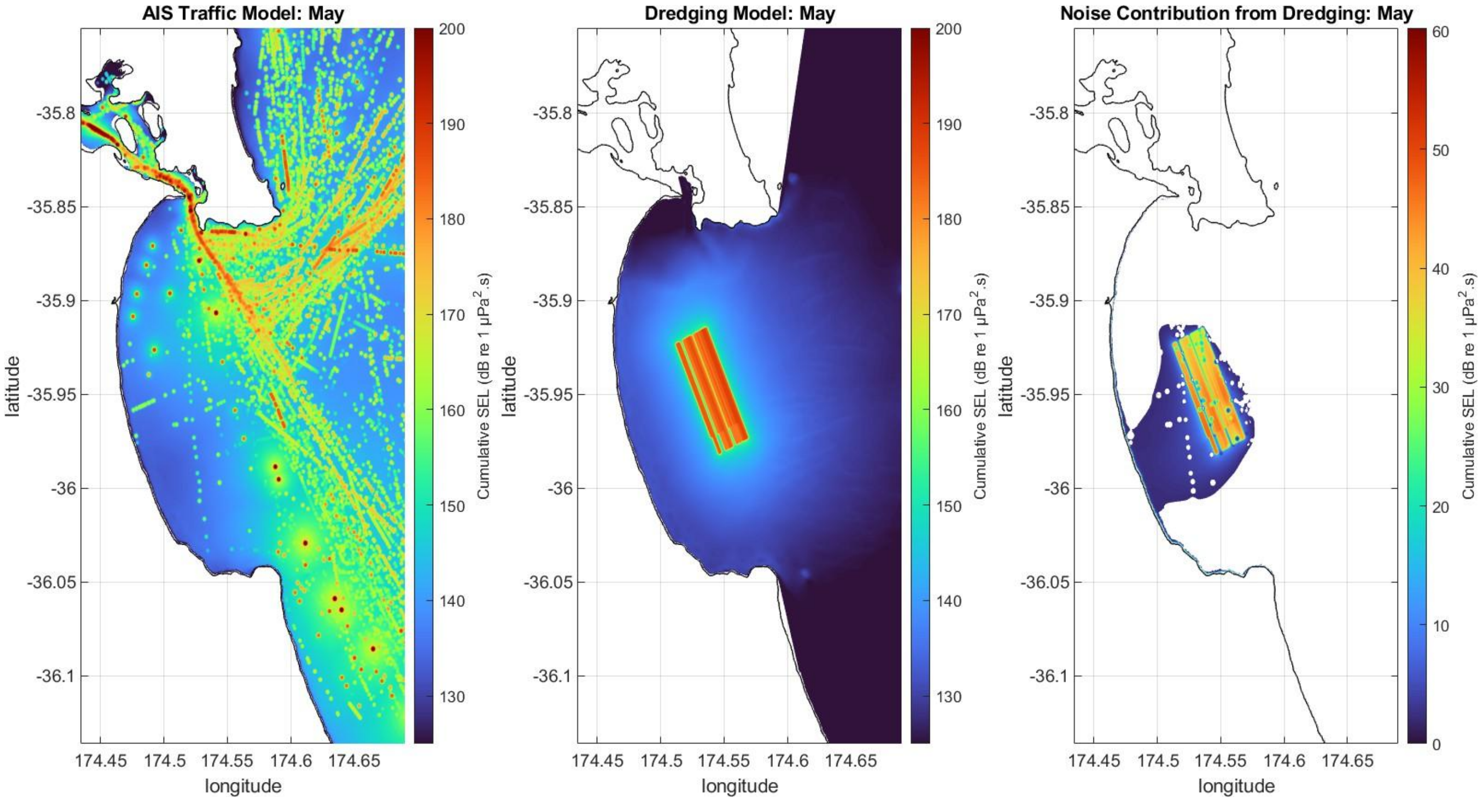

Figure 45: Monthly cumulative sound exposure levels (dB re 1 μPa^2•s) for May 2024 from the AIS traffic only (left panel), the TSHD actively extracting during the same time (centre panel) and the difference between the two (right panel).

150,000m^3

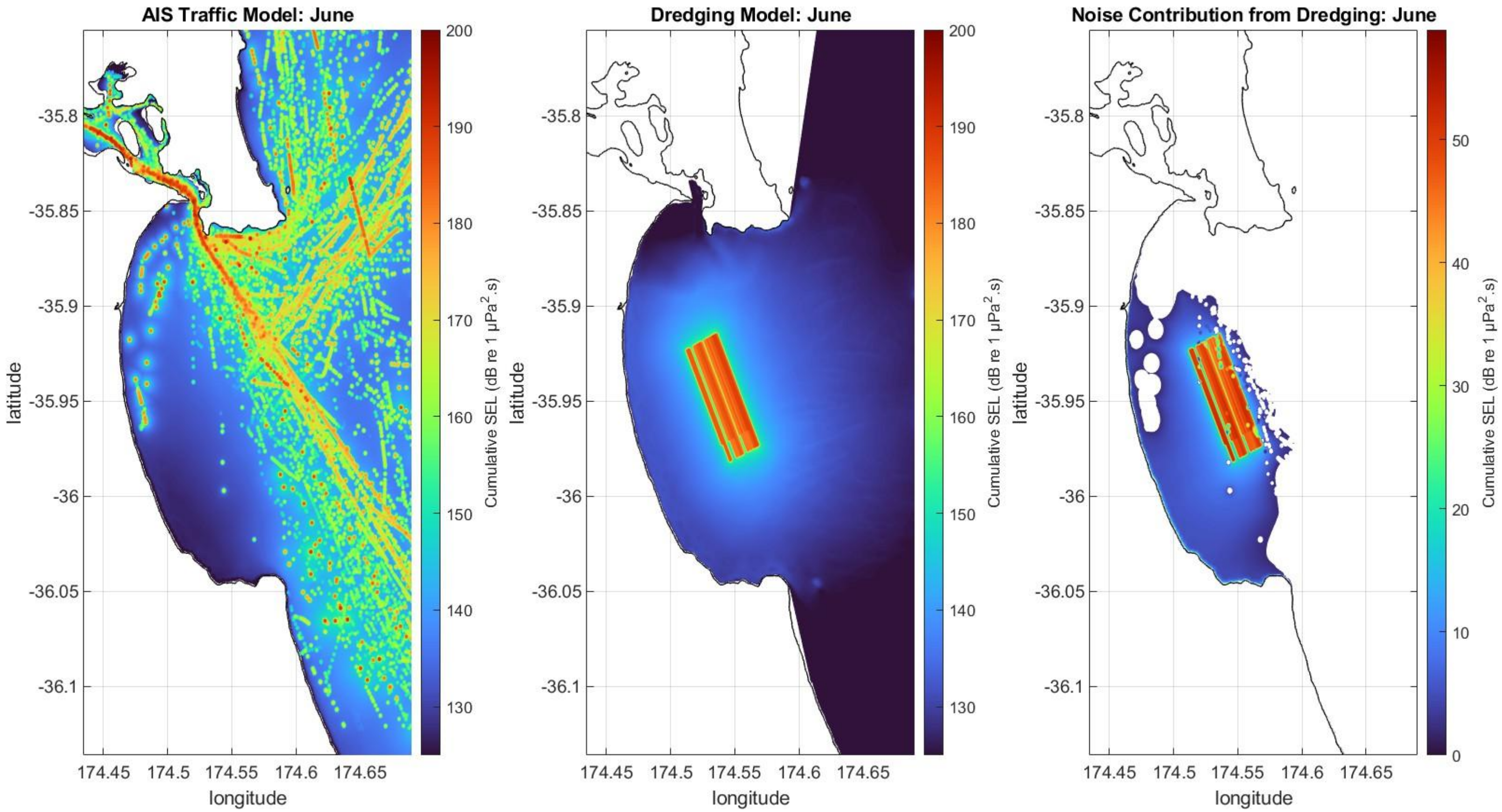

Figure 46: Monthly cumulative sound exposure levels (dB re 1 μPa^2•s) for June 2024 from the AIS traffic only (left panel), the TSHD actively extracting during the same time (centre panel) and the difference between the two (right panel).

250,000m³

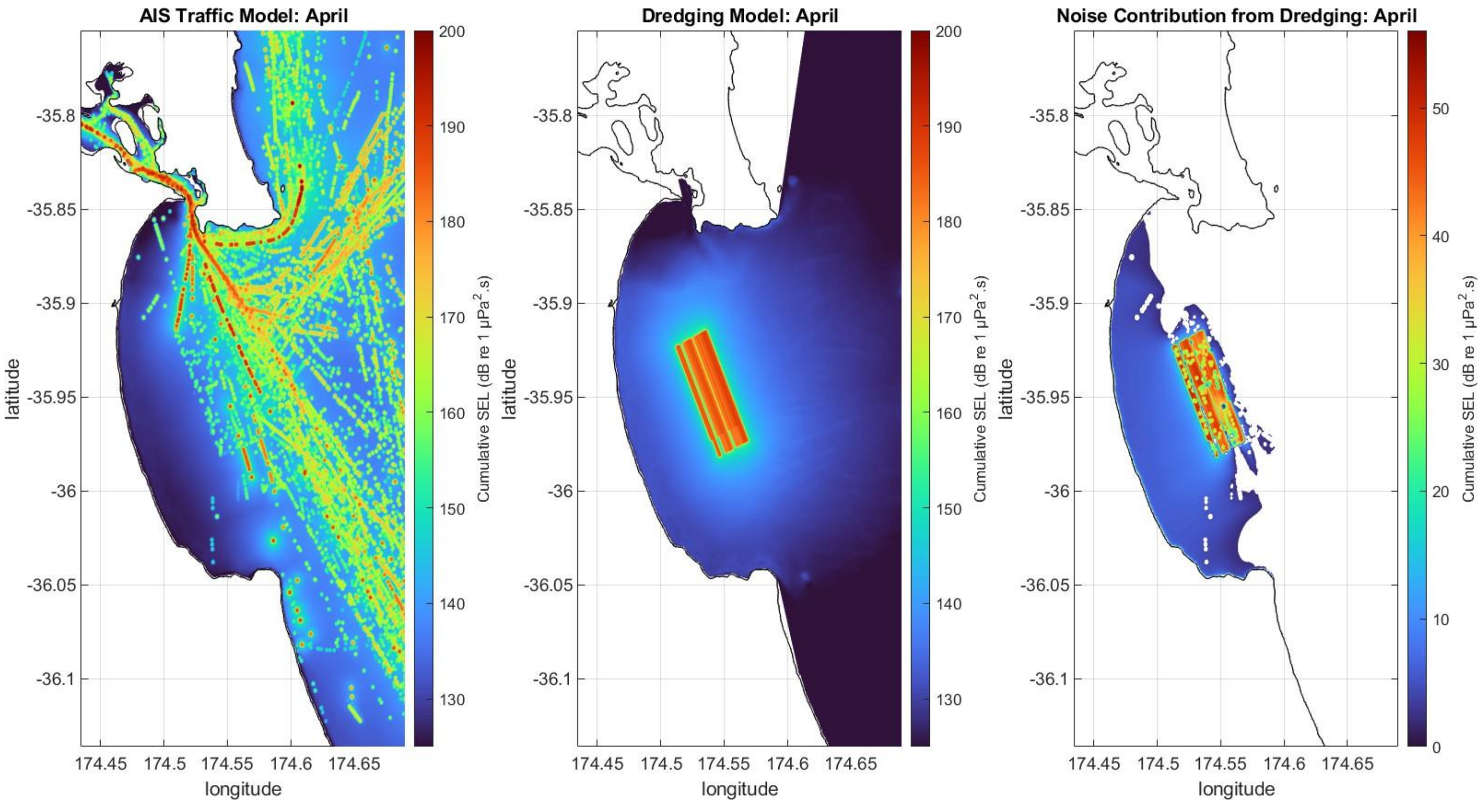

Figure 47: Monthly cumulative sound exposure levels (dB re 1 μPa^2•s) for April 2024 from the AIS traffic only (left panel), the TSHD actively extraction during the same time (centre panel) and the difference between the two (right panel).

