

StylesGroup
Underwater Acoustics

ASSESSMENT OF UNDERWATER NOISE EFFECTS

DREDGING RECONSENTING PROJECT TAURANGA HARBOUR

PREPARED FOR

Ports of Tauranga Ltd

DATE

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Assessment prepared by Styles Group for Ports of Tauranga Ltd.

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I confirm that I have read and understood the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note 2023, and I agree to comply with it. I acknowledge that, as an expert, I have an overriding duty to assist the decision maker impartially on matters within my area of expertise. In preparing this report, I have exercised my independent professional judgement, and the opinions I express are my own. I understand that my duty as an expert is not to advocate for the interests of the applicant or any other party.

I confirm that the matters addressed in this report are within my area of expertise, except where I expressly state that I am relying on information or opinions provided by another person. I have not omitted to consider any material facts known to me that might alter or detract from the opinions expressed in this report.

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Acronym List

AIS:	Automatic Identification System
CPA:	Closest Point of Approach
EF:	Energy-Flux
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
PoTL:	Ports of Tauranga 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

Executive Summary

Ports of Tauranga Ltd (**PoTL**) has engaged Styles Group Underwater Acoustics to provide an underwater noise assessment to inform their reconsenting project (the **Project**). The Project relates to the renewal of resource consents that will enable PoTL to carry out maintenance dredging and capital dredging to deepen the wharf sitting basins, the approach to Berth 1 and a small area in the Passing Lane to smooth the corner in the Entrance Channel. This report has been prepared to inform the marine ecology-related assessments that accompany the resource consent application to renew those relevant consents.

Noise criteria

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 on marine mammals. 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. This guidance has been extensively used around New Zealand and the world for underwater noise assessments. In the absence of specific guidance on underwater noise effects criteria in New Zealand, the adoption of overseas standards and peer-reviewed research is common and considered appropriate in the Tauranga and Bay of Plenty area.

Policy NS 2 of the Bay of Plenty Regional Coastal Environment Plan (**RCEP**) aims to protect the natural character of Tauranga Harbour outside the Port Zone, and therefore to avoid substantial changes to the existing soundscape in those areas. Cumulative noise modelling (unweighted and auditory weighted for various marine mammals) of the existing anthrophonic environment (i.e., vessel noise) between 2022 and 2023 was undertaken to determine the changes to the soundscape arising from the proposal (**Soundscape Changes**). Those models were used to investigate changes to harbour's anthrophony during the 2023 maintenance dredging campaign using the 75m-long TSHD *Albatros*.

Noise effects on marine mammals

The modelling showed no risk for auditory injury onset or temporary threshold shift beyond 1m from TSHD *Albatros* actively dredging in marine mammal species that may frequent the dredge area.

Low severity behavioural changes in marine mammals occurring outside the harbour entrance may occur during the TSHD dredging within 1666m (dolphin species, delphinids) or 3497m (baleens). There is a 50% risk of low severity behavioural responses occurring within 1987m for baleen whale species and 528m for dolphins. For seals, low severity behavioural responses may occur within 1948m, with more moderate responses occurring within approximately 530m.

During the quietest noise conditions (5th percentile), onset of auditory masking effects could occur within approximately 5500m from a TSHD actively dredging. More than 50% of an animal's listening space may be reduced within approximately 1687m (otariids, for example),

1682m (phocids), 1500m (dolphins) and 1438m (baleen whales) of the TSHD actively dredging.

Soundscape changes

Capital or maintenance dredging was found to cause negligible changes to the existing anthrophony of the harbour outside the Port Zone. For example, changes to the daily L_{eq} (average) levels outside the Port Area were below +1 dB re 1 µPa (unweighted). Averaged over 23 positions within and or outside the Port Zone, mean increases to the daily Leq levels from the 2023 maintenance dredging campaign were an average 1.1 ± 0.2 dB re 1 µPa (unweighted), 1.2 ± 0.2 dB re 1 µPa (LF-weighted), 1.9 ± 0.3 dB re 1 µPa (HF-weighted) and 2.0 ± 0.3 dB re 1 µPa (OW-weighted). Averaged over a complete month of maintenance dredging, soundscape changes were largely contained within the Port Zone, in both monthly Leq and cumulative sound exposure metrics.

The effects arising from the proposal will be similar to the modelling of the 2023 maintenance dredging campaign, as a similar sized TSHD will be used.

It is important to note that these changes are based on AIS data, which is widely known to underrepresent true vessel activity because it misses most recreational vessels. Passive acoustic monitoring within the harbour revealed a high degree of recreational boating activity, both within and outside the Port Zone. Including the ‘missed’ vessel traffic will mean that the contributions from dredging will be even less.

Overall conclusion

Maintenance and capital dredging within the Port Zone will expose marine mammals to acoustic-related disturbances within a limited range from the TSHD vessel actively dredging. The noise will not be high enough to cause auditory injuries or hearing loss. The risk for disturbances is substantially higher, by way of covering a greater spatial area, outside the harbour than inside. The change in soundscape generated by the dredging is expected to be negligible in habitats outside the Port Zone – especially when considering that the AIS data that it is based upon does not include all vessel traffic.

1.0 Introduction

Port of Tauranga (**PoTL**) has engaged Styles Group Underwater Acoustics to provide an underwater noise assessment to inform their reconsenting project (the **Project**).

The Project relates to the renewal of resource consents that will enable PoTL to carry out dredging to deepen the existing sitting basins (depths vary from 1 – 7 m), the approach to Berth 1 (c. 3 m) and deepen a small area in the Passing Lane to smooth the corner in the Entrance Channel and enhance navigational safety (c. 7 m). The Project seeks to enable PoTL to continue to conduct routine maintenance dredging, and to enable capital works to occur as and when required.

The purpose of this underwater noise assessment is to demonstrate the nature and extent of noise emissions, how those emissions can be evaluated by the marine ecologist(s) and how the emissions compare to the current noise levels experienced by marine fauna in the area today.

1.1 Aims of this assessment

The underwater noise assessment had the following aims:

- To set out the predicted noise levels from a TSHD dredging different areas of the harbour.
- To provide underwater cumulative noise models of the existing anthropogenic noise environment from vessels, based on the AIS records between June 2022 and June 2023.
- To provide underwater cumulative noise models of a TSHD vessel dredging inside the Port Zone over a complete dredging campaign in July and August 2023.
- To use cumulative noise models to show the expected cumulative noise effects on the existing anthropogenic soundscape.
- To use the predicted noise levels to determine potential effects radii for various marine fauna to inform ecological assessments.

2.0 The proposal

Figure 1 displays the extent of the proposed capital dredging works and Figure 2 displays the extent of proposed maintenance dredging works. Figure 3 displays the locations where dredged material will be deposited nearshore and offshore in the coastal marine area (CMA).