250,000m³

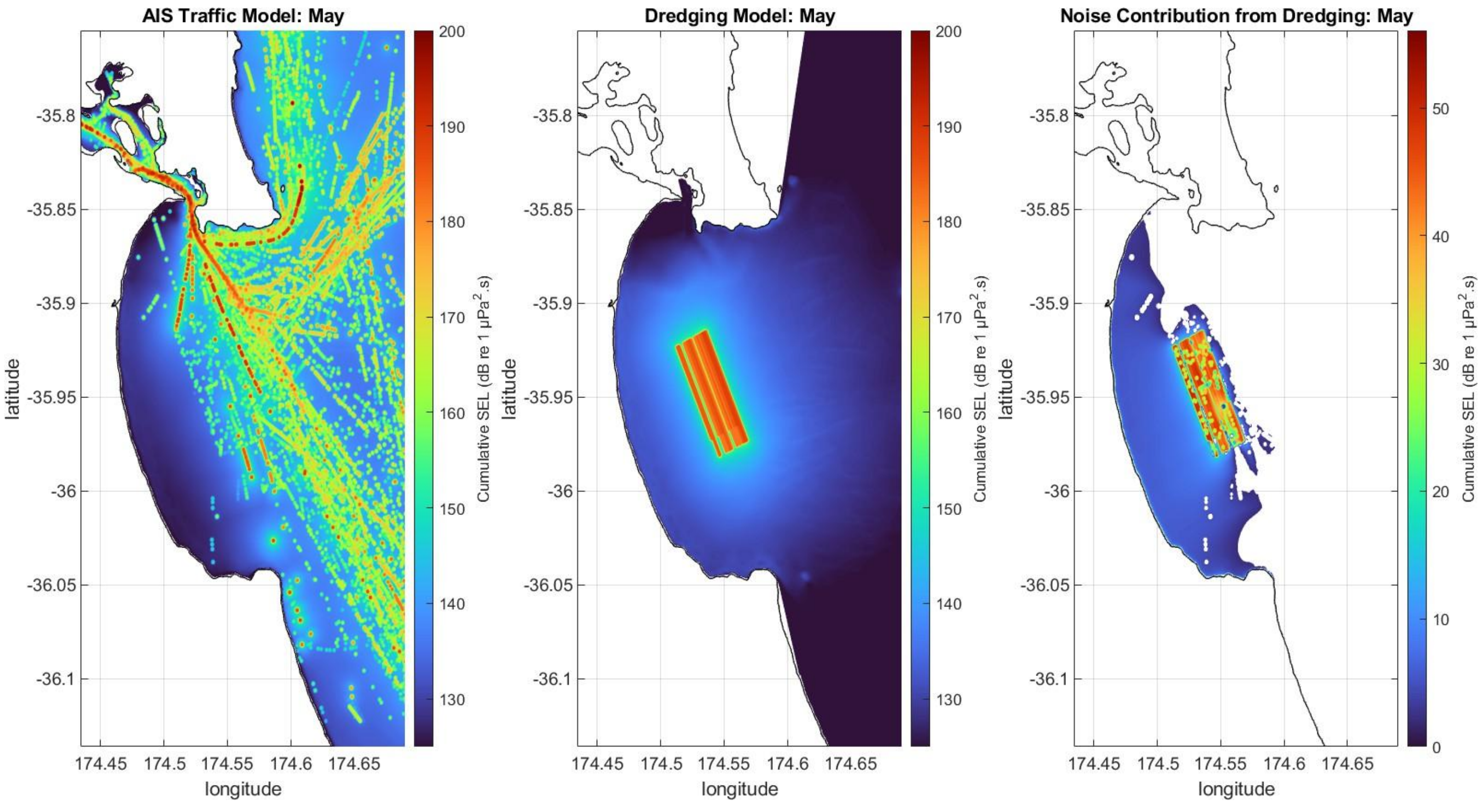

Figure 48: Monthly cumulative sound exposure levels (dB re 1 µPa²•s) for May 2024 from the AIS traffic only (left panel), the TSHD actively extracting during the same time (centre panel) and the difference between the two (right panel).

250,000m^3

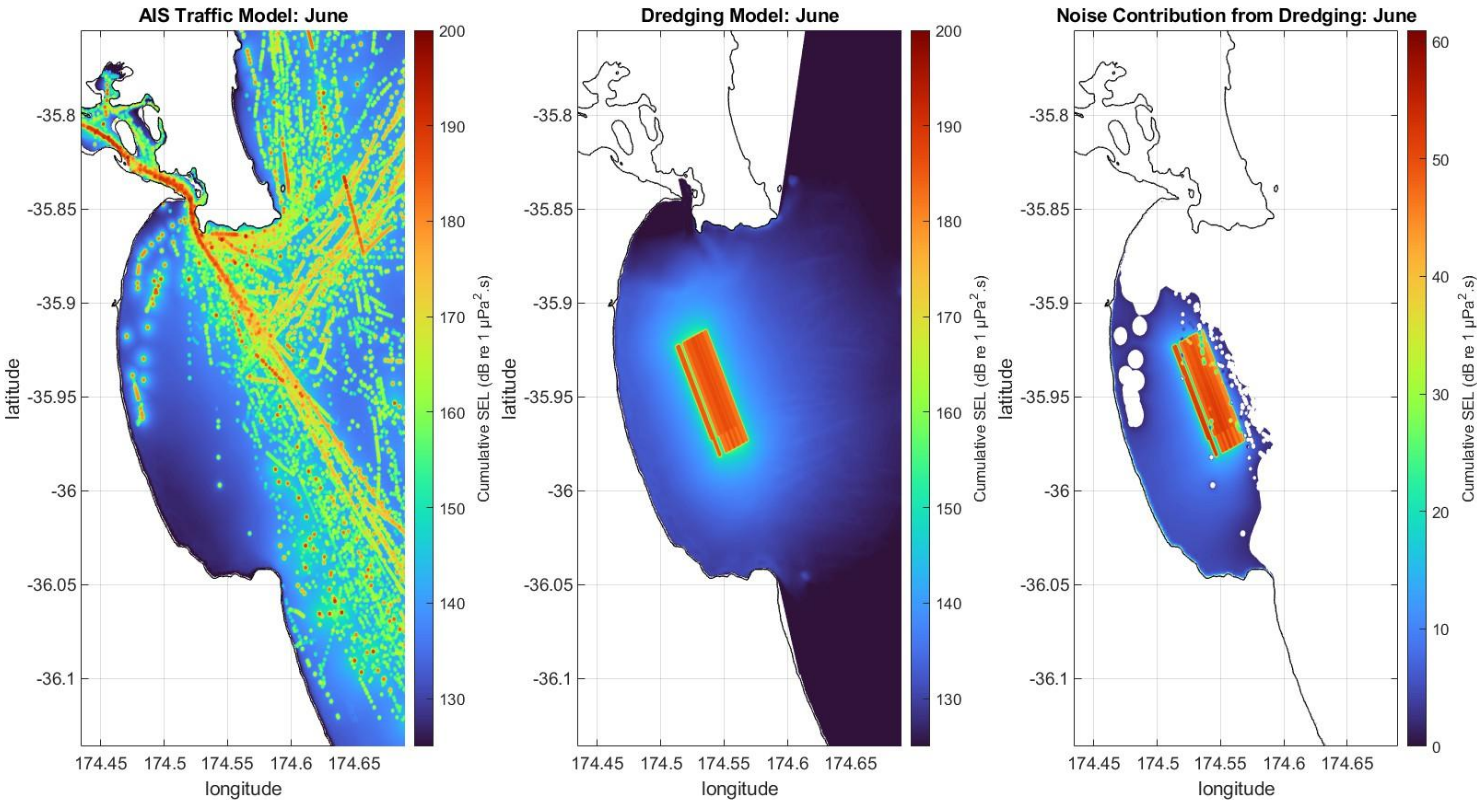

Figure 49: Monthly cumulative sound exposure levels (dB re 1 µPa^2•s) for June 2024 from the AIS traffic only (left panel), the TSHD active extracting during the same time (centre panel) and the difference between the two (right panel).

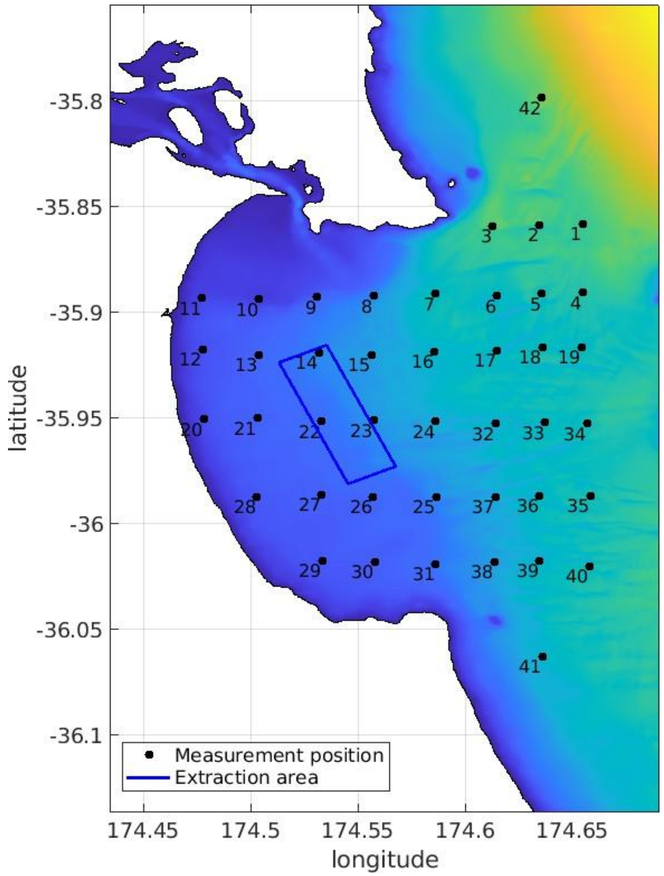

Figure 50: Map showing the positions of each 'measurement position' used to calculate the average soundscape changes from the proposed sand extraction activity within Te Ākau Bream Bay.

150,000m^3 Extraction Volume

Frequency-dependent sound pressure levels from the AIS traffic and extraction noise (of the *William Fraser,* WF) models at each measurement position in Figure 50 above.

5th Perc Ambient + AIS Traffic, April 2024			1/1 Octave Bands, Monthly Leq (dB re 1 µPa)									
Position Number	Position Latitude	Position Longitude	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	174.6547747	-35.85806309	136.616	129.909	128.235	125.318	122.169	119.048	115.974	112.93	109.901	106.879
2	174.6348335	-35.85858042	110.498	110.818	109.805	107.036	103.82	100.552	97.1662	93.2669	87.9722	83.5455
3	174.6128982	-35.85909775	111.404	113.466	112.246	109.427	106.237	103.028	99.7523	96.0621	90.7316	83.822
4	174.6547747	-35.89065461	130.054	130.811	129.135	126.217	123.068	119.948	116.876	113.836	110.815	107.8
5	174.6356312	-35.89117194	121.077	120.342	118.733	115.835	112.681	109.546	106.447	103.36	100.291	97.227
6	174.6148923	-35.89220659	132.625	125.977	124.332	121.423	118.273	115.148	112.066	108.998	105.912	102.725
7	174.586177	-35.89117194	130.79	124.137	122.503	119.598	116.45	113.324	110.239	107.168	104.074	100.875
8	174.5574617	-35.89220659	138.567	131.942	130.279	127.369	124.224	121.104	118.033	114.989	111.952	108.91
9	174.5311393	-35.89272391	132.042	125.51	124.06	121.301	118.221	115.116	112.037	108.953	105.781	102.503
10	174.5040193	-35.89375856	76.6282	80.5424	101.934	105.369	105.265	103.133	100.162	96.6254	91.8176	85.4227
11	174.4772981	-35.89324124	76.6282	77.1337	89.6468	96.8376	96.7598	95.3926	92.6888	89.1	85.0922	82.7179
12	174.4776969	-35.91755554	76.6282	78.1829	96.1515	99.2275	98.171	95.5804	92.2366	88.5263	84.9868	82.7196
13	174.5036205	-35.92014217	85.7084	102.977	105.888	105.079	102.559	99.516	96.2417	92.6228	88.1228	83.6475
14	174.531937	-35.91910752	105.135	110.075	110.355	108.147	105.151	101.992	98.7443	95.2055	90.6479	84.9565
15	174.5562652	-35.92014217	123.495	124.583	123.015	120.13	116.986	113.859	110.77	107.679	104.483	100.986
16	174.5857782	-35.91859019	117.838	112.829	111.701	108.964	105.81	102.622	99.418	96.1137	92.5899	89.1395
17	174.6148923	-35.91807287	118.37	119.13	117.551	114.671	111.519	108.383	105.282	102.201	99.1597	96.1718
18	174.63603	-35.91652089	124.212	117.669	116.131	113.263	110.106	106.957	103.836	100.726	97.6449	94.4433
19	174.6543759	-35.91652089	103.197	104.298	104.782	102.487	99.2264	95.7394	91.9853	88.048	85.2773	82.9858
20	174.4780957	-35.95066438	76.6282	77.1528	91.8695	97.1892	96.4988	93.9205	90.3767	86.7152	84.5095	82.7138
21	174.5032216	-35.95014706	76.6282	83.1866	98.4063	99.4978	97.6974	94.6909	91.1114	87.4346	84.6427	82.714
22	174.5331334	-35.95169903	84.7145	101.943	104.96	103.753	100.942	97.6984	94.2138	90.4166	86.1011	82.823
23	174.5574617	-35.95118171	116.27	114.255	113.409	110.741	107.616	104.445	101.255	97.9181	93.9733	89.0031
24	174.586177	-35.95169903	113.075	114.342	113.259	110.523	107.376	104.198	101.007	97.6777	93.8132	89.1634

25	174.5865758	-35.9873945	114.376	114.232	113.099	110.402	107.279	104.119	100.962	97.7812	94.4524	90.9822
26	174.5570629	-35.9873945	93.2441	105.134	107.167	105.638	102.807	99.6267	96.2995	92.827	88.9366	84.3561
27	174.5331334	-35.98635985	76.6339	88.0061	99.6605	100.128	97.9599	94.783	91.2057	87.7079	84.8383	82.7188
28	174.5028228	-35.9873945	76.6282	77.2335	92.09	96.277	95.4196	92.656	88.9281	85.9051	84.4672	82.7137
29	174.5335323	-36.01739939	76.6316	78.2431	93.1802	96.7106	95.7148	92.872	89.2186	86.2787	84.5414	82.7152
30	174.5578605	-36.01791671	76.6283	87.6061	99.7022	100.438	98.4595	95.3679	91.8175	88.3366	85.1312	82.7265
31	174.586177	-36.01895137	99.1817	108.238	109.492	107.498	104.534	101.363	98.1053	94.7138	90.6912	85.3166
32	174.6140947	-35.95273369	130.283	123.597	121.957	119.054	115.904	112.779	109.699	106.644	103.598	100.558
33	174.6372265	-35.95221636	134.533	135.286	133.607	130.688	127.54	124.42	121.35	118.312	115.292	112.278
34	174.6567689	-35.95273369	120.318	121.115	119.48	116.581	113.43	110.301	107.216	104.167	101.159	98.1693
35	174.6583641	-35.98687718	101.701	104.671	104.823	102.507	99.3008	95.918	92.4145	88.8928	85.5534	82.9112
36	174.6348335	-35.98687718	108.581	110.327	109.439	106.803	103.646	100.426	97.1715	93.8223	90.0258	85.6549
37	174.6140947	-35.9873945	136.108	129.745	128.082	125.169	122.02	118.899	115.826	112.779	109.729	106.637
38	174.6136959	-36.01791671	115.701	116.781	115.35	112.54	109.399	106.253	103.134	100.012	96.794	93.5823
39	174.6348335	-36.01739939	128.019	128.805	127.138	124.224	121.075	117.954	114.881	111.835	108.788	105.71
40	174.6579653	-36.01998602	137.749	131.005	129.329	126.412	123.264	120.144	117.072	114.032	111.007	107.986
41	174.63603	-36.06292404	100.678	105.371	105.471	103.133	99.9768	96.6669	93.2846	89.876	85.9473	82.7709
42	174.6356312	-35.79857065	117.427	118.394	116.813	113.917	110.757	107.613	104.499	101.36	98.1559	95.1

5th Perc Ambient + WF extracting, April 2024

			1/1 Octave Bands, Monthly Leq (dB re 1 µPa)									
Position Number	Position Latitude	Position Longitude	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	174.6547747	-35.85806309	135.248	128.542	126.871	123.959	120.811	117.694	114.617	111.574	108.546	105.528
2	174.6348335	-35.85858042	109.133	109.46	108.644	106.268	103.143	100.238	96.6268	93.0701	88.2038	84.7926
3	174.6128982	-35.85909775	110.038	112.104	111.003	108.431	105.304	102.34	98.9201	95.4822	90.2929	84.9462
4	174.6547747	-35.89065461	128.687	129.444	127.771	124.859	121.711	118.596	115.52	112.481	109.458	106.447
5	174.6356312	-35.89117194	119.71	118.976	117.406	114.588	111.451	108.392	105.236	102.186	99.0378	96.0107
6	174.6148923	-35.89220659	131.258	124.61	122.982	120.105	116.962	113.87	110.764	107.72	104.578	101.401
7	174.586177	-35.89117194	129.423	122.771	121.17	118.331	115.2	112.149	109.023	106.048	102.779	99.5738
8	174.5574617	-35.89220659	137.2	130.575	128.925	126.042	122.905	119.82	116.733	113.758	110.631	107.554
9	174.5311393	-35.89272391	130.674	124.145	122.777	120.215	117.202	114.335	111.169	108.641	104.915	101.204

10	174.5040193	-35.89375856	78.2713	80.8151	102.573	107.729	107.49	106.476	102.975	102.056	95.0484	86.0718
11	174.4772981	-35.89324124	78.2713	78.7729	92.6208	102.149	102.089	101.683	97.9847	96.8709	88.6375	84.3624
12	174.4776969	-35.91755554	78.2713	79.4426	99.7949	104.63	103.71	102.872	99.0451	98.485	90.6575	84.4111
13	174.5036205	-35.92014217	86.1817	102.823	110.496	111.963	109.68	108.721	105.072	105.811	101.252	93.3529
14	174.531937	-35.91910752	151.169	149.771	157.971	158.371	155.771	155.071	151.571	153.371	151.57	151.069
15	174.5562652	-35.92014217	122.137	123.233	121.898	119.343	116.281	113.574	110.352	108.39	104.596	100.023
16	174.5857782	-35.91859019	116.472	111.506	111.035	109.22	106.28	104.023	100.45	98.6645	92.8858	88.6694
17	174.6148923	-35.91807287	117.003	117.768	116.292	113.601	110.492	107.555	104.332	101.441	97.9747	94.9962
18	174.63603	-35.91652089	122.845	116.307	114.864	112.178	109.06	106.091	102.843	99.8391	96.492	93.3583
19	174.6543759	-35.91652089	101.841	103.013	104.439	103.391	100.419	98.0984	93.8832	90.8406	86.5579	84.495
20	174.4780957	-35.95066438	78.2713	78.8046	96.8778	103.025	102.42	101.634	97.6831	96.7354	88.5974	84.3631
21	174.5032216	-35.95014706	78.2721	86.7569	104.378	107.258	105.442	104.556	100.751	100.916	94.3499	85.2282
22	174.5331334	-35.95169903	146.382	144.983	153.183	153.583	150.983	150.283	146.783	148.583	146.783	146.282
23	174.5574617	-35.95118171	122.488	121.335	129.068	129.453	126.852	126.131	122.62	124.356	122.379	121.351
24	174.586177	-35.95169903	111.73	113.048	112.938	111.399	108.527	106.545	102.983	102.026	96.2342	88.9513
25	174.5865758	-35.9873945	113.01	112.909	112.676	111.397	108.659	106.799	103.266	102.593	97.2333	90.5756
26	174.5570629	-35.9873945	92.6514	105.235	112.701	113.926	111.56	110.68	107.058	108.083	104.078	96.8229
27	174.5331334	-35.98635985	78.3629	92.2132	106.846	109.401	107.39	106.565	102.828	103.429	97.9563	88.4627
28	174.5028228	-35.9873945	78.2713	78.8916	97.3421	102.788	101.995	101.205	97.2474	96.5182	88.703	84.3662
29	174.5335323	-36.01739939	78.273	79.3746	96.6211	102.395	101.777	100.992	97.0581	96.2868	88.4817	84.3632
30	174.5578605	-36.01791671	78.2714	86.6423	101.12	104.395	103.083	102.019	98.1209	97.3335	89.386	84.3737
31	174.586177	-36.01895137	97.8385	106.875	108.43	107.375	104.915	102.763	99.1566	97.1284	90.9413	85.8515
32	174.6140947	-35.95273369	128.915	122.232	120.642	117.832	114.708	111.692	108.554	105.656	102.336	99.2618
33	174.6372265	-35.95221636	133.165	133.919	132.242	129.328	126.181	123.067	119.993	116.959	113.929	110.916
34	174.6567689	-35.95273369	118.951	119.749	118.152	115.334	112.202	109.153	106.011	103.009	99.8881	96.924
35	174.6583641	-35.98687718	100.348	103.356	104.354	103.356	100.486	98.2777	94.2847	91.7255	86.7724	84.4567
36	174.6348335	-35.98687718	107.217	108.981	108.551	106.749	103.812	101.394	97.7683	95.3399	89.9671	86.0718
37	174.6140947	-35.9873945	134.741	128.378	126.726	123.838	120.697	117.606	114.518	111.519	108.392	105.288
38	174.6136959	-36.01791671	114.335	115.414	114.061	111.49	108.458	105.59	102.329	99.4976	95.7319	92.5569
39	174.6348335	-36.01739939	126.652	127.438	125.775	122.874	119.73	116.623	113.541	110.506	107.438	104.364
40	174.6579653	-36.01998602	136.382	129.638	127.964	125.053	121.906	118.792	115.716	112.68	109.65	106.631

41	174.63603	-36.06292404	99.3274	104.01	104.265	102.524	99.7148	97.0712	93.3992	90.4854	86.9046	84.3855
42	174.6356312	-35.79857065	116.06	117.028	115.464	112.609	109.455	106.342	103.203	100.102	96.9691	93.9765

5th Perc Ambient + AIS Traffic, May 2024			1/1 Octave Bands, Monthly Leq (dB re 1 µPa)									
Position Number	Position Latitude	Position Longitude	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	174.6547747	-35.85806309	145.024	138.263	136.584	133.667	130.518	127.398	124.327	121.287	118.264	115.243
2	174.6348335	-35.85858042	108.595	110.554	110.501	108.281	105.145	101.774	98.1228	93.6867	89.1517	85.4557
3	174.6128982	-35.85909775	129.789	130.561	128.904	125.998	122.851	119.728	116.649	113.59	110.545	107.5
4	174.6547747	-35.89065461	104.461	108.403	109.079	107.025	103.848	100.348	96.4078	91.2965	86.5335	83.1512
5	174.6356312	-35.89117194	132.845	126.155	124.539	121.654	118.506	115.373	112.275	109.181	106.123	103.104
6	174.6148923	-35.89220659	106.167	110.207	111.292	109.305	106.195	102.791	98.9992	93.6995	86.4942	83.1148
7	174.586177	-35.89117194	136.805	130.56	128.931	126.038	122.893	119.768	116.684	113.607	110.528	107.484
8	174.5574617	-35.89220659	143.668	137.018	135.37	132.468	129.324	126.204	123.129	120.075	117.018	113.972
9	174.5311393	-35.89272391	120.951	123.125	122.801	120.53	117.58	114.49	111.332	107.945	103.913	99.5373
10	174.5040193	-35.89375856	78.7177	113.316	119.255	119.067	116.809	114.071	111.045	107.752	103.975	99.6076
11	174.4772981	-35.89324124	81.9799	108.819	112.567	112.28	110.184	107.447	104.336	100.784	96.5755	91.8487
12	174.4776969	-35.91755554	76.6287	94.4538	107.146	108.602	107.097	104.252	100.806	96.3159	90.206	84.1597
13	174.5036205	-35.92014217	78.97	105.217	111.815	111.521	109.093	105.999	102.545	98.0935	90.9802	83.7913
14	174.531937	-35.91910752	108.963	117.843	118.804	116.649	113.666	110.504	107.217	103.389	97.5522	87.0271
15	174.5562652	-35.92014217	109.467	116.51	117.333	115.083	112.05	108.849	105.505	101.5	95.1396	85.1469
16	174.5857782	-35.91859019	127.386	121.935	120.606	117.85	114.72	111.562	108.393	105.088	101.664	98.4113
17	174.6148923	-35.91807287	137.029	130.296	128.648	125.747	122.6	119.475	116.392	113.326	110.284	107.268
18	174.63603	-35.91652089	126.341	119.798	118.383	115.608	112.461	109.288	106.105	102.85	99.7174	96.7321
19	174.6543759	-35.91652089	99.8988	106.225	108.489	106.917	103.71	99.9941	95.5436	89.4115	84.8208	82.7935
20	174.4780957	-35.95066438	76.6283	79.6322	100.713	105.296	104.477	101.661	97.8592	92.2224	85.4821	82.7341
21	174.5032216	-35.95014706	88.4026	92.8232	106.539	107.519	105.621	102.533	98.7952	93.4476	86.0449	82.8404
22	174.5331334	-35.95169903	94.8247	102.829	109.561	109.305	106.801	103.57	99.846	94.5873	86.4887	82.827
23	174.5574617	-35.95118171	101.168	109.426	111.343	109.815	106.902	103.59	99.9125	94.9609	88.0633	83.5828
24	174.586177	-35.95169903	152.991	153.741	152.059	149.14	145.991	142.872	139.803	136.765	133.746	130.731
25	174.5865758	-35.9873945	138.553	139.862	138.322	135.438	132.295	129.173	126.091	123.012	119.835	116.307