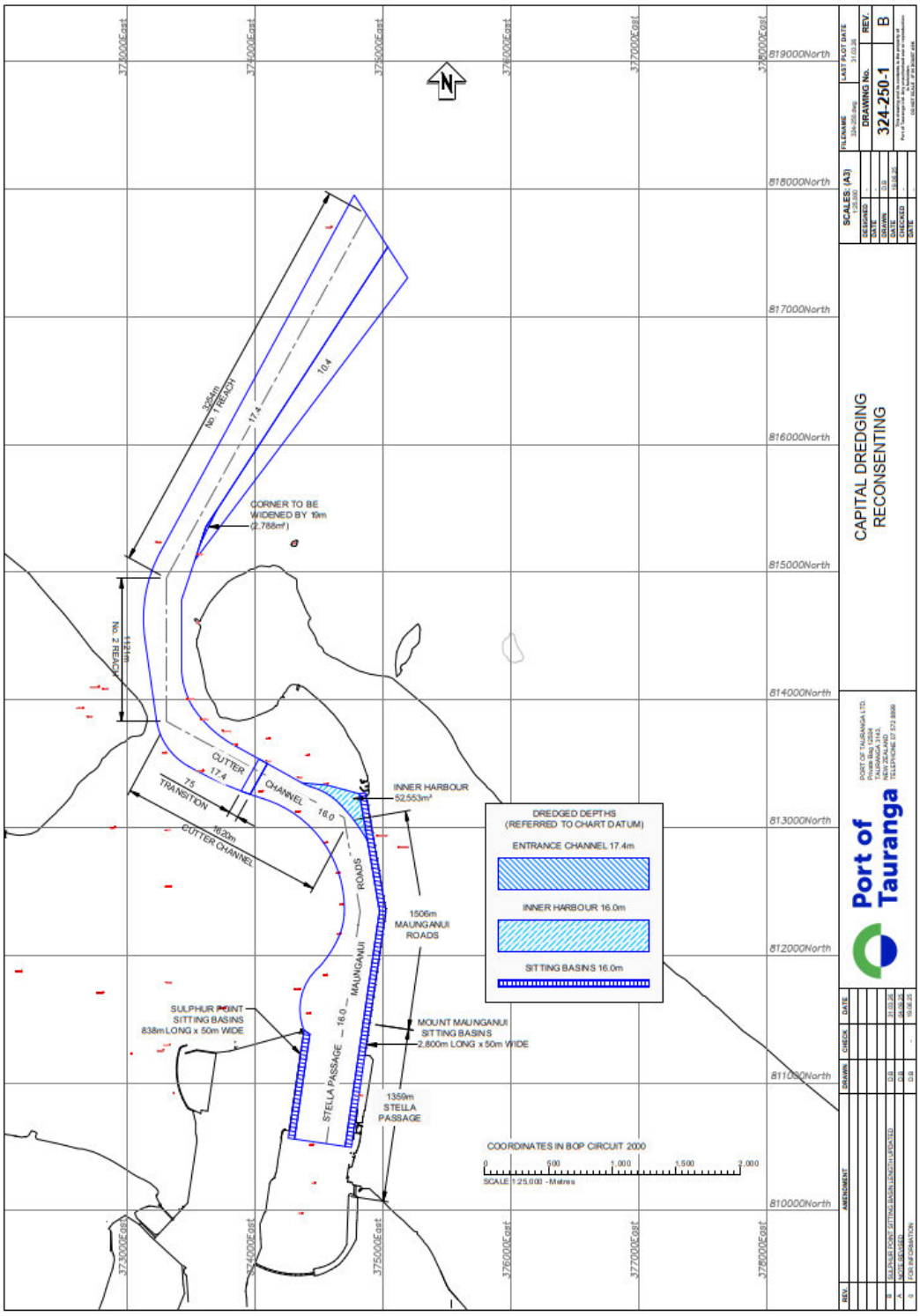


Figure 1 Proposed capital dredging

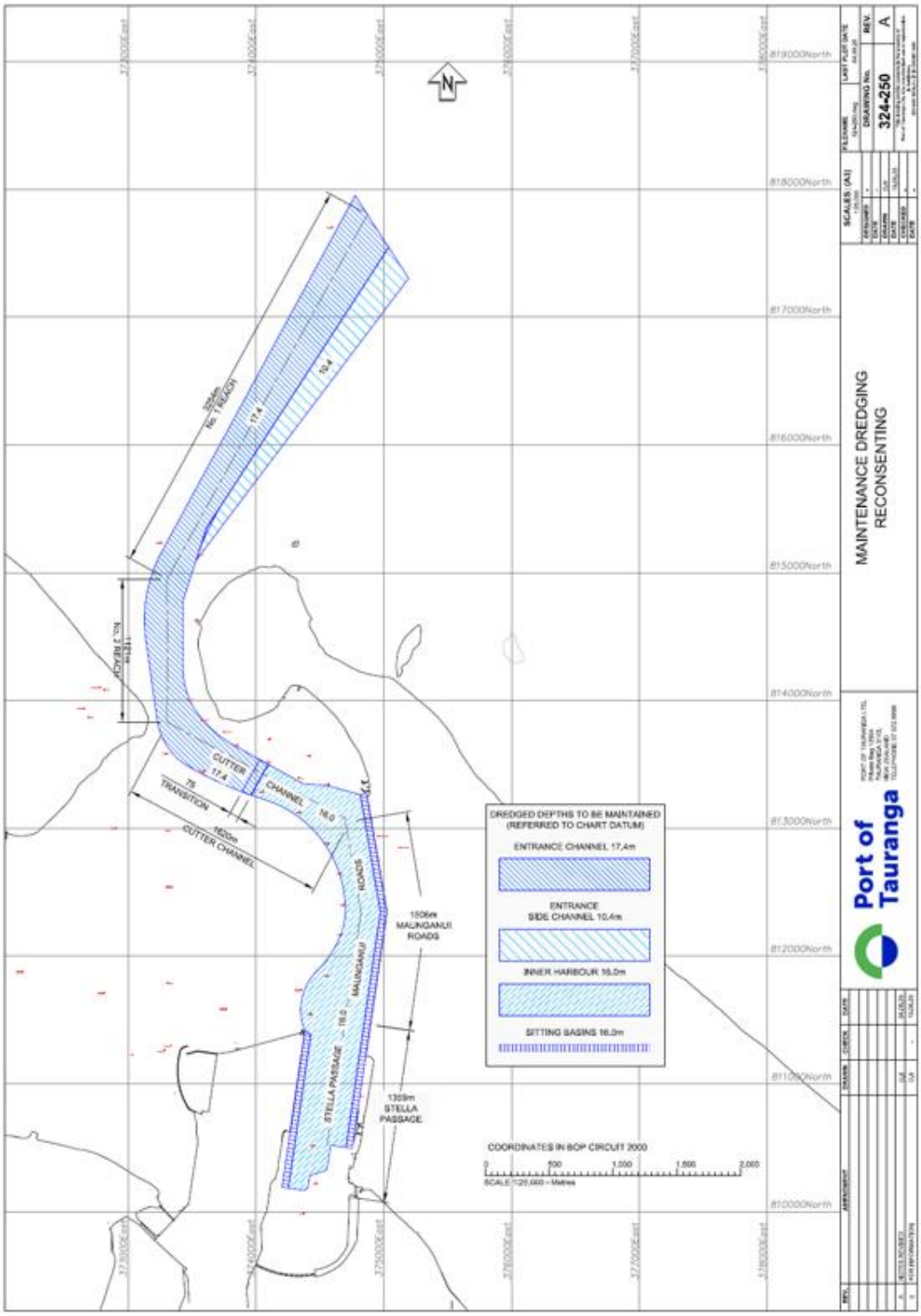


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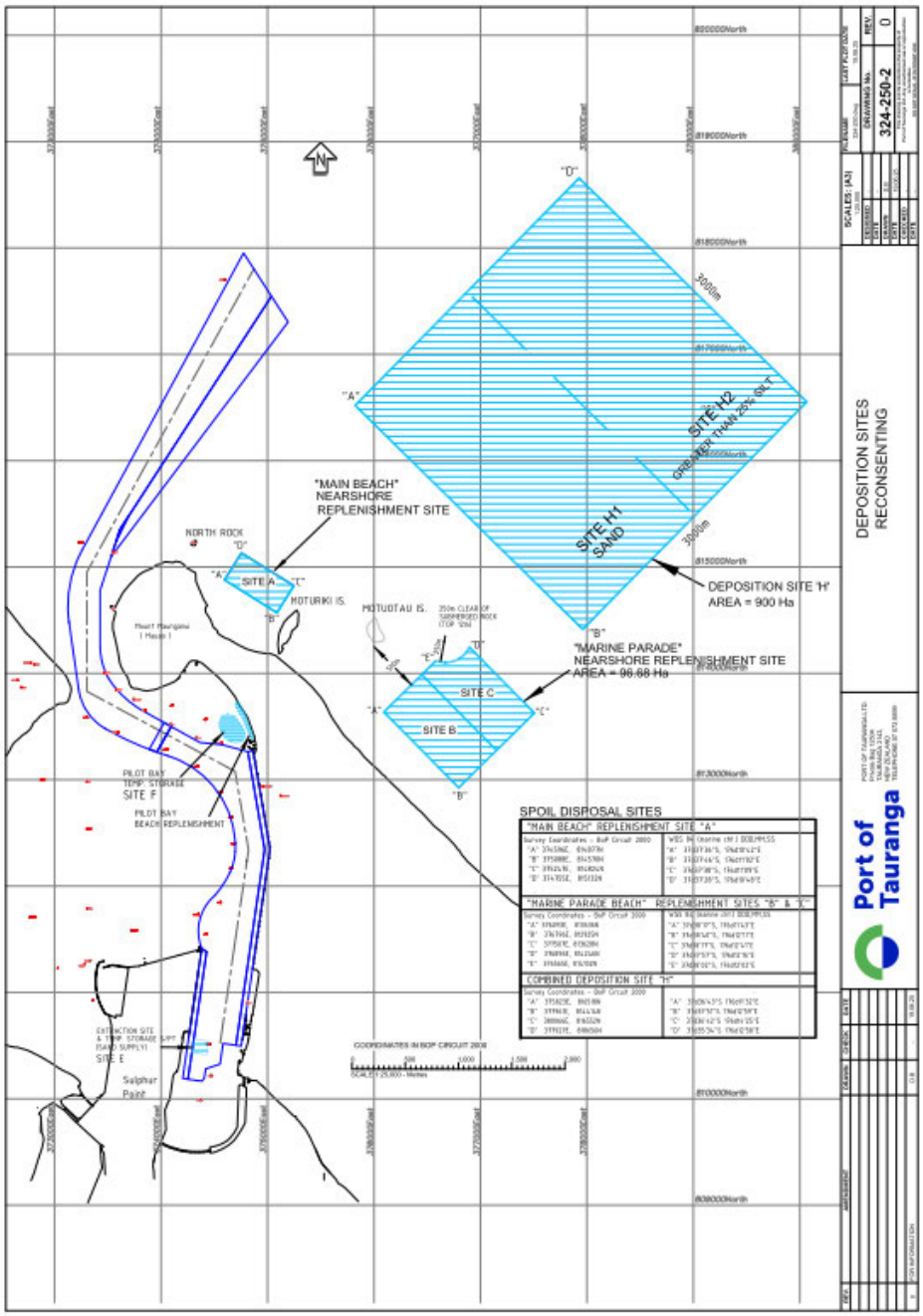


Figure 3 Deposition sites reconsenting

2.1 The site

The Project will be undertaken in the Port Zone of the Bay of Plenty Regional Coastal Environment Plan (**RCEP**, Figure 4). There are three zones that the underwater noise effects from the dredging would likely propagate into:

1. Port Zone. This area is subject to high vessel traffic, both port-related and recreational.
2. Mooring Areas.

3. Indigenous Biological Diversity Area (IBDA) – B. This area is outside the Harbour, it is also subject to vessel-related noise, such as shipping and recreational vessels.



Figure 4 Bay of Plenty Regional Coastal Environment Plan Zoning.

2.3 Relevant RCEP standards for underwater noise

There are no prescriptive noise limits in the RCEP concerning underwater noise. However, the relevant policy for underwater noise is under Section 10.1 of the RCEP, as set out below:

10 **Noise (NS)**

10.1 **Policies**

Policy NS 1 Recreational vessels such as personal watercraft, water ski boats, and hovercraft, which exceed the noise standards, should only operate within the personal watercraft and water ski areas identified in the Bay of Plenty Regional Council Navigation Safety Bylaws, or beyond 200 metres off the coast.

Policy NS 2 Protect the natural character and amenity values of the Tauranga Harbour (excluding the Port Zone) and Ōhiwa Harbour coastal environments from the adverse effects of noise.

Policy NS 3 In the coastal marine area outside the Tauranga Harbour, Port Zone and Ōhiwa Harbour, apply best management practices to manage noise, except in relation to Policy NS 4.

Advisory note:

1 The 2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations is an example of best management practice.

Policy NS 4 Manage noise resulting from activities that otherwise need a resource consent under this Plan as part of those consents.

Refer to Section 9 – Port Zone of this Plan for noise management in the Port of Tauranga.

3.0 Underwater noise and effects modelling

We have prepared several underwater noise models to investigate the existing anthropogenic noise within the harbour and how the proposed dredging may increase it.

Appendices C through G set out the methodology for the underwater noise modelling, as well as effects, including details on the source levels, propagation models, environmental inputs and effects thresholds.

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

- Empirical source level data from the TSHD *Albatros* while actively dredging (draghead on seafloor, pumps and generators all operating while vessel is underway at approximately 1-2 knots) was used in the dredge noise model. Details of those measurements are provided in Appendix H.
- 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 details).

- All noise models incorporated bathymetry, sound speed, frequency-dependent absorption, and seafloor data. The required environmental parameters were provided by the Port of Tauranga, Waikato University and MetOcean.
- The primary propagation algorithms 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). The model has also shown very good agreement with empirical data from a TSHD in full production mode off Mangawhai-Pakiri coastline. Due to the models' computational efficiency, very high-resolutions models can be used to investigate a range of scenarios. It's use therefore presents several advantages for quantifying cumulative noise effects on the existing soundscape of Tauranga Harbour.
- Monthly average (L_{eq}) and cumulative sound exposure levels (L_E) from vessels transmitting their positions via AIS[1], were mapped to understand the existing anthrophony of the harbour for the period between June 2022 and June 2023.
- To understand the noise levels from a typical dredging campaign in and around the harbour, the full maintenance dredging that occurred in 2023 was modelled using source levels of the TSHD *Albatros.* We understand that a TSHD similar in size to the *Albatros* (including the *Albatros* itself) will be used for the proposed dredging and the noise levels are, therefore, representative of proposed dredging. Monthly average and cumulative sound exposure maps of the dredging campaign were created.
- Passive acoustic monitoring during September 2023 was used to inform the effects modelling. The passive monitoring work included specific vessel noise detections and analysis. These data were from the larger marine mammal acoustic survey between August 2022 and July 2023.
- The resulting noise maps were used to assess soundscape changes, PTS, TTS, behavioural risks and auditory masking. General audibility ranges were also considered as the theoretical maximum area during the quietest noise conditions (5^{th} percentile) for which the potential onset of any noise impact, of any severity, may occur.

Please refer to Appendices B through H 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.

4.0 Results

This section sets out the noise modelling results for the proposed dredging using the TSHD *Albatros*, providing ranges for:

[1] 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.

- Potential onset of auditory injury (including permanent threshold shift (PTS)) and temporary threshold shift (TTS).
- Distances at which 75, 50, 25 and 0% listening space reduction (LSR) may occur for each species group of interest.
- Distances at which the potential onset of behavioural responses may occur.
- Distances within which audibility of the TSHD dredging is possible.

Appendix F provides the contour maps for each of these effects.

We note that the auditory masking and audibility ranges are based on the 5th percentile ambient noise levels (across all frequency bands) for 1st – 30thSeptember 2022, representing the quietest noise conditions. This means that ambient sound levels were louder 95% of the time. Soundscape changes were assessed using averaged levels (L_{eq}) over days or months.

4.1 Noise effects on marine mammals

4.1.1 Auditory injury and temporary threshold shift

During full dredging conditions (pump on, draghead down and loading the hopper), the 75m-long TSHD *Albatros*) is not expected to induce TTS beyond 1m distance (Table 1), and no risk for auditory injury onset, including PTS, was found.

Table 1: Ranges (in metres) from the TSHD vessel actively dredging within which temporary threshold shift, TTS, may occur in the different marine mammal hearing groups.

Functional hearing group	M-weighted source level (dB re 1 µPa)	TTS range (m)
Low Frequency (LF)	168.69	0.46
High Frequency (HF)	164.02	0.06
Very High Frequency (VHF)*	159.47	2.21
Otariid Pinnipeds (OCW)	162.80	0.08
Phocid Pinnipeds (PCW)	165.37	0.34

*VHF cetaceans (i.e., Hector's/Māui dolphins) are provided for completeness, but are not expected inside, or outside, Tauranga Harbour.

4.1.2 Behavioural Effects

Table 2: Distances at which 75, 50, 25 and 0% risk of low and moderate behavioural responses for each of the species of interest may occur.

Group	Behavioural Response	Risk isopeth (m)			
		75%	50%	25%	0%
Delphinids	Low*	374	528	715	1666
	Moderate**	74	109	241	985
Baleens	Low*	1546	1987	2166	3497
Pinnipeds	Low*	1948			
	Moderate**	530			

*minor changes in respiration rates, swimming speeds/direction.
**moderate to extensive changes in swimming speeds/direction and/or diving behaviours, moderate or prolonged cessation of vocalisations, and/or avoidance.

It is important to note risk isopleths cannot be calculated for kororā due to a lack of data.

4.1.3 Auditory masking

Table 3: Distances at which 75, 50, 25 and 0% listening space reduction (LSR) occurs for of each the species of interest during the quietest noise conditions (5th percentile).

Functional Group	Critical Distance (m)			
	75% LSR	50% LSR	25% LSR	0%LSR
LF	170	1438	2827	5107
HF	160	1500	2888	5500
PCW	919	1687	2791	5307
OCW	702	1682	2786	5312
Kororā/Little Penguins	64	670	1999	5064

4.1.4 Audibility

Table 4: Distances within which audibility is possible during the quietest noise conditions (5th percentile ambient level).

Functional Group	Maximum Audibility Range* (m)
LF	8343
HF	8336
PCW	8375
OCW	8348
Kororā/Little Penguins	8220

4.2 Changes to the Harbour's anthrophonic environment

Policy NS 2 of the RCEP is aimed at protecting the natural character of Tauranga Harbour outside the Port Zone and therefore to avoid substantial changes to the existing soundscape in those areas. From an animal's perspective, a useful measure of this is quantifying the potential increase to the existing anthropogenic noise levels by adding dredging and then assessing the change (**a soundscape change**).

A soundscape change was assessed in this report using computational noise models that showed potential increases in the daily and monthly averages, as well as the monthly cumulative sound exposure, during a dredging campaign. Additionally, 23 positions representing stationary 'measurement points', (Figure 17, Appendix D) were systematically placed within and outside the Port Zone to assess any daily soundscape changes in both the unweighted and M-weighted noise levels.

In summary, changes to soundscapes were assessed by:

- Generating noise models for each day over the PoT's maintenance dredging campaign in July and August 2023, using real-world data on the dredging activity. These produced 40 daily noise maps, written as animations, from the dredging inside the Port Zone.
- Generating noise models of the AIS-traffic for the same days as the maintenance dredging but without the dredging noise included. This was used to represent the existing anthropogenic soundscape on each of those dredging days (40 days).
- Changes to the soundscape were assessed by calculating the additional noise from the dredging noise models when added to the AIS-traffic models, which represented the contribution of noise from the dredging to the anthropogenic soundscape of the harbour during those months.

It is important to note that basing the vessel noise models on only AIS data can substantially underestimate the true vessel activity in the area, as AIS data does not include recreational vessels. Recreational vessels can contribute significantly to the underwater soundscape of an area. Consequently, the predicted soundscape changes can be considered conservative.

Averaged over each month during maintenance dredging in 2023, the soundscape changes are negligible outside the Port Zone (Figure **5**). While largely limited to the Port Zone, soundscape changes due to the dredging show spatial-temporal variation that is related to the TSHD's activity.