26	174.5570629	-35.9873945	78.3606	104.148	110.718	110.418	107.918	104.785	101.322	96.978	90.0295	82.9495
27	174.5331334	-35.98635985	76.6949	87.138	104.278	105.78	104.264	101.239	97.3174	92.2206	85.5609	82.7192
28	174.5028228	-35.9873945	76.6282	77.1897	96.6693	102.638	102.175	99.4578	95.2664	88.9818	84.5719	82.7138
29	174.5335323	-36.01739939	89.9999	91.8851	101.961	106.113	105.216	102.297	98.39	92.4241	85.2168	82.8981
30	174.5578605	-36.01791671	76.6308	94.4171	109.855	110.486	108.443	105.325	101.622	96.3113	87.1061	82.7242
31	174.586177	-36.01895137	99.8702	116.528	118.299	116.57	113.634	110.431	107.025	102.777	95.3972	83.7912
32	174.6140947	-35.95273369	142.338	135.582	133.909	130.995	127.847	124.726	121.653	118.609	115.582	112.566
33	174.6372265	-35.95221636	96.0601	108.268	110.316	108.627	105.479	101.894	97.6793	91.2814	85.0515	82.7177
34	174.6567689	-35.95273369	116.787	117.947	116.76	114.085	110.925	107.692	104.39	100.923	97.7364	94.7804
35	174.6583641	-35.98687718	107.866	112.869	113.331	111.072	107.893	104.469	100.682	95.541	89.3714	86.2808
36	174.6348335	-35.98687718	103.696	112.529	113.544	111.394	108.249	104.845	101.069	95.7283	86.8954	82.8666
37	174.6140947	-35.9873945	123.904	124.867	123.414	120.614	117.476	114.324	111.191	108.037	104.78	101.632
38	174.6136959	-36.01791671	120.345	124.344	123.816	121.17	118.046	114.866	111.629	107.993	102.746	92.7759
39	174.6348335	-36.01739939	117.412	120.622	120.078	117.436	114.288	111.065	107.736	103.831	98.2524	92.7127
40	174.6579653	-36.01998602	110.838	115.053	115.417	112.965	109.785	106.436	102.81	97.9112	89.5711	83.8648
41	174.63603	-36.06292404	131.366	132.859	131.366	128.489	125.338	122.199	119.08	115.868	112.193	107.052
42	174.6356312	-35.79857065	113.995	114.883	113.414	110.624	107.45	104.248	101.073	98.0018	94.9453	91.6789

5th Perc Ambient + WF extracting, May 2024

			1/1 Octave Bands, Monthly Leq (dB re 1 μPa)									
Position Number	Position Latitude	Position Longitude	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	174.6547747	-35.85806309	143.657	136.896	135.218	132.301	129.152	126.033	122.961	119.921	116.899	113.878
2	174.6348335	-35.85858042	107.231	109.197	109.307	107.369	104.294	101.216	97.4227	93.3745	89.0522	85.9407
3	174.6128982	-35.85909775	128.422	129.194	127.539	124.639	121.493	118.376	115.293	112.238	109.188	106.147
4	174.6547747	-35.89065461	103.102	107.055	107.988	106.34	103.255	100.21	96.1122	91.7455	87.2614	84.5811
5	174.6356312	-35.89117194	131.478	124.788	123.182	120.319	117.175	114.063	110.949	107.864	104.785	101.777
6	174.6148923	-35.89220659	104.806	108.865	110.236	108.659	105.645	102.733	98.7858	94.5641	87.3669	84.562
7	174.586177	-35.89117194	135.438	129.193	127.571	124.693	121.551	118.443	115.35	112.294	109.176	106.131
8	174.5574617	-35.89220659	142.301	135.651	134.006	131.112	127.971	124.861	121.781	118.747	115.663	112.609
9	174.5311393	-35.89272391	119.584	121.762	121.54	119.488	116.606	113.78	110.534	107.837	103.254	98.2957
10	174.5040193	-35.89375856	79.4405	111.95	117.937	117.954	115.83	113.362	110.235	107.538	103.103	98.3382

11	174.4772981	-35.89324124	81.7241	107.455	111.241	111.364	109.515	107.266	103.972	101.214	95.8363	90.9824
12	174.4776969	-35.91755554	78.2716	93.171	106.504	108.86	107.556	105.672	102.016	99.9982	92.4037	85.1776
13	174.5036205	-35.92014217	81.441	104.579	112.895	113.787	111.47	109.918	106.299	106.221	101.289	92.3187
14	174.531937	-35.91910752	149.717	148.321	156.518	156.918	154.318	153.618	150.118	151.918	150.118	149.617
15	174.5562652	-35.92014217	108.244	115.23	116.7	115.147	112.267	109.956	106.439	105.074	99.4375	89.2105
16	174.5857782	-35.91859019	126.018	120.572	119.33	116.721	113.627	110.647	107.398	104.418	100.517	97.1601
17	174.6148923	-35.91807287	135.662	128.929	127.29	124.404	121.259	118.151	115.057	112.007	108.931	105.916
18	174.63603	-35.91652089	124.973	118.434	117.075	114.405	111.281	108.216	104.959	101.775	98.4836	95.5338
19	174.6543759	-35.91652089	98.5547	104.908	107.578	106.496	103.422	100.394	95.8916	91.3429	86.3109	84.3969
20	174.4780957	-35.95066438	78.2714	80.2159	100.969	106.198	105.479	103.813	99.8983	97.6427	88.9726	84.3721
21	174.5032216	-35.95014706	87.3149	92.3105	107.502	109.545	107.695	106.103	102.308	101.503	94.5537	85.0856
22	174.5331334	-35.95169903	116.427	116.637	125.295	125.82	123.251	122.519	118.998	120.691	118.618	117.381
23	174.5574617	-35.95118171	110.544	112.2	119.313	119.651	117.047	116.193	112.64	114.126	111.684	109.566
24	174.586177	-35.95169903	151.624	152.374	150.692	147.773	144.625	141.506	138.436	135.399	132.379	129.364
25	174.5865758	-35.9873945	137.186	138.495	136.958	134.08	130.939	127.825	124.741	121.682	118.485	114.942
26	174.5570629	-35.9873945	86.5791	104.849	114.138	115.234	112.867	111.716	108.11	108.846	104.87	97.8275
27	174.5331334	-35.98635985	78.3272	91.5996	107.86	110.374	108.515	107.322	103.544	103.668	97.9023	87.5904
28	174.5028228	-35.9873945	78.2713	78.8677	98.9681	104.809	104.167	102.785	98.734	97.0323	88.852	84.3645
29	174.5335323	-36.01739939	88.8281	90.6616	101.669	106.474	105.7	103.813	99.8775	97.3506	88.8178	84.4553
30	174.5578605	-36.01791671	78.2726	93.1374	108.864	110.082	108.253	105.897	102.103	99.1855	90.1649	84.3737
31	174.586177	-36.01895137	98.5235	115.162	116.974	115.381	112.53	109.529	106.063	102.28	94.6543	84.9302
32	174.6140947	-35.95273369	140.971	134.214	132.545	129.637	126.49	123.376	120.299	117.265	114.221	111.204
33	174.6372265	-35.95221636	94.7536	106.945	109.399	108.241	105.245	102.394	98.1427	94.0922	86.7646	84.3588
34	174.6567689	-35.95273369	115.42	116.583	115.461	112.92	109.795	106.706	103.319	99.9699	96.5765	93.675
35	174.6583641	-35.98687718	106.502	111.509	112.095	110.078	106.969	103.836	99.9589	95.4415	89.2621	86.4968
36	174.6348335	-35.98687718	102.337	111.173	112.354	110.507	107.454	104.438	100.578	96.3394	87.8439	84.434
37	174.6140947	-35.9873945	122.537	123.501	122.076	119.343	116.227	113.155	109.985	106.961	103.499	100.32
38	174.6136959	-36.01791671	118.978	122.977	122.459	119.846	116.738	113.601	110.344	106.77	101.458	91.817
39	174.6348335	-36.01739939	116.045	119.255	118.731	116.145	113.02	109.864	106.503	102.692	97.0742	91.7596
40	174.6579653	-36.01998602	109.473	113.688	114.096	111.757	108.62	105.406	101.728	97.0886	89.3806	84.9704
41	174.63603	-36.06292404	129.999	131.491	129.999	127.124	123.974	120.838	117.718	114.508	110.833	105.701

42	174.6356312	-35.79857065	112.628	113.517	112.085	109.382	106.224	103.088	99.862	96.8663	93.9477	90.8306

5th Perc Ambient + AIS Traffic, June 2024

Position Number	Position Latitude	Position Longitude	1/1 Octave Bands, Monthly Leq (dB re 1 µPa) 63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	174.6547747	-35.85806309	123.877	118.541	116.969	114.122	110.998	107.86	104.735	101.568	98.2829	94.7286
2	174.6348335	-35.85858042	141.829	135.078	133.4	130.483	127.335	124.215	121.144	118.102	115.07	112.029
3	174.6128982	-35.85909775	115.029	116.097	114.645	111.902	108.833	105.697	102.532	99.2194	95.5487	91.1607
4	174.6547747	-35.89065461	102.631	104.761	104.875	103.243	100.455	97.14	93.4084	89.0383	85.3408	82.8349
5	174.6356312	-35.89117194	106.868	105.668	105.731	104.087	101.344	98.0792	94.4211	89.9933	85.8414	83.1069
6	174.6148923	-35.89220659	133.991	127.252	125.59	122.693	119.553	116.433	113.353	110.294	107.256	104.24
7	174.586177	-35.89117194	108.452	108.914	109.055	107.216	104.532	101.437	98.0627	94.0084	88.503	84.0585
8	174.5574617	-35.89220659	112.887	113.84	113.696	112.019	109.471	106.483	103.285	99.6742	95.0042	89.5369
9	174.5311393	-35.89272391	85.712	98.2456	107.97	109.778	108.429	105.779	102.601	98.7214	92.8397	84.9173
10	174.5040193	-35.89375856	76.6282	77.4462	101.126	106.722	107.194	105.364	102.436	98.626	93.3705	86.5235
11	174.4772981	-35.89324124	105.138	115.868	116.233	114.39	111.745	108.851	105.818	102.602	99.1504	95.3611
12	174.4776969	-35.91755554	76.6462	94.307	103.335	104.426	103.32	100.873	97.6808	93.6739	89.085	84.5909
13	174.5036205	-35.92014217	76.6299	90.5098	100.87	103.107	102.204	99.6677	96.2363	91.6141	85.9832	82.782
14	174.531937	-35.91910752	90.7849	101.152	104.403	104.895	103.19	100.35	96.8702	92.2477	85.996	82.7354
15	174.5562652	-35.92014217	111.668	113.835	112.832	110.523	107.684	104.599	101.358	97.7812	93.6703	88.8758
16	174.5857782	-35.91859019	140.926	134.178	132.501	129.587	126.441	123.322	120.25	117.207	114.176	111.141
17	174.6148923	-35.91807287	139.956	140.717	139.038	136.12	132.972	129.852	126.782	123.741	120.713	117.671
18	174.63603	-35.91652089	100.84	103.897	104.499	103.1	100.516	97.2428	93.5038	89.0314	85.458	83.0163
19	174.6543759	-35.91652089	109.709	110.947	109.806	107.352	104.392	101.195	97.8611	94.3921	91.2762	88.3193
20	174.4780957	-35.95066438	131.948	134.628	133.843	131.149	128.058	124.952	121.879	118.818	115.717	112.438
21	174.5032216	-35.95014706	76.6283	85.9639	98.2643	101.329	100.561	97.9613	94.2455	89.2217	85.0417	82.7405
22	174.5331334	-35.95169903	77.5407	96.0207	101.365	102.826	101.274	98.3764	94.5806	89.3856	84.773	82.7147
23	174.5574617	-35.95118171	98.0956	104.085	105.241	104.207	101.841	98.7406	95.105	90.5701	85.8711	82.8046
24	174.586177	-35.95169903	112.49	114.48	113.362	110.771	107.762	104.609	101.364	97.8883	93.8727	88.2202
25	174.5865758	-35.9873945	97.2841	105.519	106.717	105.086	102.351	99.1472	95.6043	91.5923	87.0527	82.9624
26	174.5570629	-35.9873945	76.6672	93.065	100.616	101.677	99.9677	96.939	92.9344	88.1444	84.7534	82.7152