These results show that the predicted soundscape change arising from the dredging inside the Port Zone is negligible in habitats outside the shipping channel (i.e., the dredged area). This is also the case after the noise levels are auditory filtered for the different functional hearing groups of marine mammals (NMFS 2024). For example, for delphinids (HF cetaceans, which include killer whales, bottlenose and common dolphins, and pilot whales), the cumulative noise effects from the dredging was found to range between 0.3 dB re 1 µPa (outside the Port Zone) and 4.3 dB re 1 µPa (immediate dredge area inside the Port Zone), giving an average (±SE) over the whole area of 1.9 ± 0.3 dB re 1 µPa (**Table 5**). For baleen whales (LF) and fur seals (Otariidae, OW), the cumulative effects were also relatively small, with respective average (±SE) increases of 1.2 ± 0.2 dB re 1 µPa and 2.0 ± 0.3 dB re 1 µPa. These differences are very small.

Table 5: Modelled increases to the daily anthropogenic noise levels ($L_{eq\text{-}24hr}$ dB re 1 µPa) during active dredging, based on AIS traffic and the dredging noise models between July and August 2023. Metrices were calculated over 23 locations within and outside the Port Zone (see**Figure 17**, Appendix D).

Group	Auditory weighting	Mean ± SE	Median	Min	Max
	Unweighted	1.1 ± 0.2	0.9	0.1	4.4
Cetaceans	LF	1.2 ± 0.2	0.8	0.1	4.4
	HF	1.9 ± 0.3	1.5	0.3	4.3
	VHF*	2.7 ± 0.4	2.2	0.4	6.4
Seals	PCW	1.6 ± 0.2	1.3	0.2	4.3
	OCW	2.0 ± 0.3	1.6	0.3	4.4

*VHF cetaceans (i.e., Hector's/Māui dolphins) are provided for completeness, but are not expected inside, or outside, Tauranga Harbour.

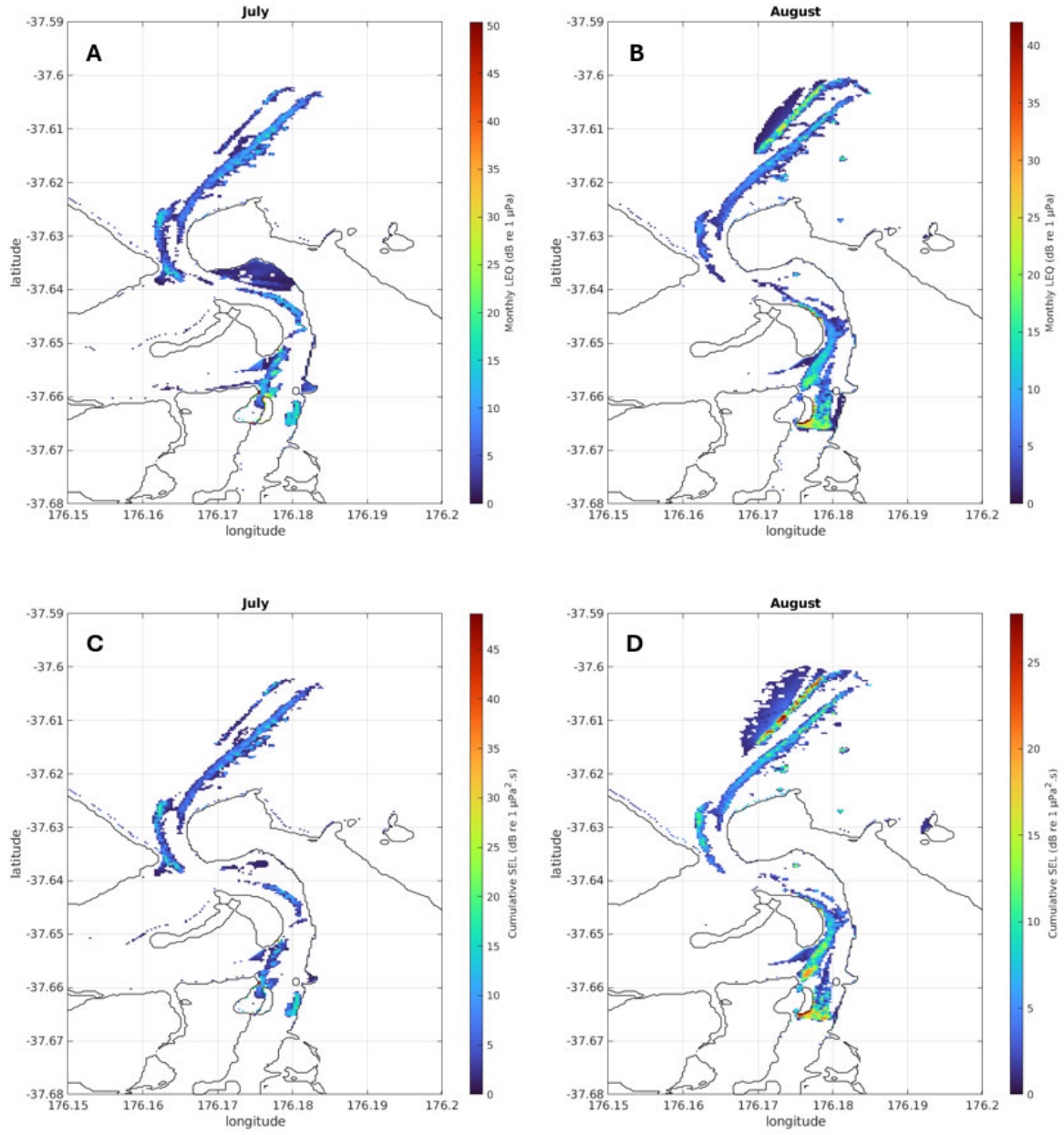


Figure 5 Monthly additional noise for each month during 2023 dredging

5.0 Response to Cultural Values Reports

We have reviewed feedback from the Cultural Value Reports (CVR's) from Ngāti Hangarau, Ngā Pōtiki a Tamapahore Trust and Ngāi Tamarāwaho that relate to underwater noise effects. The Project marine mammal ecologist addresses feedback relating to noise effects on marine mammals.

5.1 Cumulative noise effects

Ngā Pōtiki a Tamapahore Trust and Ngāi Tamarāwaho point out that dredging contributes to the cumulative underwater noise soundscape of Tauranga moana. We agree. This assessment has been informed by empirically-characterised passive acoustic monitoring data and comprehensive cumulative noise mapping of AIS shipping traffic and dredging. The cumulative noise models are based on real-world AIS data and maintenance dredging tracking data over a complete dredge campaign.

Ngāi Tamarāwaho consider that underwater noise should be managed not only for injury thresholds, but also for behavioural disturbance, masking, cultural soundscape and cumulative industrial presence. This assessment addresses further-ranging effects, such as behavioural and masking, as well as the cumulative effect of noise from the dredging to the wider-area. The Project marine mammal ecologist's assessment report addresses the management of these effects.

This assessment demonstrates that the Project will have a small and spatially confined cumulative impact on the Port Zone's soundscape, and a negligible impact beyond the Port Zone (i.e., areas beyond the shipping channel (see Section 4.2).

The assessment of cumulative noise effects we have undertaken demonstrates that cumulative underwater noise from the Project will be very low. We consider that no specific conditions are required to manage cumulative noise effects.

5.2 Request for active noise monitoring

Ngāti Hangarau find that "*While physical injury may be avoided, underwater noise disrupts the moana. Active monitoring by kaitiaki is required to verify these limits*". Ngāti Hangarau do not specifically define the active monitoring, or the "limits" the monitoring would be measuring.

This assessment is informed by a range of empirical acoustic data along a spatial gradient, real-world observations (by way of AIS tracking of shipping and previous maintenance dredging campaigns) and internationally accepted guidelines and scientific information. These various data sources have directly informed the computational models used to determine the spatial-extent of physiological, behavioural and auditory effects on marine mammals (Section 4.0). Those models demonstrate the Project will have very small effects on the harbour soundscape.

The computational models are based on empirical monitoring data of the proposed activities undertaken on earlier projects in Tauranga moana. This method results in a very high level of certainty for the modelling results and assessment of effects. We consider that a condition requiring active noise monitoring is not required to verify the data or findings.

6.0 Conclusion

The renewing of resource consents that enable the Port of Tauranga to carry out dredging to deepen the sitting basins, the approach to Berth 1 and small area in the Passing Lane to smooth the corner in the Entrance Channel , as well as conduct routine maintenance dredging, may possibility expose marine mammals to acoustic-related disturbances. Those acoustic-related disturbances, however, are expected to occur within a limited range from the TSHD vessel actively dredging and are primarily related to behavioural and masking effects only. No auditory injury is expected, or temporary threshold shift risk beyond 2.5m.

Policy NS 2 of the Bay of Plenty Regional Coastal Environment Plan is aimed at protecting the natural character of Tauranga Harbour outside the Port Zone. Based on data from the 2023 maintenance dredging campaign and complete AIS record, noise models show that soundscape changes (both daily and monthly) outside the Port Zone will be below 1 dB re 1 µPa, if there is any increase at all. The auditory-weighted cumulative noise from the dredging for marine mammals in the area was found to range between 0.1 $dB_{Leq-24hr}$ re 1 µPa (outside the Port Zone) and 4.4 $dB_{Leq-24hr}$ re 1 µPa (within in the Port Zone). These are very small changes. Since the proposal will be using a similar size vessel to the *Albatros* (and including the *Albatros*), the effects from the proposal will be similar to the modelling of the 2023 maintenance campaign.

7.0 References

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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).
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).
Halocline	A strong change in salinity in a body of water with depth, where the salinity is markedly different above and below the layer in which the salinity change occurs.
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.
Sub-lethal	Sub-lethal effects are biological (including ecological), physiological or behavioural effects on individuals that survive exposure to the invasive noise.
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 mammals, fish and invertebrates 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). Thei ability to communicate and perceive biologically important sounds are directly related to the surrounding acoustic environment as signals must be audible over the background soundscape within some critical bandwidth. Coastal activities, such as dredging or vessels 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 sub-lethal 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/regions because the physical environment changes. Generally, noise effects 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.

Autonomous recorders were therefore deployed at two sites to provide data on the current soundscape of the area, including marine mammal presence.

Materials and methods

Several studies were undertaken to assess the existing acoustic environment within and around the harbour. These were:

- Passive acoustic monitoring within the harbour.
- Vessel noise detection within the harbour.
- Cumulative AIS traffic noise mapping within and outside the harbour.

Here, we detail the passive acoustic monitoring and vessel noise detection components, while the cumulative vessel noise mapping is detailed in Appendix C.

SoundTrap 300 and 600 recorders were used, deployed at three monitoring sites within the harbour between September 2022 and July 2023 (Table 6, Figure 6). Each SoundTrap was programmed to record continuously at a 96kHz sampling rate and were bottom-mounted (Figure 7).

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 6: 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
Deployment 1 (31/08/2022 – 04/11/2022)			
Outer East	ST600	31/08/2022 – 29/10/2022	Soundscape, Vessels, Marine Mammals
Outer West	ST600	31/08/2022 – 04/11/2022	Soundscape, Vessels, Marine Mammals
Stella Passage	ST300HF	31/08/2022 – 19/10/2022	Soundscape, Vessels, Marine Mammals
Deployment 2 (04/11/2022 – 08/03/2023)			
Outer East	ST600	04/11/2022 – 02/01/2023	Marine Mammals
Outer West	ST600	04/11/2022 – 19/12/2022	Marine Mammals
Stella Passage	ST300HF	04/11/2022 – 06/02/2023	Marine Mammals
Deployment 3 (09/03/2023 – 06/07/2023)			
Outer East	ST600	09/03/2023 – 11/06/2023	Marine Mammals
Outer West	ST600	09/03/2023 – 22/05/2023	Marine Mammals
Stella Passage	ST300HF	09/03/2023 – 31/05/2023	Marine Mammals

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

Every 60sec 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 60sec. Time-stamped hourly

averages were then calculated. Daytime periods were defined as the time between sunrise and sunset times for each site.

Vessel activity within and around the harbour was quantified as general presence and individual pass-by events that were identifiable from their closest-point-of-approach (CPA) were characterised using the maximum received SPL (1-sec average, L_{max}) and L_{eq} over the complete pass-by. Pass-by events were defined by the start/end times when the received SPL between 1 and 5 kHz exceeded 10dB above the ambient noise floor without the vessel noise. Noise floors were based on the moving average in between vessel detections within successive audio files. Vessel presence was determined in the recording using a vessel noise detector (see Pine et al. 2021 for more details).



Figure 6 Aerial photograph of Tauranga Harbour showing the locations of the three passive acoustic monitoring sites.



Figure 7 Two SoundTrap recorders inside their bottom-mounted deployment tubes prior to deployment on the seafloor.

Results & Discussion

The ambient soundscape within Tauranga Harbour is complex with a range of sound sources occurring simultaneously at any given time (Figure 8and Figure 9). Wind, waves and tides (causing sediment entrainment) were the primary contributor to the harbour's geophony, while fish, marine mammals and snapping shrimp formed the harbour's biophony. Vessel noise was the primary anthropogenic noise source.