27	174.5331334	-35.98635985	76.6283	83.9402	97.0706	100.041	99.0808	96.2859	92.2684	87.2211	84.5185	82.7138
28	174.5028228	-35.9873945	76.6282	77.1563	90.4833	97.8093	97.9602	95.5503	91.5905	86.7454	84.512	82.7142
29	174.5335323	-36.01739939	76.6282	77.1497	90.1341	96.7279	96.8258	94.3451	90.2382	86.0474	84.4578	82.7137
30	174.5578605	-36.01791671	76.6282	81.1625	96.4295	99.1688	98.0914	95.2308	91.2634	86.9839	84.5842	82.7139
31	174.586177	-36.01895137	84.0561	100.709	103.37	102.727	100.33	97.1753	93.4923	89.4593	85.5532	82.7399
32	174.6140947	-35.95273369	148.172	141.444	139.762	136.843	133.695	130.576	127.506	124.468	121.449	118.433
33	174.6372265	-35.95221636	100.66	103.991	104.608	103.013	100.259	96.9455	93.2169	88.9638	85.2919	82.7465
34	174.6567689	-35.95273369	101.245	104.948	104.887	102.985	100.12	96.7957	93.1382	89.1646	85.5483	82.7762
35	174.6583641	-35.98687718	108.043	105.683	105.44	103.321	100.387	97.0794	93.5247	89.8418	86.3675	83.4076
36	174.6348335	-35.98687718	108.615	108.863	108.225	105.834	102.833	99.5993	96.2129	92.6146	88.4939	84.1176
37	174.6140947	-35.9873945	117.813	119.137	117.661	114.835	111.712	108.574	105.448	102.28	98.8851	94.7707
38	174.6136959	-36.01791671	112.181	114.472	113.323	110.632	107.547	104.387	101.194	97.9161	94.2323	89.3565
39	174.6348335	-36.01739939	106.315	108.786	108.012	105.578	102.555	99.3253	95.9729	92.5247	88.6467	84.1531
40	174.6579653	-36.01998602	135.37	129.115	127.443	124.529	121.381	118.26	115.187	112.143	109.106	106.042
41	174.63603	-36.06292404	110.025	112.524	111.452	108.76	105.654	102.472	99.2523	95.9133	91.8578	86.5639
42	174.6356312	-35.79857065	108.63	110.433	109.118	106.279	103.082	99.8753	96.6632	93.3017	89.2223	84.3747

5th Perc Ambient + WF extracting, June 2024			1/1 Octave Bands, Monthly Leq (dB re 1 µPa)									
Position Number	Position Latitude	Position Longitude	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	174.6547747	-35.85806309	122.509	117.175	115.636	112.862	109.751	106.674	103.495	100.356	97.0913	93.6263
2	174.6348335	-35.85858042	140.462	133.711	132.034	129.118	125.971	122.853	119.78	116.739	113.707	110.667
3	174.6128982	-35.85909775	113.663	114.733	113.348	110.747	107.707	104.704	101.449	98.2397	94.5096	90.3739
4	174.6547747	-35.89065461	101.275	103.438	104.2	103.35	100.625	98.0305	93.9611	90.3965	86.5647	84.4178
5	174.6356312	-35.89117194	105.506	104.348	105.085	104.226	101.541	99.0196	95.0285	91.5537	86.8738	84.5579
6	174.6148923	-35.89220659	132.624	125.885	124.235	121.361	118.228	115.131	112.034	108.991	105.913	102.903
7	174.586177	-35.89117194	107.089	107.594	108.353	107.27	104.657	102.3	98.6271	95.9575	89.1223	85.0815
8	174.5574617	-35.89220659	111.521	112.501	112.843	111.795	109.308	106.951	103.508	101.329	95.281	89.0164
9	174.5311393	-35.89272391	84.8651	97.7988	109.046	111.262	109.57	107.873	104.349	103.178	96.6324	86.2341
10	174.5040193	-35.89375856	78.2713	78.9497	102.171	108.434	108.503	107.437	104.056	102.665	95.767	86.8084
11	174.4772981	-35.89324124	103.777	114.501	114.883	113.304	110.874	108.369	105.183	102.491	98.1407	94.2242

12	174.4776969	-35.91755554	78.2803	93.0274	103.549	106.459	105.467	104.216	100.568	99.3394	91.9889	85.4392
13	174.5036205	-35.92014217	82.9773	97.6353	109.925	111.956	109.856	108.97	105.31	106.05	101.481	93.5154
14	174.531937	-35.91910752	149.717	148.318	156.518	156.918	154.318	153.618	150.118	151.918	150.118	149.617
15	174.5562652	-35.92014217	110.39	112.628	113.292	112.427	109.762	108.085	104.508	104.22	99.1263	90.671
16	174.5857782	-35.91859019	139.559	132.811	131.14	128.236	125.093	121.986	118.908	115.886	112.822	109.78
17	174.6148923	-35.91807287	138.589	139.35	137.671	134.755	131.607	128.489	125.418	122.379	119.347	116.306
18	174.63603	-35.91652089	99.4943	102.638	104.377	103.989	101.416	99.1418	95.0303	91.9349	86.7196	84.5107
19	174.6543759	-35.91652089	108.344	109.597	108.779	106.847	103.961	101.227	97.5785	94.3631	90.7388	88.0074
20	174.4780957	-35.95066438	130.58	133.261	132.477	129.79	126.705	123.61	120.532	117.487	114.359	111.075
21	174.5032216	-35.95014706	78.2725	87.9989	104.586	107.757	106.13	105.146	101.343	101.281	94.6888	85.3089
22	174.5331334	-35.95169903	143.694	142.295	150.496	150.896	148.296	147.596	144.096	145.896	144.095	143.595
23	174.5574617	-35.95118171	117.499	116.764	124.999	125.437	122.845	122.128	118.609	120.328	118.285	117.127
24	174.586177	-35.95169903	111.14	113.175	112.922	111.4	108.594	106.517	102.949	101.736	95.8281	88.1389
25	174.5865758	-35.9873945	95.9748	104.403	108.209	108.869	106.505	105.206	101.452	101.406	95.1649	85.4501
26	174.5570629	-35.9873945	85.967	100.975	112.442	114.089	111.795	111.016	107.373	108.522	104.62	97.5369
27	174.5331334	-35.98635985	78.4172	91.6797	106.831	109.648	107.738	106.905	103.149	103.717	98.2757	88.7479
28	174.5028228	-35.9873945	78.2713	78.8582	97.2921	103.292	102.707	101.815	97.8408	96.8514	88.8981	84.3671
29	174.5335323	-36.01739939	78.2713	78.7945	95.99	102.548	102.143	101.344	97.3588	96.4786	88.602	84.3629
30	174.5578605	-36.01791671	78.2713	81.3504	99.8029	104.177	103.114	102.133	98.1706	97.4005	89.3922	84.3686
31	174.586177	-36.01895137	83.4107	99.3635	103.145	104.401	102.638	101.104	97.1749	95.6869	88.1449	84.3714
32	174.6140947	-35.95273369	146.805	140.076	138.396	135.479	132.331	129.213	126.142	123.107	120.083	117.067
33	174.6372265	-35.95221636	99.3141	102.743	104.72	104.489	101.884	99.8584	95.7688	93.3485	86.8865	84.3733
34	174.6567689	-35.95273369	99.8932	103.637	104.468	103.704	100.997	98.7075	94.6566	91.78	86.7564	84.3882
35	174.6583641	-35.98687718	106.679	104.353	104.823	103.81	101.074	98.7453	94.7879	92.021	87.2304	84.7176
36	174.6348335	-35.98687718	107.25	107.522	107.437	105.99	103.198	100.852	97.1103	94.6387	88.8527	85.1153
37	174.6140947	-35.9873945	116.446	117.774	116.403	113.822	110.775	107.911	104.659	101.923	97.846	93.6664
38	174.6136959	-36.01791671	110.815	113.106	112.07	109.727	106.8	104.037	100.659	97.8286	93.3956	88.8409
39	174.6348335	-36.01739939	104.953	107.426	106.956	105.249	102.473	99.9578	96.2901	93.534	88.7598	85.1359
40	174.6579653	-36.01998602	134.003	127.748	126.079	123.173	120.028	116.916	113.837	110.797	107.754	104.695
41	174.63603	-36.06292404	108.659	111.158	110.122	107.606	104.611	101.641	98.3087	95.1265	91.2149	86.6953
42	174.6356312	-35.79857065	107.266	109.071	107.853	105.245	102.089	99.0502	95.7121	92.5855	89.0993	85.2662

250,000m^3 Extraction Volume

Frequency-dependent sound pressure levels from the AIS traffic and extraction noise (of the *William Fraser,* WF) models at each measurement position in Figure 50 above.

5th Perc Ambient + AIS Traffic, April 2024			1/1 Octave Bands, Monthly Leq (dB re 1 µPa)									
Position Number	Position Latitude	Position Longitude	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	174.6547747	-35.85806309	136.616	129.909	128.235	125.318	122.169	119.048	115.974	112.93	109.901	106.879
2	174.6348335	-35.85858042	110.498	110.818	109.805	107.036	103.82	100.552	97.1662	93.2669	87.9722	83.5455
3	174.6128982	-35.85909775	111.404	113.466	112.246	109.427	106.237	103.028	99.7523	96.0621	90.7316	83.822
4	174.6547747	-35.89065461	130.054	130.811	129.135	126.217	123.068	119.948	116.876	113.836	110.815	107.8
5	174.6356312	-35.89117194	121.077	120.342	118.733	115.835	112.681	109.546	106.447	103.36	100.291	97.227
6	174.6148923	-35.89220659	132.625	125.977	124.332	121.423	118.273	115.148	112.066	108.998	105.912	102.725
7	174.586177	-35.89117194	130.79	124.137	122.503	119.598	116.45	113.324	110.239	107.168	104.074	100.875
8	174.5574617	-35.89220659	138.567	131.942	130.279	127.369	124.224	121.104	118.033	114.989	111.952	108.91
9	174.5311393	-35.89272391	132.042	125.51	124.06	121.301	118.221	115.116	112.037	108.953	105.781	102.503
10	174.5040193	-35.89375856	76.6282	80.5424	101.934	105.369	105.265	103.133	100.162	96.6254	91.8176	85.4227
11	174.4772981	-35.89324124	76.6282	77.1337	89.6468	96.8376	96.7598	95.3926	92.6888	89.1	85.0922	82.7179
12	174.4776969	-35.91755554	76.6282	78.1829	96.1515	99.2275	98.171	95.5804	92.2366	88.5263	84.9868	82.7196
13	174.5036205	-35.92014217	85.7084	102.977	105.888	105.079	102.559	99.516	96.2417	92.6228	88.1228	83.6475
14	174.531937	-35.91910752	105.135	110.075	110.355	108.147	105.151	101.992	98.7443	95.2055	90.6479	84.9565
15	174.5562652	-35.92014217	123.495	124.583	123.015	120.13	116.986	113.859	110.77	107.679	104.483	100.986
16	174.5857782	-35.91859019	117.838	112.829	111.701	108.964	105.81	102.622	99.418	96.1137	92.5899	89.1395
17	174.6148923	-35.91807287	118.37	119.13	117.551	114.671	111.519	108.383	105.282	102.201	99.1597	96.1718
18	174.63603	-35.91652089	124.212	117.669	116.131	113.263	110.106	106.957	103.836	100.726	97.6449	94.4433
19	174.6543759	-35.91652089	103.197	104.298	104.782	102.487	99.2264	95.7394	91.9853	88.048	85.2773	82.9858
20	174.4780957	-35.95066438	76.6282	77.1528	91.8695	97.1892	96.4988	93.9205	90.3767	86.7152	84.5095	82.7138
21	174.5032216	-35.95014706	76.6282	83.1866	98.4063	99.4978	97.6974	94.6909	91.1114	87.4346	84.6427	82.714
22	174.5331334	-35.95169903	84.7145	101.943	104.96	103.753	100.942	97.6984	94.2138	90.4166	86.1011	82.823
23	174.5574617	-35.95118171	116.27	114.255	113.409	110.741	107.616	104.445	101.255	97.9181	93.9733	89.0031
24	174.586177	-35.95169903	113.075	114.342	113.259	110.523	107.376	104.198	101.007	97.6777	93.8132	89.1634

25	174.5865758	-35.9873945	114.376	114.232	113.099	110.402	107.279	104.119	100.962	97.7812	94.4524	90.9822
26	174.5570629	-35.9873945	93.2441	105.134	107.167	105.638	102.807	99.6267	96.2995	92.827	88.9366	84.3561
27	174.5331334	-35.98635985	76.6339	88.0061	99.6605	100.128	97.9599	94.783	91.2057	87.7079	84.8383	82.7188
28	174.5028228	-35.9873945	76.6282	77.2335	92.09	96.277	95.4196	92.656	88.9281	85.9051	84.4672	82.7137
29	174.5335323	-36.01739939	76.6316	78.2431	93.1802	96.7106	95.7148	92.872	89.2186	86.2787	84.5414	82.7152
30	174.5578605	-36.01791671	76.6283	87.6061	99.7022	100.438	98.4595	95.3679	91.8175	88.3366	85.1312	82.7265
31	174.586177	-36.01895137	99.1817	108.238	109.492	107.498	104.534	101.363	98.1053	94.7138	90.6912	85.3166
32	174.6140947	-35.95273369	130.283	123.597	121.957	119.054	115.904	112.779	109.699	106.644	103.598	100.558
33	174.6372265	-35.95221636	134.533	135.286	133.607	130.688	127.54	124.42	121.35	118.312	115.292	112.278
34	174.6567689	-35.95273369	120.318	121.115	119.48	116.581	113.43	110.301	107.216	104.167	101.159	98.1693
35	174.6583641	-35.98687718	101.701	104.671	104.823	102.507	99.3008	95.918	92.4145	88.8928	85.5534	82.9112
36	174.6348335	-35.98687718	108.581	110.327	109.439	106.803	103.646	100.426	97.1715	93.8223	90.0258	85.6549
37	174.6140947	-35.9873945	136.108	129.745	128.082	125.169	122.02	118.899	115.826	112.779	109.729	106.637
38	174.6136959	-36.01791671	115.701	116.781	115.35	112.54	109.399	106.253	103.134	100.012	96.794	93.5823
39	174.6348335	-36.01739939	128.019	128.805	127.138	124.224	121.075	117.954	114.881	111.835	108.788	105.71
40	174.6579653	-36.01998602	137.749	131.005	129.329	126.412	123.264	120.144	117.072	114.032	111.007	107.986
41	174.63603	-36.06292404	100.678	105.371	105.471	103.133	99.9768	96.6669	93.2846	89.876	85.9473	82.7709
42	174.6356312	-35.79857065	117.427	118.394	116.813	113.917	110.757	107.613	104.499	101.36	98.1559	95.1