Relatively high levels of underwater noise inside the Port Zone were measured, commensurate with being near a busy port. For example, during the month of September 2022, hourly sound pressure levels (hourly Leq values) ranged between 109 and 138 dB re 1 µPa near the harbour entrance (Outer West and Outer East sites) (Figure 10). Within Stella Passage, hourly sound levels ranged between 118 and 147 dB re 1 µPa (Figure 10

The acoustic environment within the Port Zone is dominated by vessel noise. This is shown within the empirical acoustic dataset, as well as the AIS traffic noise models (Appendix C). For example, vessels (both recreational and commercial) were acoustically detected operating near the harbour entrance on 2,833 occasions (Outer East site) between 1 September and 21 October 2022. During each of those occasions, vessel noise raised the ambient noise levels

at the hydrophone over 15 dB for approximately 30 to 522 seconds (with Lmax and Leq values between [96 and 161] dB re 1 µPa and [106 to 150] dB re 1 µPa, respectively).

Similarly, between 1 August and 30 September 2022, 1,187 vessel tracks within the harbour were registered. The AIS traffic noise models show the potential noise emissions from AIS-carrying vessels of all types during August and September exceeding 180 dB re 1 µPa (Leq) inside the Port Zone and over 130 dB re 1 µPa inside IBDA – B areas of the RCEP (see Figure 28 in Appendix G). Cumulative sound levels for the same time period are provided in Figure 30, Appendix G.

Vessel engine noise from berthed ships (the nearest approximately 1km away) remained a constant source of anthropogenic noise, particularly below 1 kHz (Figure 9).

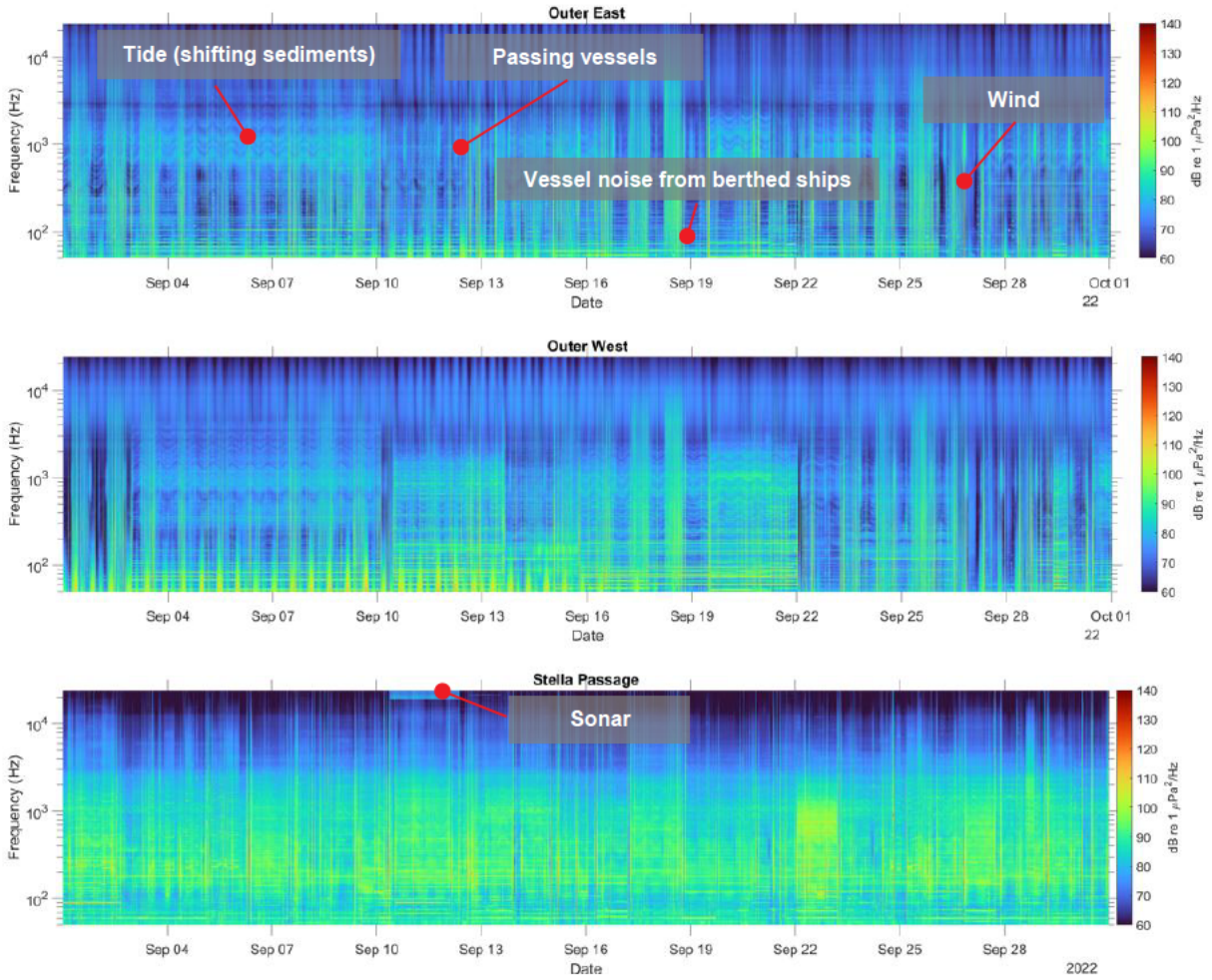


Figure 8 Spectrograms from each passive acoustic monitoring site over September 2022.

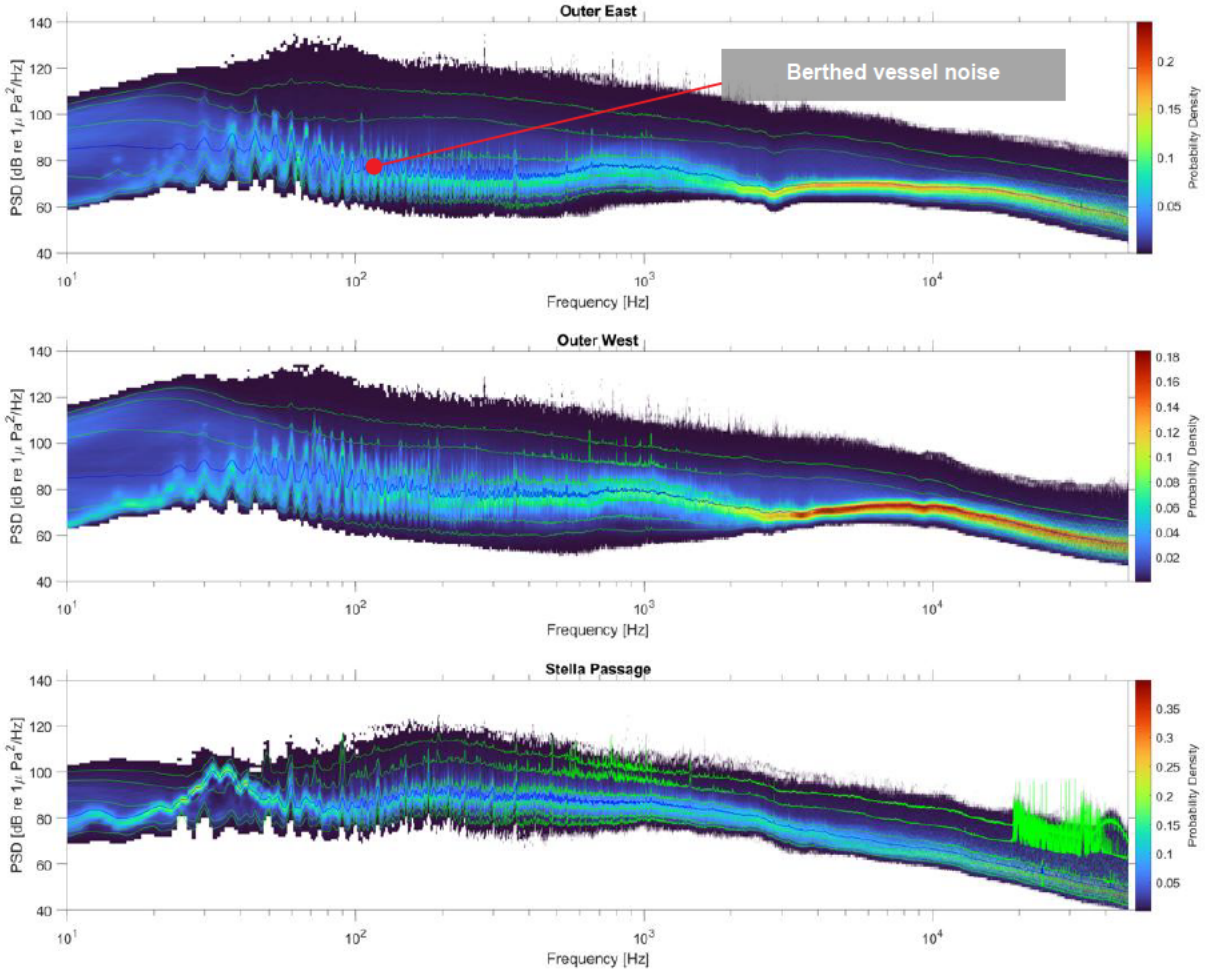


Figure 9 Power spectral densities and spectral probability densities from each monitoring site between 1st and 30th September 2022.

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 from 10 Hz to 48 kHz.

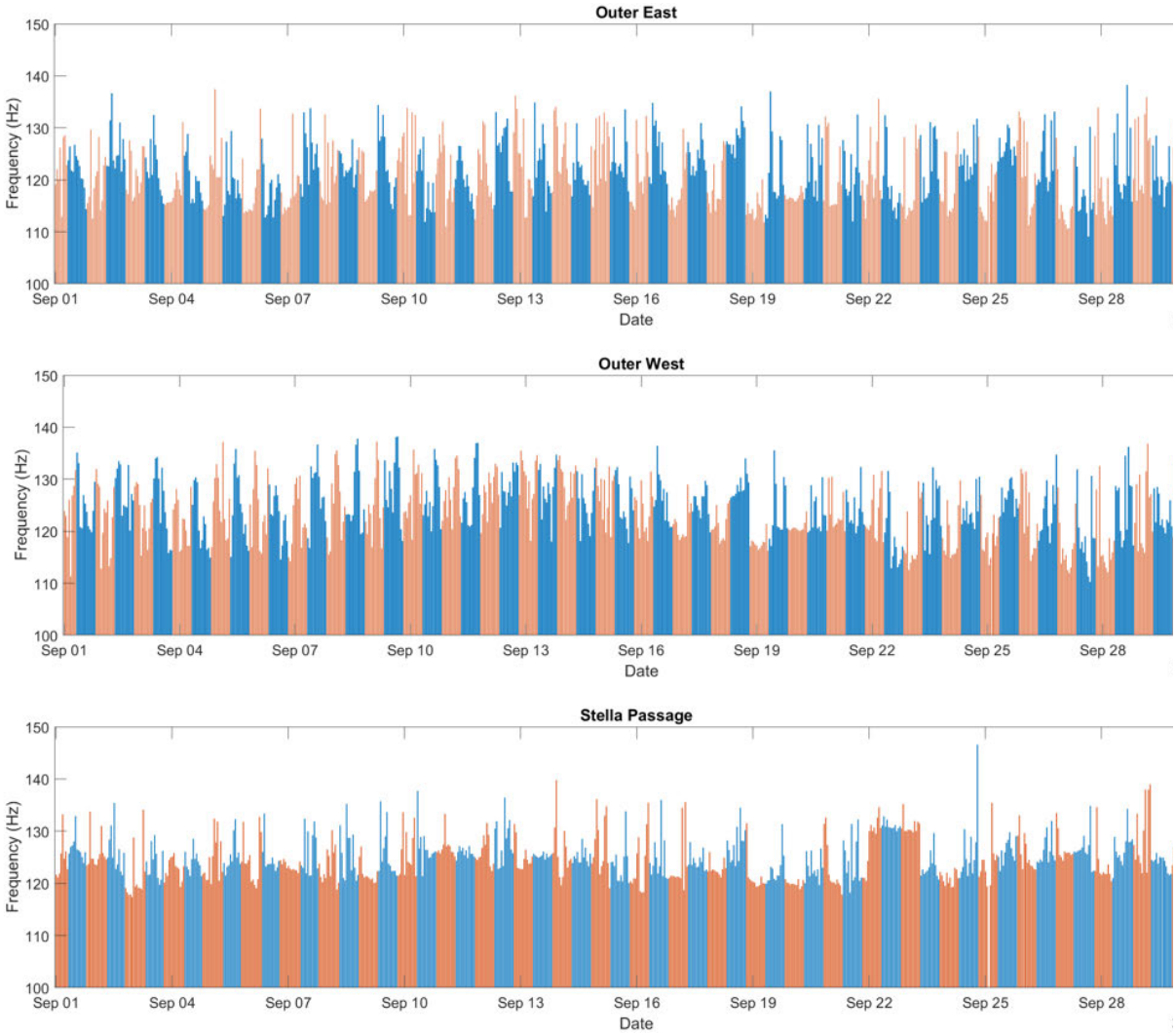


Figure 10 Hourly Leq sound levels from each monitoring site.

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

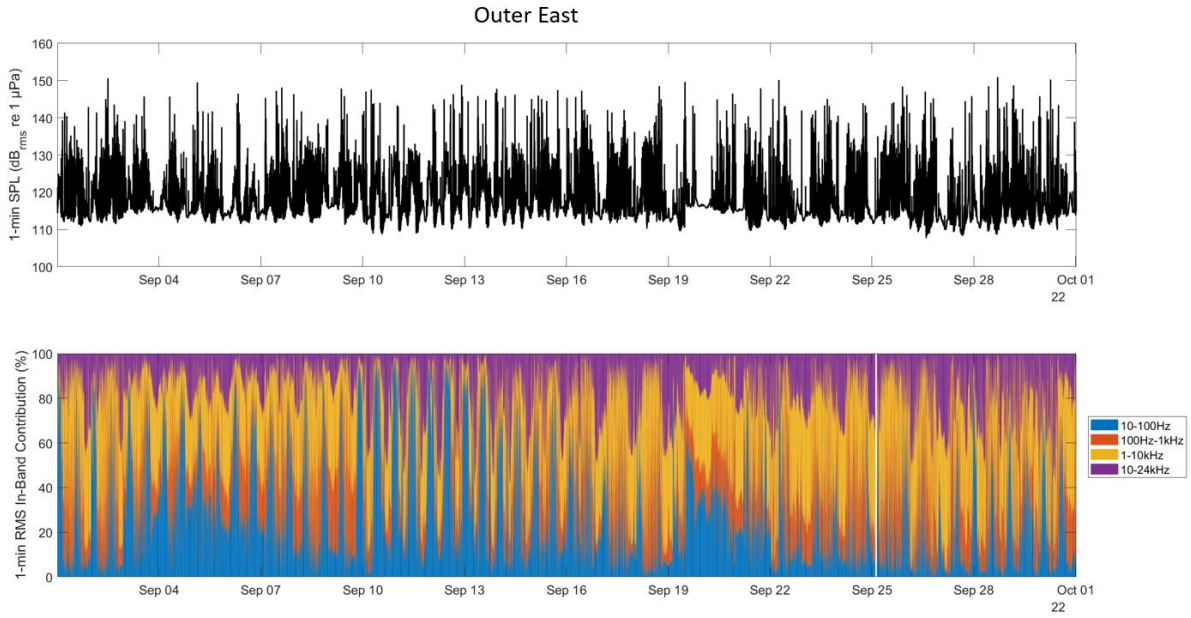


Figure 11 Broadband Sound Pressure Levels (averaged over 1-min) (dB_{rms} re 1 µPa) between 1st and 30th September 2022 (top panel) and corresponding in-band energy contributions for different frequency bands (bottom panel) at the Outer East monitoring site.

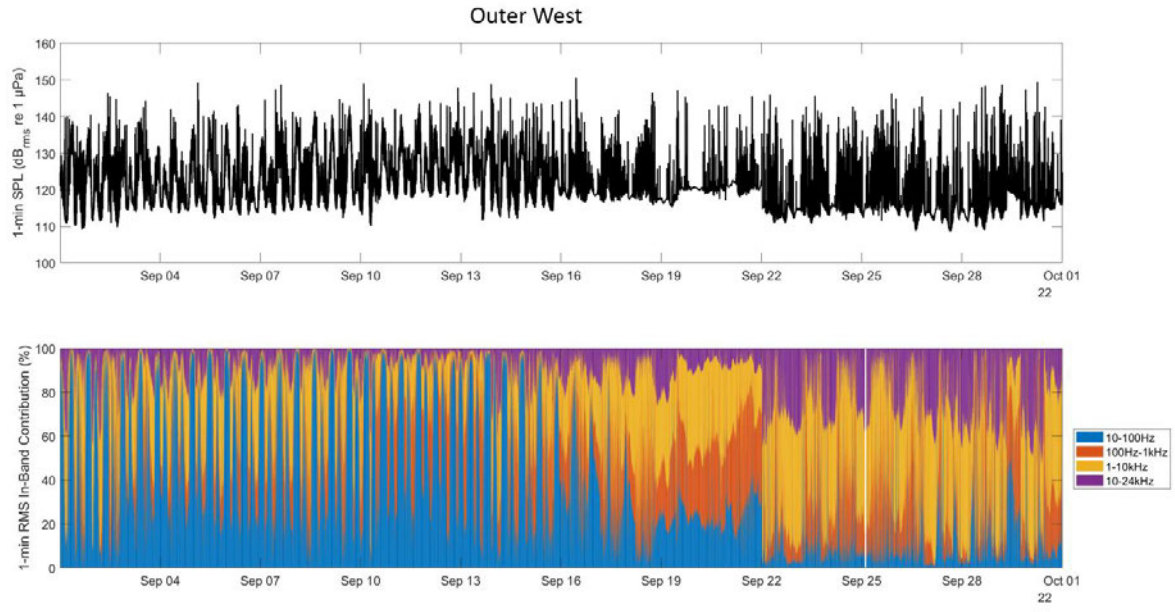


Figure 12 Broadband Sound Pressure Levels (averaged over 1-min) (dB_{rms} re 1 µPa) between 1st and 30th September 2022 (top panel) and corresponding in-band energy contributions for different frequency bands (bottom panel) at the Outer West monitoring site.

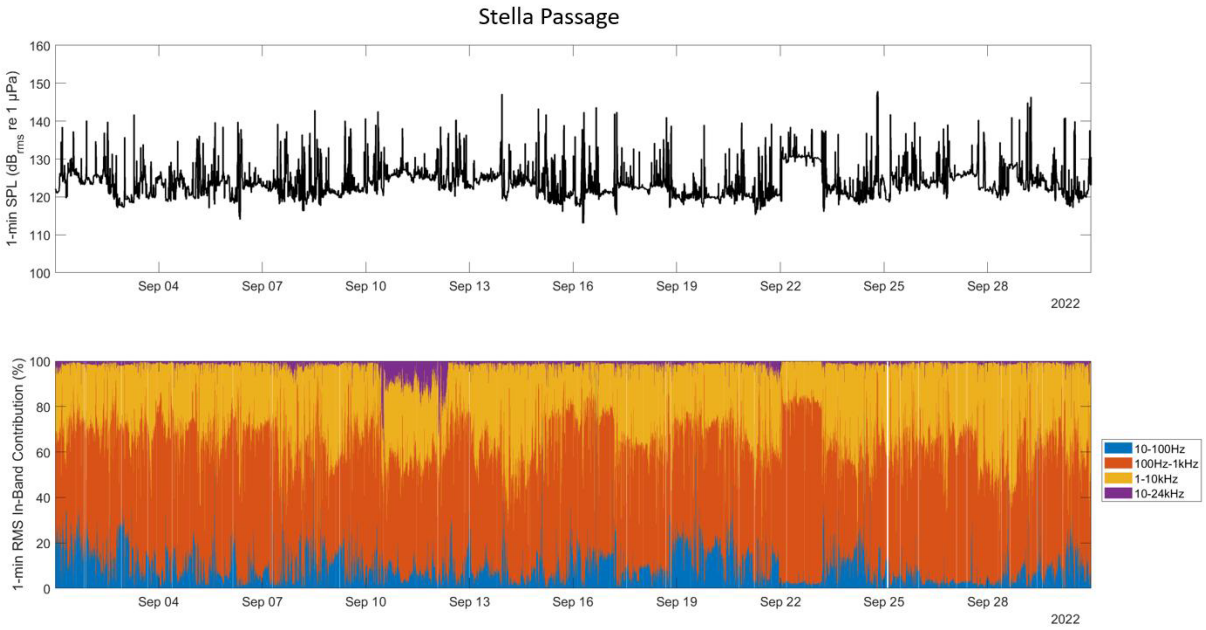


Figure 13 Broadband Sound Pressure Levels (averaged over 1-min) (dB_{rms} re 1 µPa) between 1st and 30th September 2022 (top panel) and corresponding in-band energy contributions for different frequency bands (bottom panel) at the Stella Passage monitoring site.

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Appendix C Cumulative ship noise modelling (AIS traffic)

Given vessel traffic is the primary source controlling the harbour's anthrophony, 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[2]. High resolution maps showing the overall noise levels for each month between June 2022 to May 2023 were generated, representing the cumulative sound exposure levels and average noise levels for the month.

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).

[2] AIS dataset was provided by the Ports of Tauranga in raw JSON format. 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[3] 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 capital dredging may impact the existing soundscape, because the vessel noise model contained 6,694 individual AIS-vessel tracks[4] 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 14), sound speed (Figure 15), seabed reflectivity (from de Lange et al. 2014) and frequency. Bathymetry data was of 25m gridded resolution and uploaded to the model program as an ASCII raster (decimal degrees being the reference coordinates). The seabed reflectivity coefficients were set along 2D transects from the source positions (i.e., Lat/Lon waypoints).

The sound speeds were provided by the Ports of Tauranga from ADCP devices. It is understood that mixing within and around Tauranga Harbour occurs, which prevents distinct thermoclines from forming. Isovelocity in the sound speeds is a key assumption of the EF numerical model.

[3] 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.

[4] 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).

The input parameters are summarised in Table 7 below.

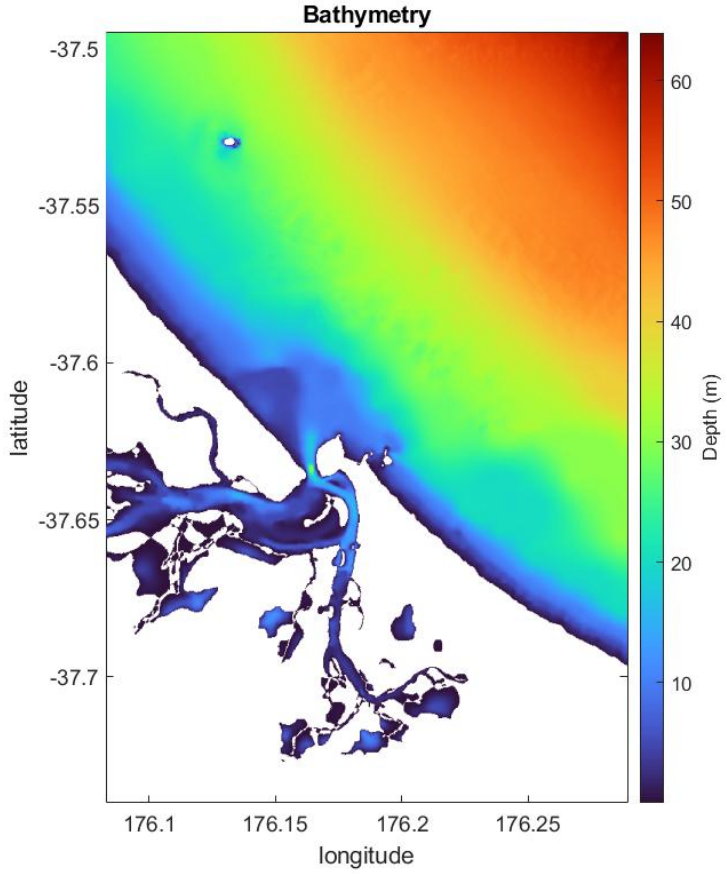


Figure 14 Bathymetry raster provided by the Ports of Tauranga.

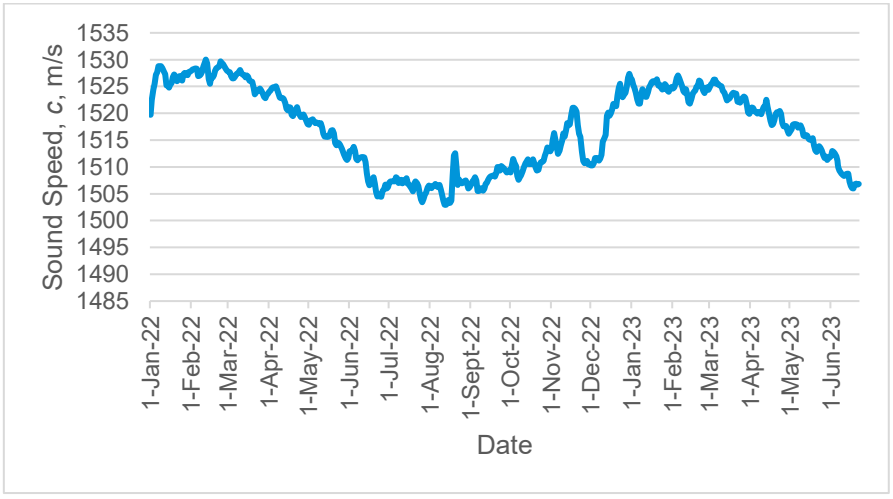


Figure 15 Sound speeds used in the modelling from ADCPs, provided by PoTL.

For each vessel waypoint, the N_{PL} was calculated for 360 radials (1° bearings), with 25m range steps out to 40km range. For each calculation point, the corresponding bathymetry, seafloor reflectivity coefficient, and sound speed was also extracted from the underlying rasters. 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 was 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 over 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 Tauranga's 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 moves through. However, smaller cell sizes increase the computational load in areas where lower spatial resolutions (therefore lower computational cost) would be appropriate, such as within the Bay of Plenty when SOG does not change, 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 7: Input parameters for the acoustic models.

Model independent variables	
Bathymetry	25m resolution ASCII raster.
Model independent variables	360 radials; 40km per radial; 25m 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. Clay: ρ 1500kg/m^3, c_p 1500m/s, α_p 0.2 dB/λ.
Water column	
Sound speed	Daily sound speed from ADCP (provided by PTL), ranging between 1502.9 ms and 1530.0 ms.
Water density	1025 kg/m^3
Salinity	35 psu.

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Appendix D Dredging noise modelling

The capital dredging will use two different types of dredgers: a trail-suction-hopper dredger (TSHD) and a backhoe dredger (BHD). Based on our understanding, the Albatros will be used within and outside the harbour, while the BHD will be largely confined to within Stella Passage.

The underwater noise modelling is based on empirical measurement data for the Albatros.

From a bioacoustic perspective, the TSHD poses the greatest impact risk rather than the BHD and was therefore the focus of this noise assessment. The restricted use of the BHD to the inner harbour (i.e., Stella Passage) and the lower expected noise emissions means cumulative changes to the harbour's soundscape is not expected.