5th Perc Ambient + WF extracting, April 2024

Position Number	Position Latitude	Position Longitude	1/1 Octave Bands, Monthly Leq (dB re 1 µPa) 63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	174.6547747	-35.85806309	135.248	128.542	126.871	123.959	120.811	117.694	114.617	111.574	108.546	105.528
2	174.6348335	-35.85858042	109.133	109.46	108.641	106.262	103.138	100.231	96.6192	93.0564	88.2034	84.7926
3	174.6128982	-35.85909775	110.038	112.104	111	108.427	105.299	102.332	98.9129	95.4698	90.2921	84.9462
4	174.6547747	-35.89065461	128.687	129.444	127.771	124.859	121.711	118.596	115.52	112.481	109.458	106.447
5	174.6356312	-35.89117194	119.71	118.976	117.405	114.586	111.449	108.389	105.234	102.182	99.0376	96.0107
6	174.6148923	-35.89220659	131.258	124.61	122.981	120.104	116.961	113.869	110.763	107.718	104.578	101.401
7	174.586177	-35.89117194	129.423	122.771	121.169	118.329	115.197	112.144	109.019	106.041	102.778	99.5738
8	174.5574617	-35.89220659	137.2	130.575	128.924	126.04	122.903	119.817	116.731	113.752	110.628	107.554
9	174.5311393	-35.89272391	130.674	124.144	122.774	120.21	117.196	114.326	111.16	108.62	104.898	101.202

10	174.5040193	-35.89375856	78.2713	80.8156	102.613	107.777	107.534	106.525	103.022	102.122	95.1151	86.0787
11	174.4772981	-35.89324124	78.2713	78.7729	92.7712	102.255	102.188	101.783	98.0822	96.9974	88.736	84.3629
12	174.4776969	-35.91755554	78.2713	79.4607	99.9743	104.789	103.856	103.03	99.2081	98.7023	90.928	84.4253
13	174.5036205	-35.92014217	86.9696	103.034	110.935	112.377	110.081	109.146	105.505	106.324	101.956	94.5781
14	174.531937	-35.91910752	151.226	149.828	158.028	158.428	155.828	155.128	151.628	153.428	151.627	151.126
15	174.5562652	-35.92014217	122.135	123.232	121.879	119.304	116.238	113.507	110.29	108.255	104.458	99.9629
16	174.5857782	-35.91859019	116.472	111.503	111.01	109.18	106.239	103.965	100.395	98.5638	92.8162	88.6684
17	174.6148923	-35.91807287	117.003	117.768	116.289	113.595	110.486	107.546	104.323	101.425	97.9721	94.9962
18	174.63603	-35.91652089	122.845	116.307	114.862	112.173	109.055	106.083	102.836	99.8292	96.4912	93.3583
19	174.6543759	-35.91652089	101.841	103.01	104.418	103.359	100.387	98.0556	93.8415	90.7833	86.5555	84.495
20	174.4780957	-35.95066438	78.2713	78.8086	97.0787	103.189	102.574	101.802	97.8572	96.9642	88.8103	84.3653
21	174.5032216	-35.95014706	78.273	87.2888	104.675	107.55	105.717	104.846	101.052	101.286	94.885	85.5367
22	174.5331334	-35.95169903	147.236	145.837	154.037	154.437	151.837	151.137	147.637	149.437	147.637	147.136
23	174.5574617	-35.95118171	120.902	119.713	127.174	127.541	124.938	124.208	120.695	122.414	120.411	119.329
24	174.586177	-35.95169903	111.726	113.043	112.882	111.309	108.433	106.419	102.861	101.831	96.0148	88.9082
25	174.5865758	-35.9873945	113.01	112.905	112.625	111.32	108.584	106.704	103.174	102.453	97.0792	90.5387
26	174.5570629	-35.9873945	92.6691	105.293	112.844	114.077	111.712	110.839	107.219	108.262	104.291	97.077
27	174.5331334	-35.98635985	78.4815	92.9587	107.318	109.806	107.77	106.958	103.235	103.912	98.6673	89.5563
28	174.5028228	-35.9873945	78.2713	78.9041	97.5767	102.979	102.166	101.387	97.4375	96.7636	88.9328	84.3694
29	174.5335323	-36.01739939	78.273	79.3756	96.7317	102.505	101.883	101.109	97.1804	96.4463	88.6223	84.3644
30	174.5578605	-36.01791671	78.2714	86.6429	101.155	104.45	103.144	102.089	98.193	97.4276	89.4748	84.3747
31	174.586177	-36.01895137	97.8385	106.875	108.428	107.378	104.923	102.774	99.1665	97.1404	90.9434	85.8515
32	174.6140947	-35.95273369	128.915	122.232	120.64	117.828	114.704	111.685	108.548	105.644	102.332	99.2618
33	174.6372265	-35.95221636	133.165	133.919	132.242	129.328	126.181	123.066	119.993	116.959	113.929	110.916
34	174.6567689	-35.95273369	118.951	119.749	118.15	115.331	112.2	109.149	106.008	103.005	99.8878	96.924
35	174.6583641	-35.98687718	100.348	103.353	104.326	103.317	100.45	98.2304	94.2395	91.6629	86.7665	84.4567
36	174.6348335	-35.98687718	107.217	108.98	108.532	106.717	103.781	101.352	97.7307	95.2788	89.9523	86.0718
37	174.6140947	-35.9873945	134.741	128.378	126.725	123.836	120.696	117.604	114.516	111.515	108.391	105.288
38	174.6136959	-36.01791671	114.335	115.414	114.058	111.482	108.451	105.581	102.322	99.4852	95.73	92.5569
39	174.6348335	-36.01739939	126.652	127.438	125.775	122.873	119.729	116.622	113.54	110.505	107.438	104.364
40	174.6579653	-36.01998602	136.382	129.638	127.964	125.053	121.906	118.791	115.716	112.68	109.65	106.631

41	174.63603	-36.06292404	99.3274	104.01	104.256	102.508	99.7053	97.0617	93.3926	90.479	86.9045	84.3855
42	174.6356312	-35.79857065	116.06	117.028	115.464	112.609	109.455	106.341	103.203	100.101	96.9691	93.9765

5th Perc Ambient + AIS Traffic, May 2024

Position Number	Position Latitude	Position Longitude	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
			1/1 Octave Bands, Monthly Leq (dB re 1 µPa)									
1	174.6547747	-35.85806309	145.024	138.263	136.584	133.667	130.518	127.398	124.327	121.287	118.264	115.243
2	174.6348335	-35.85858042	108.595	110.554	110.501	108.281	105.145	101.774	98.1228	93.6867	89.1517	85.4557
3	174.6128982	-35.85909775	129.789	130.561	128.904	125.998	122.851	119.728	116.649	113.59	110.545	107.5
4	174.6547747	-35.89065461	104.461	108.403	109.079	107.025	103.848	100.348	96.4078	91.2965	86.5335	83.1512
5	174.6356312	-35.89117194	132.845	126.155	124.539	121.654	118.506	115.373	112.275	109.181	106.123	103.104
6	174.6148923	-35.89220659	106.167	110.207	111.292	109.305	106.195	102.791	98.9992	93.6995	86.4942	83.1148
7	174.586177	-35.89117194	136.805	130.56	128.931	126.038	122.893	119.768	116.684	113.607	110.528	107.484
8	174.5574617	-35.89220659	143.668	137.018	135.37	132.468	129.324	126.204	123.129	120.075	117.018	113.972
9	174.5311393	-35.89272391	120.951	123.125	122.801	120.53	117.58	114.49	111.332	107.945	103.913	99.5373
10	174.5040193	-35.89375856	78.7177	113.316	119.255	119.067	116.809	114.071	111.045	107.752	103.975	99.6076
11	174.4772981	-35.89324124	81.9799	108.819	112.567	112.28	110.184	107.447	104.336	100.784	96.5755	91.8487
12	174.4776969	-35.91755554	76.6287	94.4538	107.146	108.602	107.097	104.252	100.806	96.3159	90.206	84.1597
13	174.5036205	-35.92014217	78.97	105.217	111.815	111.521	109.093	105.999	102.545	98.0935	90.9802	83.7913
14	174.531937	-35.91910752	108.963	117.843	118.804	116.649	113.666	110.504	107.217	103.389	97.5522	87.0271
15	174.5562652	-35.92014217	109.467	116.51	117.333	115.083	112.05	108.849	105.505	101.5	95.1396	85.1469
16	174.5857782	-35.91859019	127.386	121.935	120.606	117.85	114.72	111.562	108.393	105.088	101.664	98.4113
17	174.6148923	-35.91807287	137.029	130.296	128.648	125.747	122.6	119.475	116.392	113.326	110.284	107.268
18	174.63603	-35.91652089	126.341	119.798	118.383	115.608	112.461	109.288	106.105	102.85	99.7174	96.7321
19	174.6543759	-35.91652089	99.8988	106.225	108.489	106.917	103.71	99.9941	95.5436	89.4115	84.8208	82.7935
20	174.4780957	-35.95066438	76.6283	79.6322	100.713	105.296	104.477	101.661	97.8592	92.2224	85.4821	82.7341
21	174.5032216	-35.95014706	88.4026	92.8232	106.539	107.519	105.621	102.533	98.7952	93.4476	86.0449	82.8404
22	174.5331334	-35.95169903	94.8247	102.829	109.561	109.305	106.801	103.57	99.846	94.5873	86.4887	82.827
23	174.5574617	-35.95118171	101.168	109.426	111.343	109.815	106.902	103.59	99.9125	94.9609	88.0633	83.5828
24	174.586177	-35.95169903	152.991	153.741	152.059	149.14	145.991	142.872	139.803	136.765	133.746	130.731
25	174.5865758	-35.9873945	138.553	139.862	138.322	135.438	132.295	129.173	126.091	123.012	119.835	116.307

26	174.5570629	-35.9873945	78.3606	104.148	110.718	110.418	107.918	104.785	101.322	96.978	90.0295	82.9495
27	174.5331334	-35.98635985	76.6949	87.138	104.278	105.78	104.264	101.239	97.3174	92.2206	85.5609	82.7192
28	174.5028228	-35.9873945	76.6282	77.1897	96.6693	102.638	102.175	99.4578	95.2664	88.9818	84.5719	82.7138
29	174.5335323	-36.01739939	89.9999	91.8851	101.961	106.113	105.216	102.297	98.39	92.4241	85.2168	82.8981
30	174.5578605	-36.01791671	76.6308	94.4171	109.855	110.486	108.443	105.325	101.622	96.3113	87.1061	82.7242
31	174.586177	-36.01895137	99.8702	116.528	118.299	116.57	113.634	110.431	107.025	102.777	95.3972	83.7912
32	174.6140947	-35.95273369	142.338	135.582	133.909	130.995	127.847	124.726	121.653	118.609	115.582	112.566
33	174.6372265	-35.95221636	96.0601	108.268	110.316	108.627	105.479	101.894	97.6793	91.2814	85.0515	82.7177
34	174.6567689	-35.95273369	116.787	117.947	116.76	114.085	110.925	107.692	104.39	100.923	97.7364	94.7804
35	174.6583641	-35.98687718	107.866	112.869	113.331	111.072	107.893	104.469	100.682	95.541	89.3714	86.2808
36	174.6348335	-35.98687718	103.696	112.529	113.544	111.394	108.249	104.845	101.069	95.7283	86.8954	82.8666
37	174.6140947	-35.9873945	123.904	124.867	123.414	120.614	117.476	114.324	111.191	108.037	104.78	101.632
38	174.6136959	-36.01791671	120.345	124.344	123.816	121.17	118.046	114.866	111.629	107.993	102.746	92.7759
39	174.6348335	-36.01739939	117.412	120.622	120.078	117.436	114.288	111.065	107.736	103.831	98.2524	92.7127
40	174.6579653	-36.01998602	110.838	115.053	115.417	112.965	109.785	106.436	102.81	97.9112	89.5711	83.8648
41	174.63603	-36.06292404	131.366	132.859	131.366	128.489	125.338	122.199	119.08	115.868	112.193	107.052
42	174.6356312	-35.79857065	113.995	114.883	113.414	110.624	107.45	104.248	101.073	98.0018	94.9453	91.6789