Sound source: the TSHD vessel

The aim of the modelling was to produce a series of noise maps for a complete production cycle. For the TSHD, this generally involved two modes:

- Active dredging (draghead on the seafloor with pumps and generators extracting sand/gravel with propellors in gear, moving up to 4 knots);
- Transiting to/from the spoil disposal sites or port (draghead alongside the vessel, hopper filled or empty and underway up to 11 knots); and
- Spoil-disposal.

The source spectrum ($\mathbf{L_s}$) for the active dredging were from empirical measurements of the TSHD *Albatros* (Table 8) while actively dredging in Lyttelton Harbour. Please refer to Appendix H for an overview of the measurement protocol and details. While the dredge vessel was transiting, the L_s used was from the RSM (see Appendix C).

Table 8: TSHD *Albatros* characteristics used in the noise modelling.

Year Built	2013
Length	75 m
Beam	13.4 m
Hopper Volume	1860 m^3
Loaded Draft	3.8m
Vessel extraction speed	2 knots

Propagation modelling

The same propagation modelling that was described in Appendix C was used to model the TSHD *Albatros* while actively dredging and transiting. The key difference, however, was the model applied the empirical source spectrum for active dredging (Figure 16) when the draghead depth was deeper than 4.8m.

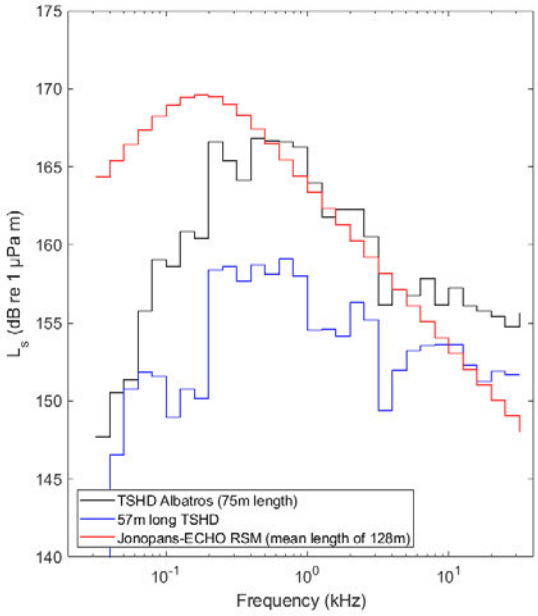


Figure 16 Source spectrum (decidecade) of the TSHD *Albatros*, as measured in shallow (<20m) water, used in the modelling. For comparative purposes, the source spectra of a smaller TSHD measured in NZ waters and the reference spectrum from JONOPAN-ECHO (based on 7 different vessels, and 52 measurements) is provided.

TSHD *Albatros* broadband source level = 184 dB_{rms} re 1 µPa m

Modelling TSHD positions and dredging behaviours

A key objective of the dredging noise model was to assess the changes to the existing anthrophonic soundscape (**a soundscape change**) over the duration of the dredging. The TSHD vessel will be dredging along transects, essentially combing the dredge area until the required depth is achieved. Once the hopper fills, the draghead is lifted and the TSHD vessel transits to the disposal site, where the spoil is released from the hopper. It then returns to the dredging area and continues.

Between July and August 2023, the Ports of Tauranga undertook maintenance dredging of the shipping channel, both within and outside the harbour using the Albatros. This provided an opportunity to generate a noise model of an actual dredge campaign using real-world data. The areas dredged during that campaign overlap very well with the application area in this consent renewal application (Figure 19). The *Albatros*' AIS data from that entire maintenance

dredging campaign were therefore used to produce daily cumulative noise maps (both L_E and L_{eq}) that included both active dredging and the transiting to and from the disposal areas (as seen in Figure 19). The resulting noise models therefore incorporated real-world data on the vessel's speed, dredging tracks and operational behaviours that would be expected of the capital dredging..

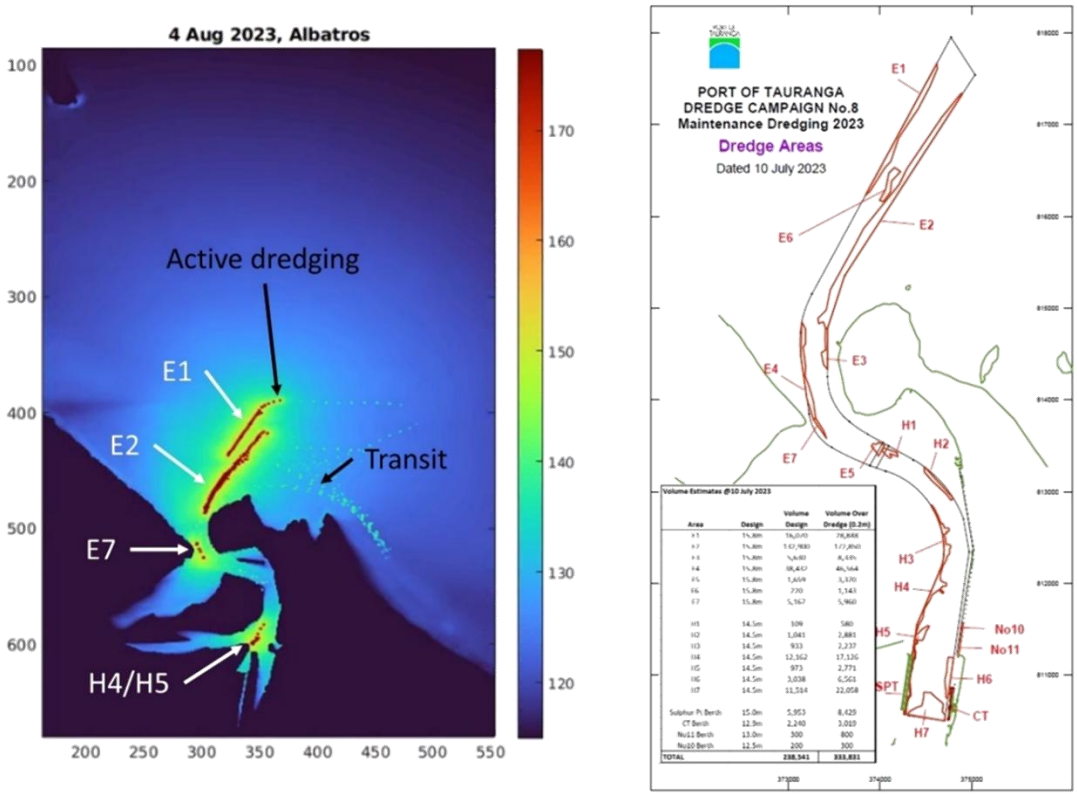


Figure 17 Daily noise model (for 2kHz decidecade band) for 4 August 2023 (left panel) and corresponding maintenance dredging area (right panel).

These models are automatically built from the provided vessel logs to give an accurate understanding of how the TSHD vessel's behaviour impacts its noise emissions.

Assessing soundscape changes

The overall AIS dataset from the same period as the maintenance dredging (July – August 2023) was used to produce noise maps of the existing daily noise levels from concurrent vessel traffic. This allowed us to contextualise the cumulative dredging noise, both daily and over the whole campaign, and calculate the additional noise to the existing soundscape that could be attributed to the proposed capital dredging. This method is likely to be very conservative because the AIS record is known to exclude most of the recreational vessel activity.

In addition to assessing the overall differences in the cumulative noise energy, the differences in the average daily L_{eq} levels (over the 40-day maintenance dredging campaign) between the AIS traffic and dredging noise models were also calculated at specific points ('measurement points') throughout the area. The specific locations are provided in Figure 20.

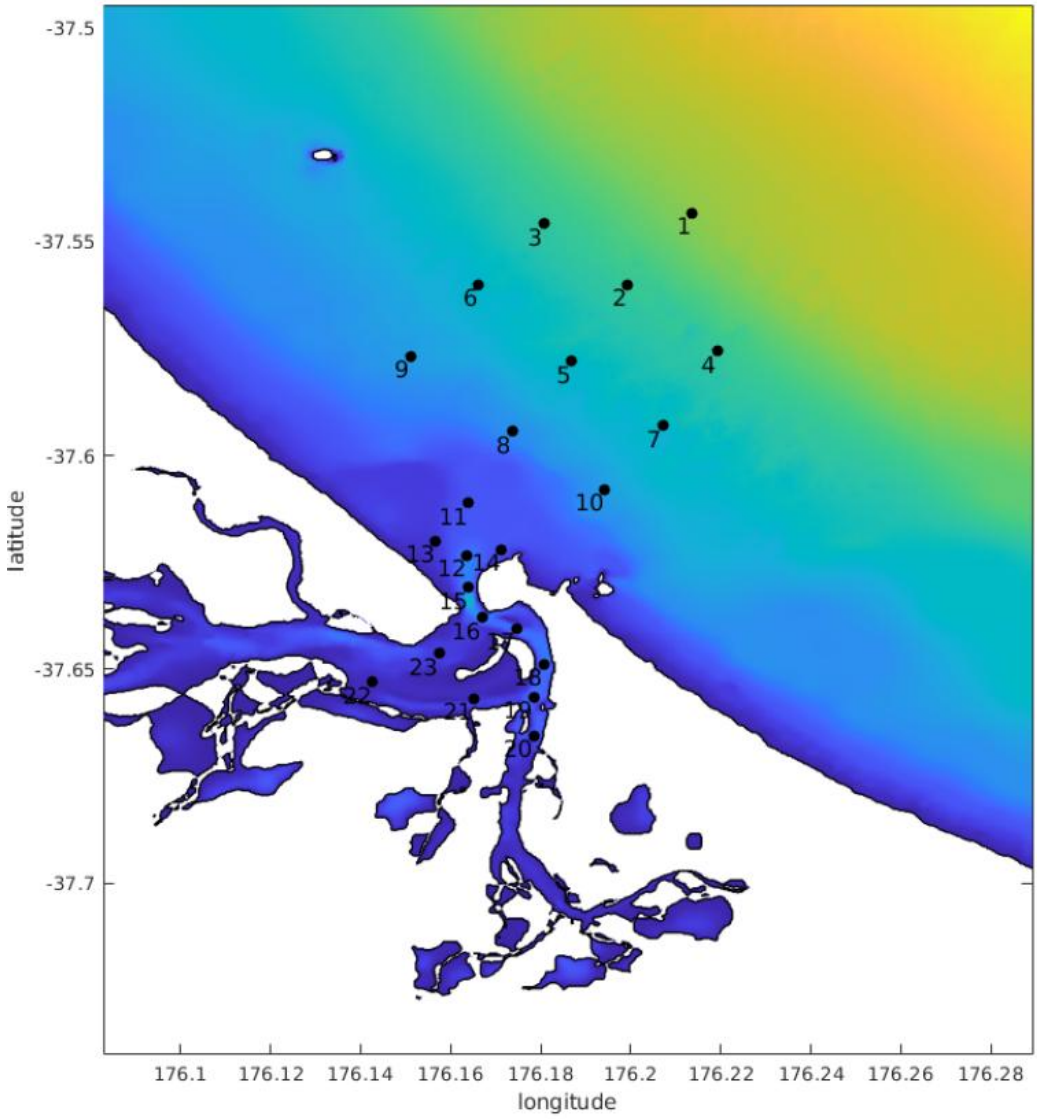


Figure 18 Map showing the positions of each 'measurement position' used to calculate the average soundscape changes from active dredging within the Port Zone.

Additional noise to the existing anthrophony at each of those measurement points is provided in Figure 21. It shows the representative spatial extent of soundscape changes from the dredging as on any given day during the July-August 2023 maintenance dredging campaign. It differs from the cumulative noise maps, which show the overall cumulative addition of noise (soundscape change) over the whole campaign rather than any given day.

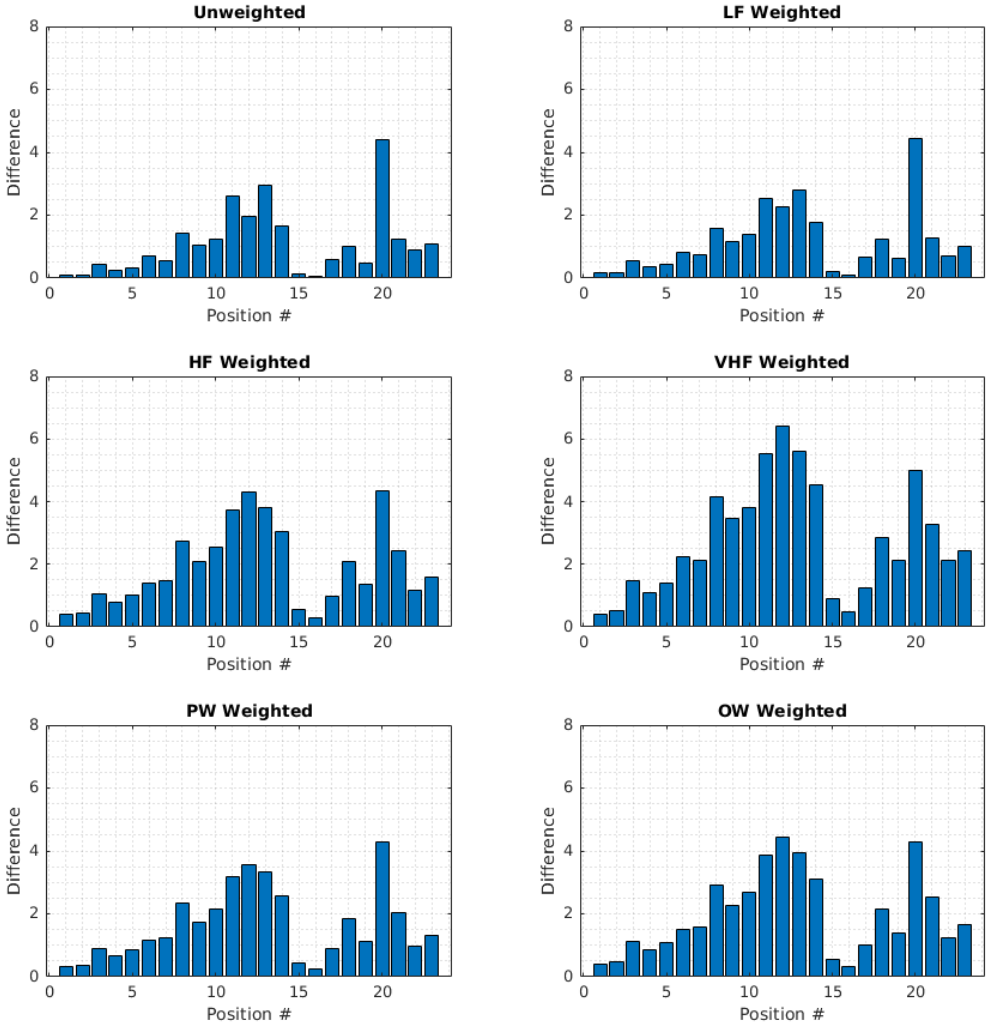


Figure 19 Plots showing the difference in the daily Leq levels between the AIS traffic levels and active dredging at each measurement point identified inFigure 17, over 40 days in July and August 2023.

Appendix E Effects modelling for marine mammals

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.

Temporary Threshold Shifts

When a receiver is exposed to high noise levels over an extended period, the cells within the inner ear being 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)[5]. The type and amount of threshold shift depends on the duration of 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 (for example, 24-hours as is the case with NMFS (2024)) that the noise source is present for (after M-weighting the noise), as defined as:

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

where L_E is the cumulative sound exposure level over 24 hours in this case, assuming a constant received L_p with no temporal variability over space and time (NMFS, 2024). However, if one was 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 dredging), then the actual exposure will 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[6]. This method "*allows one to determine the distance the receiver would have to remain in order to not exceed some predetermined exposure threshold"* (NMFS 2018). The safe distance method accounts for the source velocity, spectrum, 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:

[5] Referred to as Auditory Injury (AUD INJ) in NMFS (2024).

[6] 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.

$$R_0 = \frac{\pi}{E_0 v} SD \text{ (eq. 4)}$$

where *S* is the source factor, *D* is the duty cycle, *v* is the transit speed and E_0 is the exposure threshold[7] (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 dredging 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 was 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 simply reclassed functional hearing groups, essentially shifting MF to HF, and HF to a new group, VHF (very high frequency) (Table 9). The 2024 update to the NMFS guidance also includes new M-weighting functions, revised TTS/PTS thresholds and refers to PTS as Auditory Injury (AUD INJ).

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 9: 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 (PCW) in water.	True seals.
Otariid pinnipeds (OW) underwater	Other marine carnivores (OCW) in water.	Sea lions & fur seals.

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

Table 10: NMFS (2024) auditory threshold criteria for a non-impulsive noise source

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

Behavioural responses

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 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 dredging 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 for 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[8] or moderate[9] (respectively, a Southall severity score of 2-3 and 4-6 (Southall et al. 2007)). Briefly explained, the researchers 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 (Southall et al. 2007)) 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 was 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:

$$R = \frac{1-\left(\frac{L-B}{K}\right)^{-A}}{1-\left(\frac{L-B}{K}\right)^{-2A}} \text{ (eq. 5)}$$

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 2.5)) 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 near and within Tauranga Harbour, 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 September 2022 and July 2023). This provided a conservative baseline level specifically related to Tauranga harbour that is more useful than

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

[9] 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).

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. 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-responses functions were not used for pinnipeds. Data 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. 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[10]). Above 130 dB_{rms} re 1 µPa, the behavioural responses reviewed by Southall et al. (2007, 2019) are more moderate[11]. These unweighted thresholds were used to determine the potential onset for low and moderate severity behavioural responses in this assessment.

Auditory masking

Several species of marine mammals and fish are known to have hearing ranges that overlap with low-frequency 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). 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). Dredging noise (along with other anthropogenic noise sources commonly seen in coastal waters) has the potential to 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 marine mammals by quantifying the reduction in an animal's listening space. An animal's listening space is the immediate area (volume of ocean)

[10] 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).

[11] 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).

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). Those changes could be better modelled using the empirical data collected between September 2022 and July 2023 within the harbour.

As an animal receiver moves around an area when waterborne construction activities are underway, such as dredging, 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:

$$LSR = 100\left(1 - 10^{-2\frac{\Delta}{N}}\right)$$

where N is the frequency-dependent N_{PL} slope coefficient and Δ is the difference between the perceived base 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 dredging, 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 base ambient noise level, is the maximum of the listener's hearing threshold (audiogram value) and the ambient level inside a critical band, approximated herein by 1/3 octave bands (Erbe et al. 2016; Pine et al. 2018). Audiogram values for bottlenose dolphins and killer whales (reconstructed from Nedwell et al. 2004) were used to estimate hearing thresholds in each critical band. There are no audiograms available for the New Zealand fur seal or mystecete whales. Consequently, a Northern fur seal (*Callorhinus ursinus*) and leopard seal (*Hydrurga leptonyx*) audiogram (Nedwell et al. 2004) and modelled audiogram for the fin whale (Cranford & Krysl 2015) were used.

Using modelled audiograms requires special care, as they are based on the structure of the skull and no true hearing data is available (as AEP experiments, or behavioural audiograms, are not able to be done on mytecetes). However, their use in scientific studies occurs when no other data exists – as is the case with this assessment.

The N_{PL} slope coefficient was calculated by curve fitting the empirical N_{PL} of each 1/3 octave band between 32 Hz and 32 kHz 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):

$$\Delta L_{SE} = SL - PL - NL_1 - \Delta L_{DT}$$

where signal excess (ΔL_{SE}) is set to zero to indicate detection onset, NL_1 was the 5th 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.

The empirical source levels, ambient levels and audiograms are provided in Figure 22.

The LSR was then calculated for each decidecade band at each depth 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).

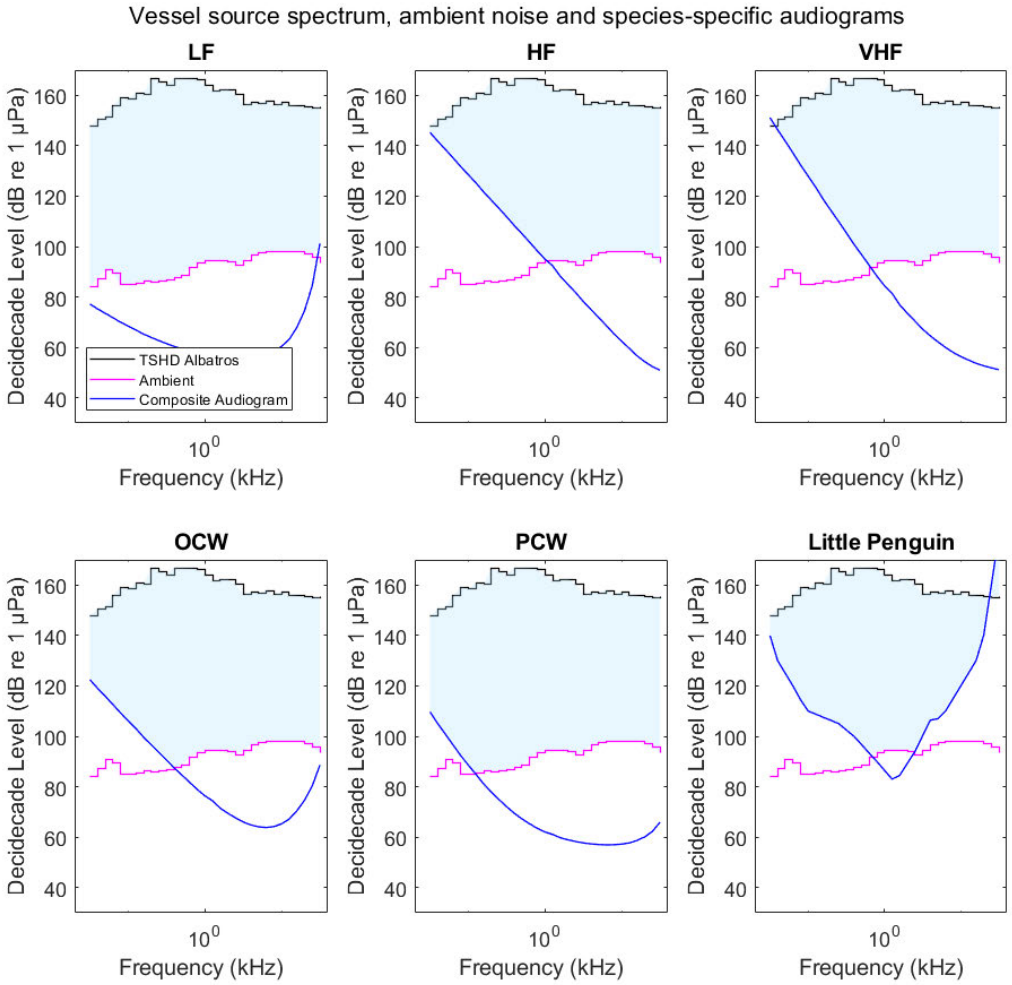


Figure 20: Decidecade source levels for the *Albatros* actively dredging, RMS decidecade ambient sound levels recorded during the PAM survey (1-min Leq values between Apr-Jul 2024) and NMFS (2024) composite audiograms for each functional hearing group, as well as Wei & Erbe (2024)'s little penguin audiogram. The blue shading represents the area used as NL1 in the LSR equation and the larger the area, the more sensitive a listener is to masking effects.

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. The exclusion of masking release is an important assumption as it means the results are likely to overstate true masking.

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

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 quietest background noise conditions[12]. 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 dredging.

Audibility limits were calculated based on the hearing sensitivities of killer whales, common dolphins, bottlenose dolphins, New Zealand fur seals (approximated based on the Northern fur seal, being the closest phylogenetic relative to the NZ fur seal for which audiogram studies have been undertaken), leopard seals and baleen whales in the context of the ambient soundscape.

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. Furthermore, by basing the calculations on the basement noise level (5th percentile), the audibility limit range is during the quietest noise conditions (exceeded 95% of the time). Masking release mechanisms have also been left out for the same reason. The key assumption, therefore, is that detectability of the anthropogenic noise

[12] Quietest background sound level was defined as the 5th percentile levels, which means that level is exceeded 95% of the time.

is omnidirectional[13] and directly relates to the difference between the ambient sound, the anthropogenic noise and hearing thresholds at each critical band.

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Appendix F Noise effects contours

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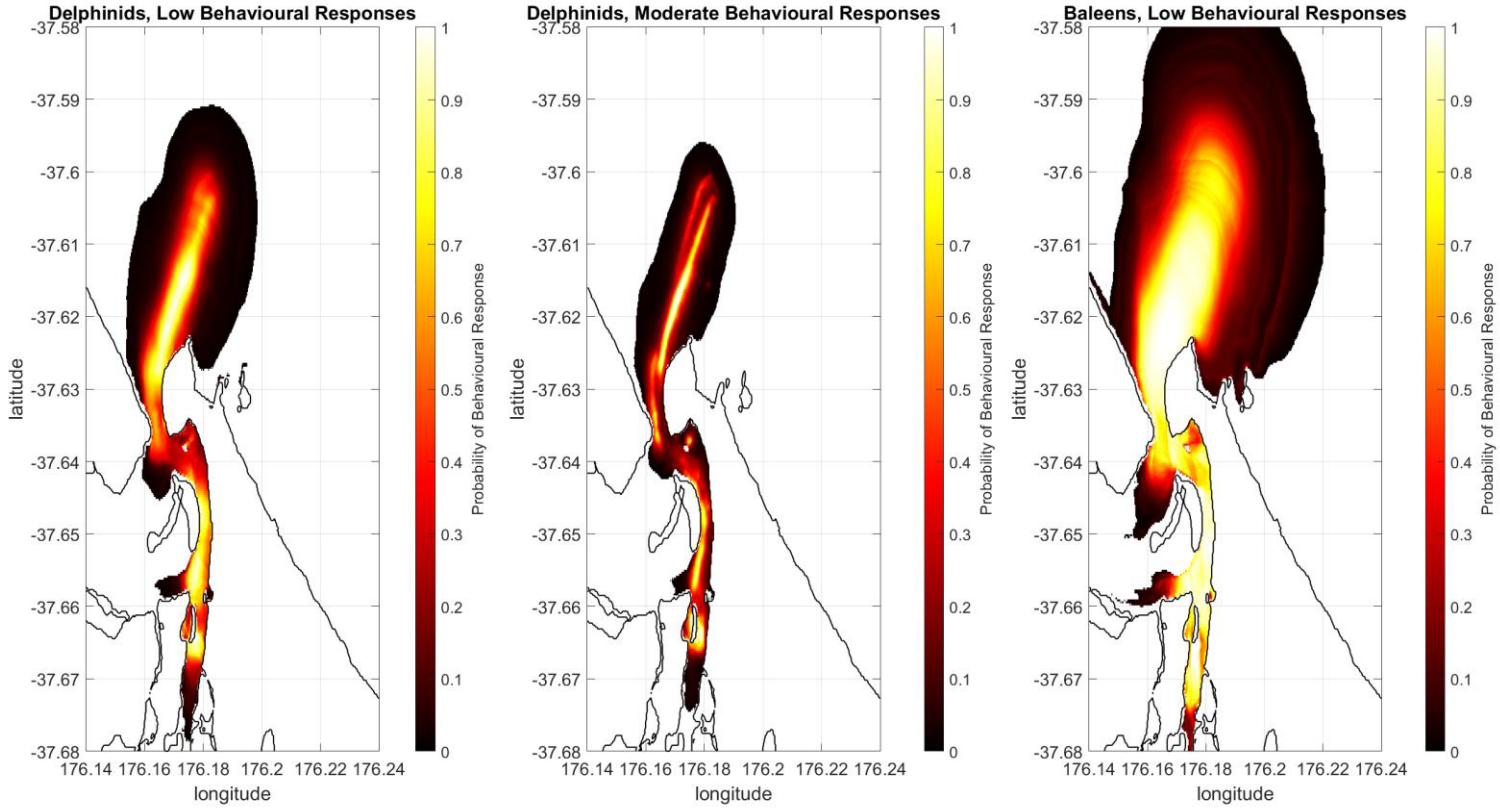


Figure 21 Low and moderate behavioural response risk for dolphin species (Delphinidae) (left and centre panels) and baleen whales (right panel) from the TSHD vessel actively dredging.