5th Perc Ambient + WF extracting, May 2024

			1/1 Octave Bands, Monthly Leq (dB re 1 μPa)									
Position Number	Position Latitude	Position Longitude	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	174.6547747	-35.85806309	143.657	136.896	135.218	132.301	129.152	126.033	122.961	119.921	116.899	113.878
2	174.6348335	-35.85858042	107.231	109.196	109.3	107.361	104.286	101.204	97.4107	93.351	89.0515	85.9407
3	174.6128982	-35.85909775	128.422	129.194	127.539	124.639	121.493	118.376	115.293	112.238	109.188	106.147
4	174.6547747	-35.89065461	103.102	107.053	107.977	106.328	103.246	100.195	96.096	91.7111	87.2603	84.5811
5	174.6356312	-35.89117194	131.478	124.788	123.182	120.318	117.174	114.062	110.948	107.862	104.785	101.777
6	174.6148923	-35.89220659	104.806	108.863	110.22	108.638	105.624	102.701	98.7533	94.4866	87.3502	84.562
7	174.586177	-35.89117194	135.438	129.193	127.571	124.692	121.55	118.442	115.349	112.291	109.176	106.131
8	174.5574617	-35.89220659	142.301	135.651	134.006	131.112	127.97	124.859	121.78	118.744	115.661	112.608
9	174.5311393	-35.89272391	119.584	121.761	121.533	119.474	116.592	113.757	110.513	107.782	103.201	98.2891
10	174.5040193	-35.89375856	79.4405	111.95	117.939	117.96	115.839	113.376	110.248	107.564	103.118	98.3388

11	174.4772981	-35.89324124	81.7241	107.455	111.245	111.387	109.548	107.316	104.016	101.3	95.8738	90.9826
12	174.4776969	-35.91755554	78.2716	93.1724	106.58	108.977	107.672	105.832	102.175	100.297	92.7655	85.1984
13	174.5036205	-35.92014217	83.6579	104.84	113.372	114.301	111.973	110.524	106.912	107.078	102.515	94.4859
14	174.531937	-35.91910752	145.996	144.604	152.799	153.198	150.598	149.898	146.398	148.198	146.397	145.896
15	174.5562652	-35.92014217	108.203	115.215	116.605	114.997	112.107	109.726	106.214	104.641	98.7857	88.441
16	174.5857782	-35.91859019	126.018	120.572	119.324	116.708	113.614	110.624	107.378	104.371	100.498	97.1599
17	174.6148923	-35.91807287	135.662	128.929	127.289	124.403	121.259	118.15	115.056	112.004	108.93	105.916
18	174.63603	-35.91652089	124.973	118.434	117.072	114.4	111.276	108.209	104.953	101.764	98.4828	95.5338
19	174.6543759	-35.91652089	98.554	104.904	107.56	106.478	103.404	100.365	95.8591	91.2722	86.3067	84.3969
20	174.4780957	-35.95066438	78.2714	80.221	101.131	106.361	105.633	104.017	100.109	98.0183	89.3623	84.3755
21	174.5032216	-35.95014706	87.315	92.5759	107.792	109.887	108.019	106.503	102.721	102.127	95.4878	85.551
22	174.5331334	-35.95169903	144.237	142.842	151.043	151.444	148.844	148.144	144.644	146.443	144.642	144.14
23	174.5574617	-35.95118171	115.289	115.269	123.003	123.387	120.787	120.021	116.495	118.151	116.047	114.817
24	174.586177	-35.95169903	151.624	152.374	150.692	147.773	144.625	141.506	138.436	135.399	132.379	129.364
25	174.5865758	-35.9873945	137.186	138.495	136.958	134.079	130.938	127.823	124.739	121.679	118.483	114.942
26	174.5570629	-35.9873945	87.1238	105.009	114.375	115.482	113.113	111.99	108.387	109.178	105.285	98.4278
27	174.5331334	-35.98635985	78.427	92.9041	108.506	110.967	109.056	107.928	104.175	104.487	99.1104	89.2995
28	174.5028228	-35.9873945	78.2713	78.8903	99.2784	105.037	104.363	103.023	98.9893	97.4454	89.2774	84.3696
29	174.5335323	-36.01739939	88.8281	90.6617	101.739	106.56	105.787	103.935	100.005	97.6002	89.0836	84.4576
30	174.5578605	-36.01791671	78.2726	93.1374	108.873	110.108	108.286	105.948	102.155	99.2989	90.3093	84.3759
31	174.586177	-36.01895137	98.5235	115.162	116.974	115.382	112.532	109.532	106.066	102.285	94.6551	84.9302
32	174.6140947	-35.95273369	140.971	134.214	132.545	129.637	126.49	123.375	120.299	117.263	114.221	111.204
33	174.6372265	-35.95221636	94.7503	106.94	109.368	108.198	105.199	102.323	98.068	93.919	86.714	84.3588
34	174.6567689	-35.95273369	115.42	116.582	115.456	112.912	109.787	106.693	103.308	99.9505	96.5753	93.675
35	174.6583641	-35.98687718	106.502	111.508	112.087	110.062	106.953	103.809	99.934	95.3885	89.256	86.4968
36	174.6348335	-35.98687718	102.337	111.172	112.34	110.481	107.427	104.394	100.537	96.2407	87.7991	84.434
37	174.6140947	-35.9873945	122.537	123.501	122.073	119.337	116.22	113.144	109.975	106.941	103.493	100.32
38	174.6136959	-36.01791671	118.978	122.977	122.458	119.844	116.736	113.598	110.342	106.765	101.457	91.817
39	174.6348335	-36.01739939	116.045	119.255	118.73	116.141	113.017	109.859	106.499	102.684	97.0731	91.7596
40	174.6579653	-36.01998602	109.473	113.688	114.092	111.748	108.613	105.396	101.72	97.0725	89.3791	84.9704
41	174.63603	-36.06292404	129.999	131.491	129.999	127.124	123.974	120.838	117.718	114.507	110.833	105.701

42	174.6356312	-35.79857065	112.628	113.517	112.084	109.38	106.223	103.086	99.8603	96.865	93.9477	90.8306

5th Perc Ambient + AIS Traffic, June 2024

			1/1 Octave Bands, Monthly Leq (dB re 1 µPa)									
Position Number	Position Latitude	Position Longitude	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	174.6547747	-35.85806309	123.877	118.541	116.969	114.122	110.998	107.86	104.735	101.568	98.2829	94.7286
2	174.6348335	-35.85858042	141.829	135.078	133.4	130.483	127.335	124.215	121.144	118.102	115.07	112.029
3	174.6128982	-35.85909775	115.029	116.097	114.645	111.902	108.833	105.697	102.532	99.2194	95.5487	91.1607
4	174.6547747	-35.89065461	102.631	104.761	104.875	103.243	100.455	97.14	93.4084	89.0383	85.3408	82.8349
5	174.6356312	-35.89117194	106.868	105.668	105.731	104.087	101.344	98.0792	94.4211	89.9933	85.8414	83.1069
6	174.6148923	-35.89220659	133.991	127.252	125.59	122.693	119.553	116.433	113.353	110.294	107.256	104.24
7	174.586177	-35.89117194	108.452	108.914	109.055	107.216	104.532	101.437	98.0627	94.0084	88.503	84.0585
8	174.5574617	-35.89220659	112.887	113.84	113.696	112.019	109.471	106.483	103.285	99.6742	95.0042	89.5369
9	174.5311393	-35.89272391	85.712	98.2456	107.97	109.778	108.429	105.779	102.601	98.7214	92.8397	84.9173
10	174.5040193	-35.89375856	76.6282	77.4462	101.126	106.722	107.194	105.364	102.436	98.626	93.3705	86.5235
11	174.4772981	-35.89324124	105.138	115.868	116.233	114.39	111.745	108.851	105.818	102.602	99.1504	95.3611
12	174.4776969	-35.91755554	76.6462	94.307	103.335	104.426	103.32	100.873	97.6808	93.6739	89.085	84.5909
13	174.5036205	-35.92014217	76.6299	90.5098	100.87	103.107	102.204	99.6677	96.2363	91.6141	85.9832	82.782
14	174.531937	-35.91910752	90.7849	101.152	104.403	104.895	103.19	100.35	96.8702	92.2477	85.996	82.7354
15	174.5562652	-35.92014217	111.668	113.835	112.832	110.523	107.684	104.599	101.358	97.7812	93.6703	88.8758
16	174.5857782	-35.91859019	140.926	134.178	132.501	129.587	126.441	123.322	120.25	117.207	114.176	111.141
17	174.6148923	-35.91807287	139.956	140.717	139.038	136.12	132.972	129.852	126.782	123.741	120.713	117.671
18	174.63603	-35.91652089	100.84	103.897	104.499	103.1	100.516	97.2428	93.5038	89.0314	85.458	83.0163
19	174.6543759	-35.91652089	109.709	110.947	109.806	107.352	104.392	101.195	97.8611	94.3921	91.2762	88.3193
20	174.4780957	-35.95066438	131.948	134.628	133.843	131.149	128.058	124.952	121.879	118.818	115.717	112.438
21	174.5032216	-35.95014706	76.6283	85.9639	98.2643	101.329	100.561	97.9613	94.2455	89.2217	85.0417	82.7405
22	174.5331334	-35.95169903	77.5407	96.0207	101.365	102.826	101.274	98.3764	94.5806	89.3856	84.773	82.7147
23	174.5574617	-35.95118171	98.0956	104.085	105.241	104.207	101.841	98.7406	95.105	90.5701	85.8711	82.8046
24	174.586177	-35.95169903	112.49	114.48	113.362	110.771	107.762	104.609	101.364	97.8883	93.8727	88.2202
25	174.5865758	-35.9873945	97.2841	105.519	106.717	105.086	102.351	99.1472	95.6043	91.5923	87.0527	82.9624
26	174.5570629	-35.9873945	76.6672	93.065	100.616	101.677	99.9677	96.939	92.9344	88.1444	84.7534	82.7152

27	174.5331334	-35.98635985	76.6283	83.9402	97.0706	100.041	99.0808	96.2859	92.2684	87.2211	84.5185	82.7138
28	174.5028228	-35.9873945	76.6282	77.1563	90.4833	97.8093	97.9602	95.5503	91.5905	86.7454	84.512	82.7142
29	174.5335323	-36.01739939	76.6282	77.1497	90.1341	96.7279	96.8258	94.3451	90.2382	86.0474	84.4578	82.7137
30	174.5578605	-36.01791671	76.6282	81.1625	96.4295	99.1688	98.0914	95.2308	91.2634	86.9839	84.5842	82.7139
31	174.586177	-36.01895137	84.0561	100.709	103.37	102.727	100.33	97.1753	93.4923	89.4593	85.5532	82.7399
32	174.6140947	-35.95273369	148.172	141.444	139.762	136.843	133.695	130.576	127.506	124.468	121.449	118.433
33	174.6372265	-35.95221636	100.66	103.991	104.608	103.013	100.259	96.9455	93.2169	88.9638	85.2919	82.7465
34	174.6567689	-35.95273369	101.245	104.948	104.887	102.985	100.12	96.7957	93.1382	89.1646	85.5483	82.7762
35	174.6583641	-35.98687718	108.043	105.683	105.44	103.321	100.387	97.0794	93.5247	89.8418	86.3675	83.4076
36	174.6348335	-35.98687718	108.615	108.863	108.225	105.834	102.833	99.5993	96.2129	92.6146	88.4939	84.1176
37	174.6140947	-35.9873945	117.813	119.137	117.661	114.835	111.712	108.574	105.448	102.28	98.8851	94.7707
38	174.6136959	-36.01791671	112.181	114.472	113.323	110.632	107.547	104.387	101.194	97.9161	94.2323	89.3565
39	174.6348335	-36.01739939	106.315	108.786	108.012	105.578	102.555	99.3253	95.9729	92.5247	88.6467	84.1531
40	174.6579653	-36.01998602	135.37	129.115	127.443	124.529	121.381	118.26	115.187	112.143	109.106	106.042
41	174.63603	-36.06292404	110.025	112.524	111.452	108.76	105.654	102.472	99.2523	95.9133	91.8578	86.5639
42	174.6356312	-35.79857065	108.63	110.433	109.118	106.279	103.082	99.8753	96.6632	93.3017	89.2223	84.3747

5th Perc Ambient + WF extracting, June 2024			1/1 Octave Bands, Monthly Leq (dB re 1 µPa)									
Position Number	Position Latitude	Position Longitude	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	174.6547747	-35.85806309	122.509	117.175	115.635	112.861	109.75	106.672	103.495	100.355	97.0913	93.6263
2	174.6348335	-35.85858042	140.462	133.711	132.034	129.118	125.971	122.853	119.78	116.739	113.707	110.667
3	174.6128982	-35.85909775	113.663	114.733	113.347	110.744	107.705	104.701	101.446	98.2362	94.5094	90.3739
4	174.6547747	-35.89065461	101.275	103.437	104.188	103.332	100.608	98.0084	93.9423	90.3752	86.5643	84.4178
5	174.6356312	-35.89117194	105.506	104.347	105.074	104.212	101.528	99.0015	95.0121	91.53	86.8727	84.5579
6	174.6148923	-35.89220659	132.624	125.885	124.235	121.361	118.227	115.13	112.034	108.99	105.913	102.903
7	174.586177	-35.89117194	107.089	107.593	108.343	107.256	104.643	102.28	98.6075	95.9192	89.1053	85.0814
8	174.5574617	-35.89220659	111.521	112.5	112.832	111.775	109.289	106.925	103.483	101.28	95.243	89.0153
9	174.5311393	-35.89272391	84.8645	97.7659	109.011	111.226	109.542	107.838	104.315	103.12	96.5532	86.2089
10	174.5040193	-35.89375856	78.2713	78.9498	102.179	108.445	108.514	107.45	104.067	102.683	95.7815	86.8096
11	174.4772981	-35.89324124	103.777	114.501	114.884	113.309	110.882	108.382	105.195	102.513	98.1484	94.2243

12	174.4776969	-35.91755554	78.2803	93.028	103.605	106.534	105.537	104.299	100.651	99.4714	92.148	85.4478
13	174.5036205	-35.92014217	83.7001	98.1672	110.319	112.283	110.159	109.287	105.634	106.435	102.016	94.3566
14	174.531937	-35.91910752	150.248	148.849	157.049	157.449	154.849	154.149	150.649	152.449	150.648	150.148
15	174.5562652	-35.92014217	110.387	112.623	113.25	112.371	109.706	108.015	104.439	104.119	99.0038	90.6008
16	174.5857782	-35.91859019	139.559	132.811	131.14	128.236	125.093	121.986	118.908	115.885	112.821	109.78
17	174.6148923	-35.91807287	138.589	139.35	137.671	134.755	131.607	128.489	125.418	122.379	119.347	116.306
18	174.63603	-35.91652089	99.4941	102.635	104.359	103.972	101.399	99.1203	95.0112	91.9038	86.7165	84.5107
19	174.6543759	-35.91652089	108.344	109.596	108.774	106.84	103.952	101.215	97.5687	94.3515	90.7384	88.0074
20	174.4780957	-35.95066438	130.58	133.261	132.477	129.79	126.705	123.611	120.533	117.488	114.359	111.075
21	174.5032216	-35.95014706	78.2728	88.2978	104.801	107.95	106.302	105.331	101.535	101.535	95.0723	85.5023
22	174.5331334	-35.95169903	145.989	144.591	152.791	153.191	150.591	149.891	146.391	148.191	146.391	145.89
23	174.5574617	-35.95118171	117.899	117.129	125.366	125.802	123.21	122.494	118.976	120.699	118.668	117.539
24	174.586177	-35.95169903	111.139	113.172	112.896	111.356	108.549	106.457	102.891	101.645	95.7463	88.1301
25	174.5865758	-35.9873945	95.9739	104.393	108.156	108.805	106.447	105.14	101.384	101.317	95.051	85.4123
26	174.5570629	-35.9873945	86.0879	101.03	112.492	114.134	111.839	111.062	107.419	108.574	104.689	97.6628
27	174.5331334	-35.98635985	78.4482	92.2661	107.164	109.93	107.995	107.172	103.427	104.051	98.7655	89.368
28	174.5028228	-35.9873945	78.2713	78.8676	97.4482	103.393	102.79	101.905	97.9371	96.9933	89.0581	84.3693
29	174.5335323	-36.01739939	78.2713	78.7953	96.0759	102.614	102.201	101.408	97.4283	96.5768	88.7026	84.3638
30	174.5578605	-36.01791671	78.2713	81.3502	99.8146	104.196	103.135	102.158	98.198	97.44	89.4394	84.3693
31	174.586177	-36.01895137	83.4107	99.3634	103.138	104.394	102.634	101.099	97.1703	95.6795	88.1391	84.3714
32	174.6140947	-35.95273369	146.805	140.076	138.396	135.479	132.331	129.213	126.142	123.107	120.083	117.067
33	174.6372265	-35.95221636	99.3139	102.74	104.698	104.467	101.865	99.8331	95.742	93.3035	86.876	84.3733
34	174.6567689	-35.95273369	99.8932	103.636	104.456	103.687	100.981	98.6857	94.6348	91.7464	86.7537	84.3882
35	174.6583641	-35.98687718	106.679	104.352	104.808	103.789	101.055	98.7177	94.7627	91.9869	87.2279	84.7176
36	174.6348335	-35.98687718	107.25	107.521	107.425	105.971	103.179	100.826	97.086	94.6007	88.8443	85.1153
37	174.6140947	-35.9873945	116.446	117.774	116.401	113.816	110.769	107.902	104.651	101.907	97.8408	93.6664
38	174.6136959	-36.01791671	110.815	113.106	112.068	109.722	106.795	104.031	100.653	97.8186	93.3938	88.8409
39	174.6348335	-36.01739939	104.953	107.426	106.95	105.238	102.464	99.9467	96.2804	93.519	88.758	85.1359
40	174.6579653	-36.01998602	134.003	127.748	126.079	123.173	120.028	116.916	113.836	110.797	107.754	104.695
41	174.63603	-36.06292404	108.659	111.158	110.122	107.604	104.61	101.64	98.3075	95.1253	91.2149	86.6953
42	174.6356312	-35.79857065	107.266	109.07	107.851	105.241	102.085	99.0464	95.7095	92.584	89.0993	85.2662

Appendix I Sound source characterisation for the TSHD William Fraser

Underwater noise measurements of the *William Fraser* were undertaken on the 28th November 2019, during fine weather conditions (variable 10 knot breeze, sea state zero and no swell). A measurement array was deployed that consisted of six SoundTrap 202STD recorders (Ocean Instruments Ltd, Auckland, New Zealand). The hydrophones were calibrated using the same method described in Section 2.1.1 *Study Sites and Recorders* and operated continuously.

The array was deployed the morning of the 28th of November, and each hydrophone was bottom-mounted along the 30m (the inner hydrophones, ST 1, 2, 3, and 4) and 35m (ST 5, and 6) contours. The hydrophones were set at 3 m above the seafloor, with a subsurface float (2 L volume) set a further 2 m above the hydrophone. This was done to ensure the subsurface float was far enough away so to not contaminate the measurements. The differing depths between the inner and outer hydrophones are not expected to cause any differences in the noise levels recorded in this case. The rationale for the outer hydrophones was to simultaneously record the noise emissions of the *William Fraser* at two distances that were in-line of each other to further investigate the empirical frequency dependent propagation loss. The inner hydrophones (ST 1,2,3,4) were placed between 200 and 300m apart, while the outer ones were placed 400m away to the east from ST 2 and 3 (the middle of the inner 'line') (Figure 51). This shape of the array effectively allowed for four replicates as the TSHD passed the array (whilst actively extracting, i.e. draghead down with pump and generator operating), for multiple bearings. The vessel operated as normal, with no issues reported. Once it passed, the vessel continued north for approximately 1.4 km after passing the last hydrophone of the array (ST1), before turning around and passing the array again, southbound. The TSHD followed the 30m contour, as per the offshore consent owned by Kaipara Ltd but operated by MBL.

The vessel was tracked using a Garmin Map62 GPS unit, logging the vessels' position in relation to the array every few seconds (with an error of 3m). The same GPS unit was used to mark the GPS positions of each of the hydrophones, and those were used to calculate the horizontal distances between the vessel and hydrophones for every 10 seconds (since the *SPL* data was averaged over a 10 second period).

During the measurements, the research vessel left the area but remained 10 km away. The times when other vessels were visible anywhere were recorded and checked against the hydrophone data to ensure no contamination. In addition, bespoke vessel detectors were used to ensure no vessel noise was confounding the results. If there was any contamination (i.e. another vessel was detectable on the hydrophone (using both power spectra and detection of modulation of noise methods), those data were excluded from the analysis (Figure 52).

Figure 51: Google Earth image showing the GPS track of the TSHD *William Fraser* in relation to the measurement (hydrophone) array (ST1 through 6) on 28 November 2019 in fine weather conditions.

Data analysis

Time-series of the recorded power spectral densities (*PSD*s) were calculated and plotted to examine the quality of the data from all six hydrophones. The received third octave band levels (*TOL*s) were also calculated and plotted, providing the frequency-dependent sound pressure levels that were used to represent the critical bandwidths of cetaceans in the effects modelling.

The *PSD*s and *TOL*s were calculated using a 1-sec Hamming window and 50% overlap with 10-sec averaging. The broadband (10Hz – 48 kHz) *SPL*s, as 1-sec and 10-sec averages, were calculated for each horizontal distance between the TSHD *William Fraser*'s GPS position and the respective hydrophone position. This analysis was performed using the Haversine formula, after the source and receivers latitude and longitude coordinates' were time-synced.

It is important to note that the Haversine formula assumes the earth to be a perfect sphere, however the distances between the *William Fraser* and all hydrophones were inside 3.1km, the margin of error from assuming a perfect sphere is trivial. For each distance, the 10 second *SPL*s (both broadband *SPL*s and *TOL*s) were plotted (and can be viewed as an animation through time), showing the fine-scale variations in the received sound pressures over distance as the TSHD passed the array.

For the purposes of the underwater noise modelling, the received sound pressures measured at the *William Fraser*'s closest point of approach (CPA) to each hydrophone (Figure 52) while actively extracting were back-calculated to a reference distance of 1 metre. This was done using the published sound propagation formulas by Pine et al. (2014)[26] but modifying the spreading coefficient based on the empirical data collected in this study (Figure 40 in Appendix H). The overall source spectra used in the effects modelling was the averaged spectra over the 4 closest hydrophones (thus 8 replicates – 4 hydrophones, two passes of the TSHD each).

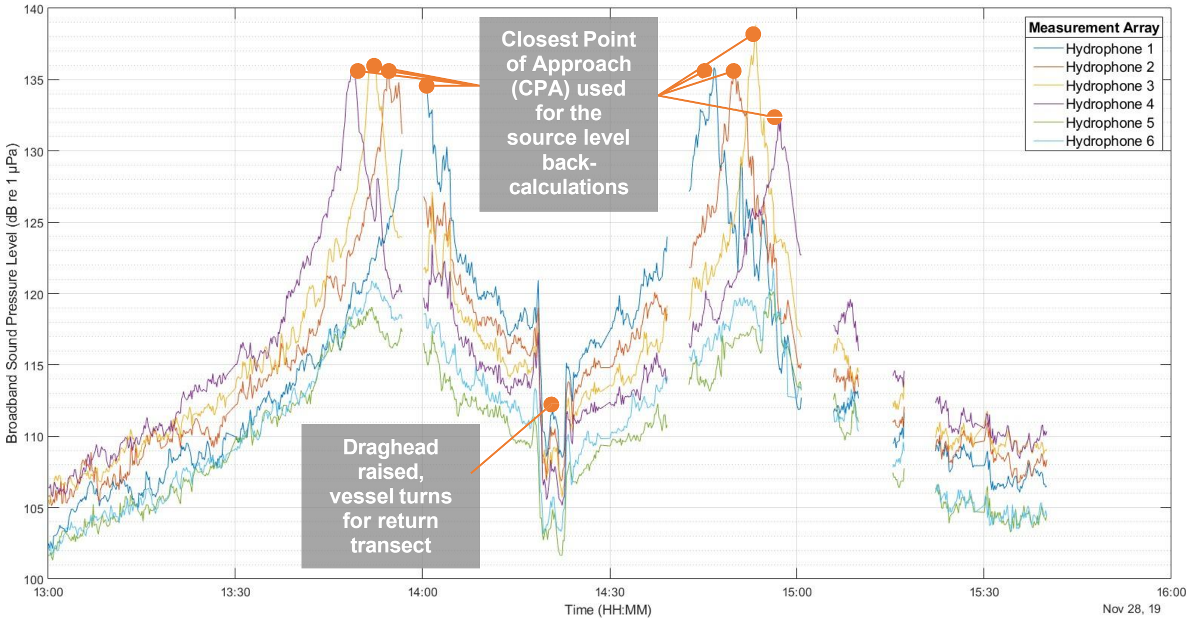

Figure 52: Measured *SPL*s from the inner hydrophones (ST 1, 2, 3, 4) as the *William Fraser* moves through the northern consent area, actively extracting, passing the measurement array.

Data containing contaminating vessel noise (extraneous) were removed from the analysis

[26]Pine, M.K., Jeffs, A.G., Radford, C.A. 2014. The cumulative effect on sound levels from multiple underwater anthropogenic sound sources in shallow coastal waters. *Journal of Applied Ecology* 51: 23-30.