Note the plots show the area over the whole 2023 maintenance dredging campaign and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

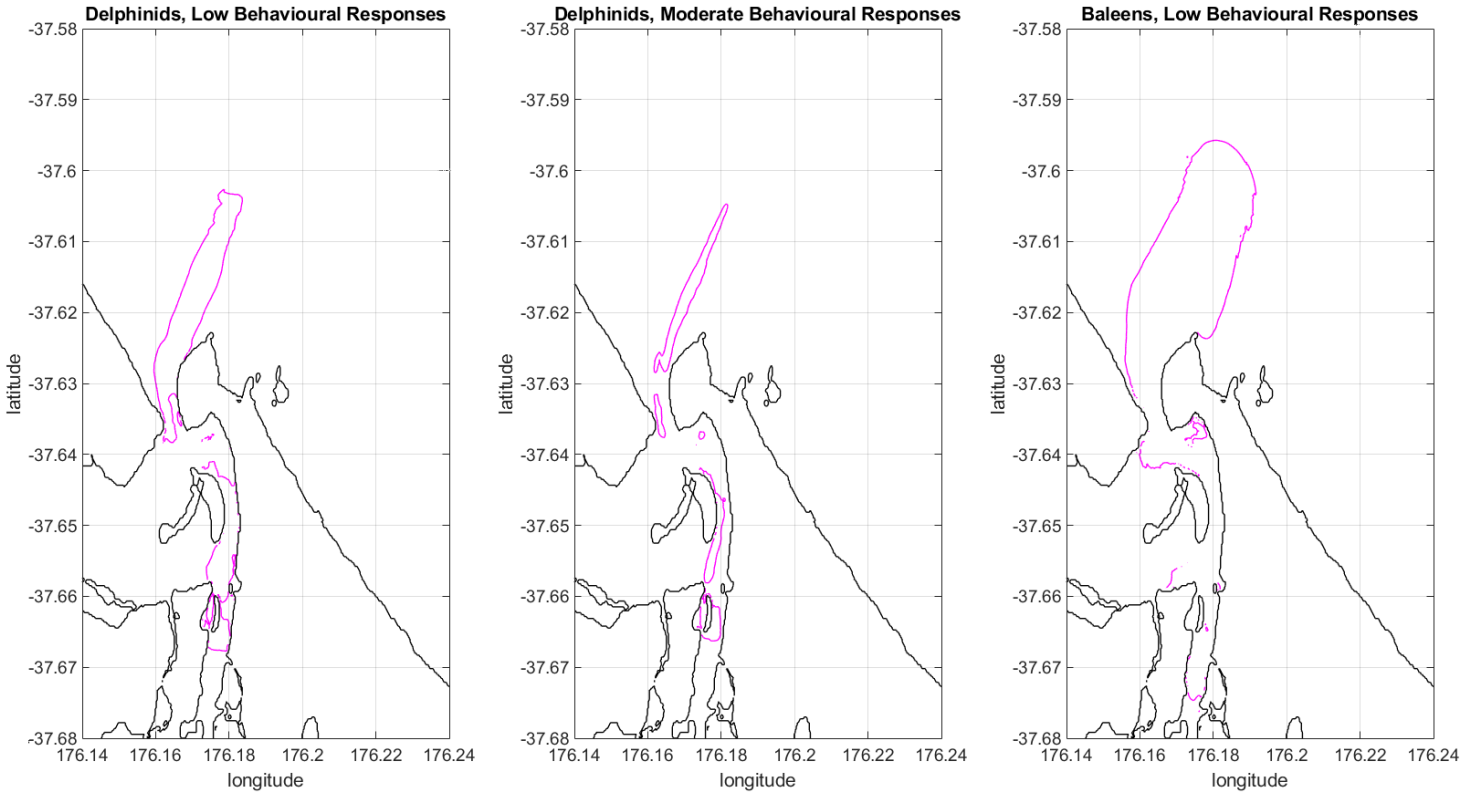


Figure 22 Contours showing the 50% risk isopeth for low and moderate behavioural response risk for dolphin species (Delphinidae) (left and centre panels) and baleen whales (right panel) from the TSHD vessel actively dredging.

Note the plots show the area over the whole 2023 maintenance dredging campaign and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

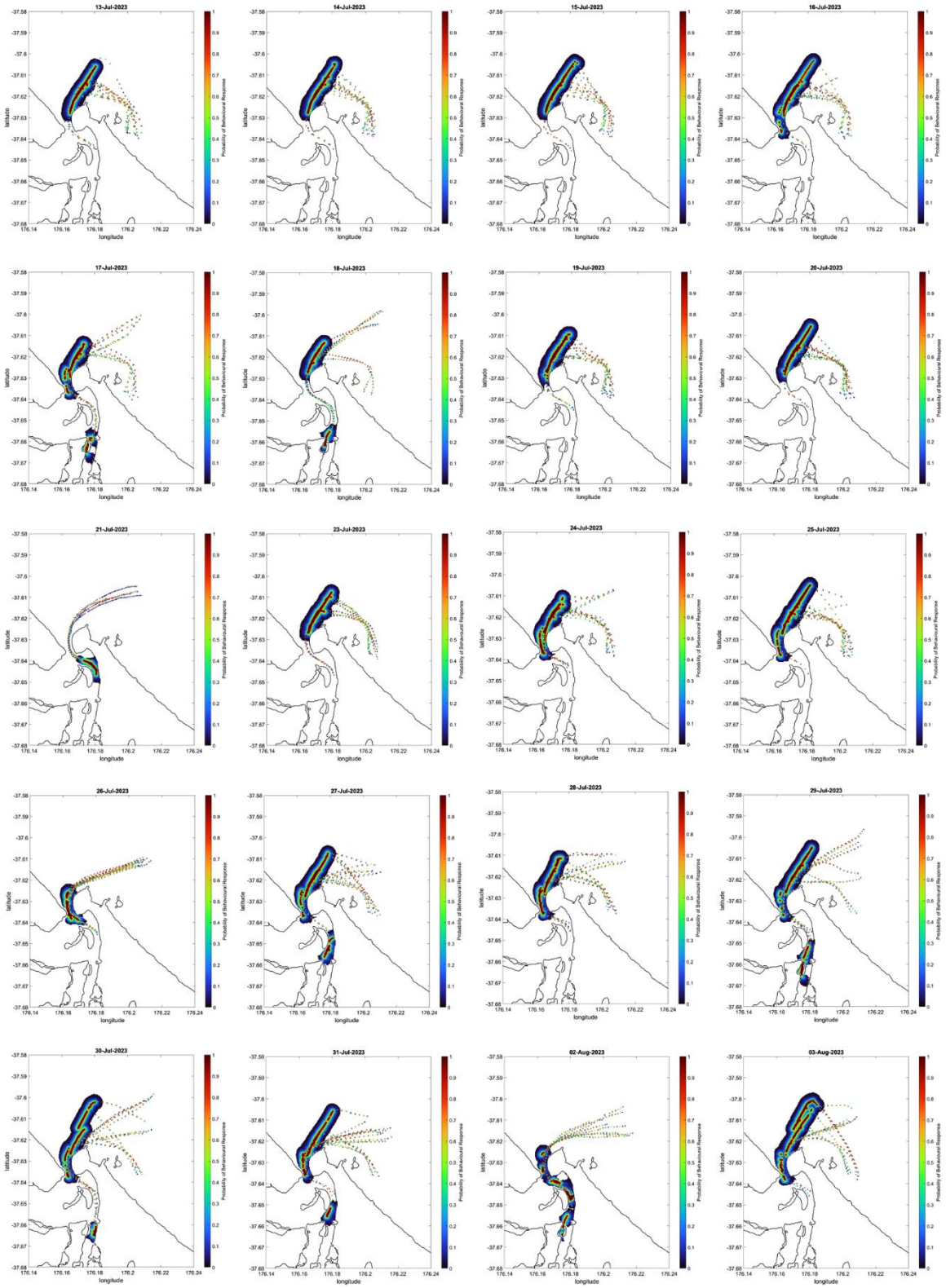


Figure 23 Behavioural response risk for dolphin species (Delphinidae) from the TSHD *Albatros* actively dredging for each day from the 13th July to 3rd August 2023. These models were used to create the overall model provided inFigure 20.

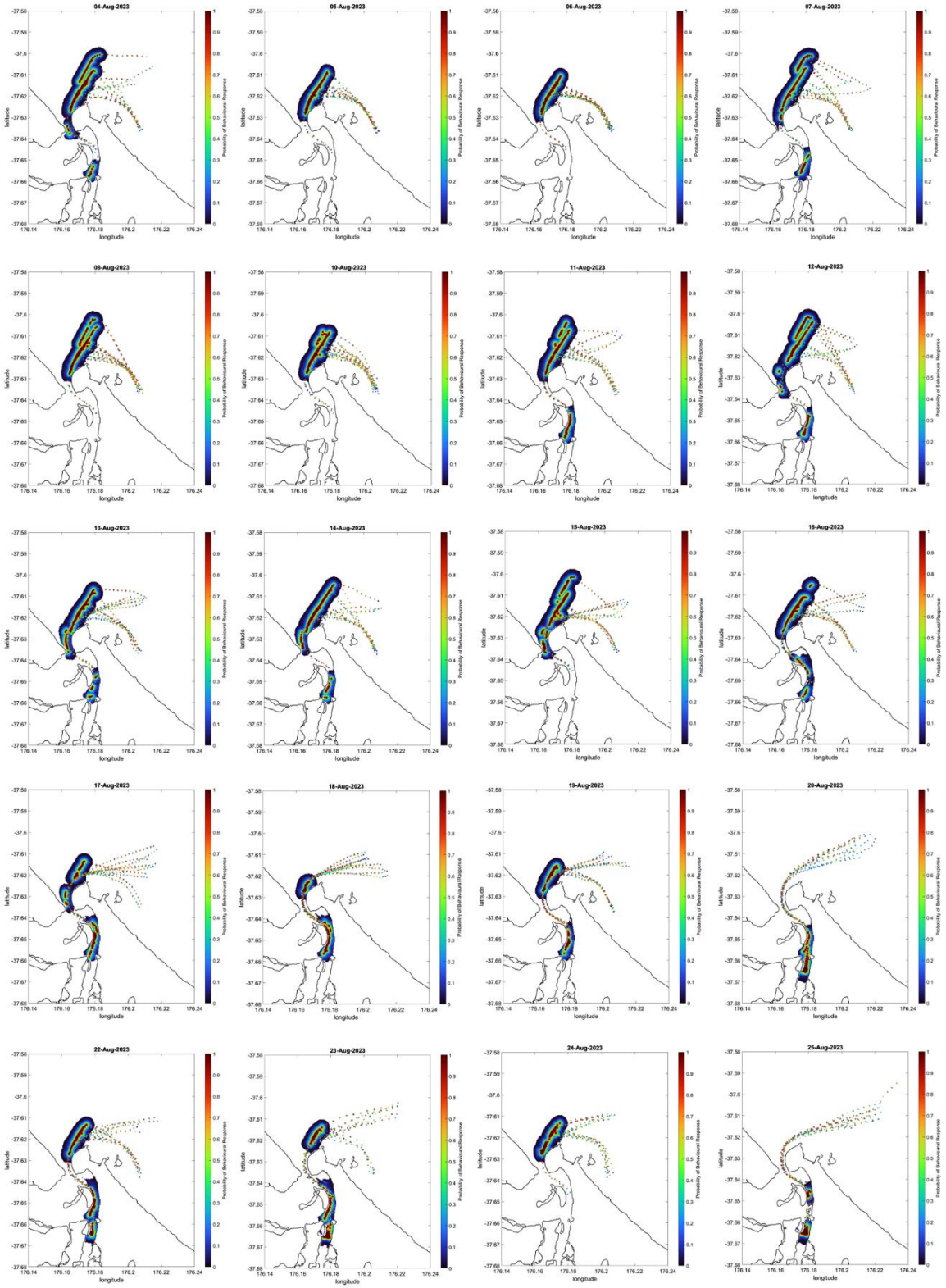


Figure 24 Behavioural response risk for dolphin species (Delphinidae) from the TSHD *Albatros* vessel actively dredging for each day from the 4th to 25th August 2023. These models were used to create the overall model provided inFigure 20.

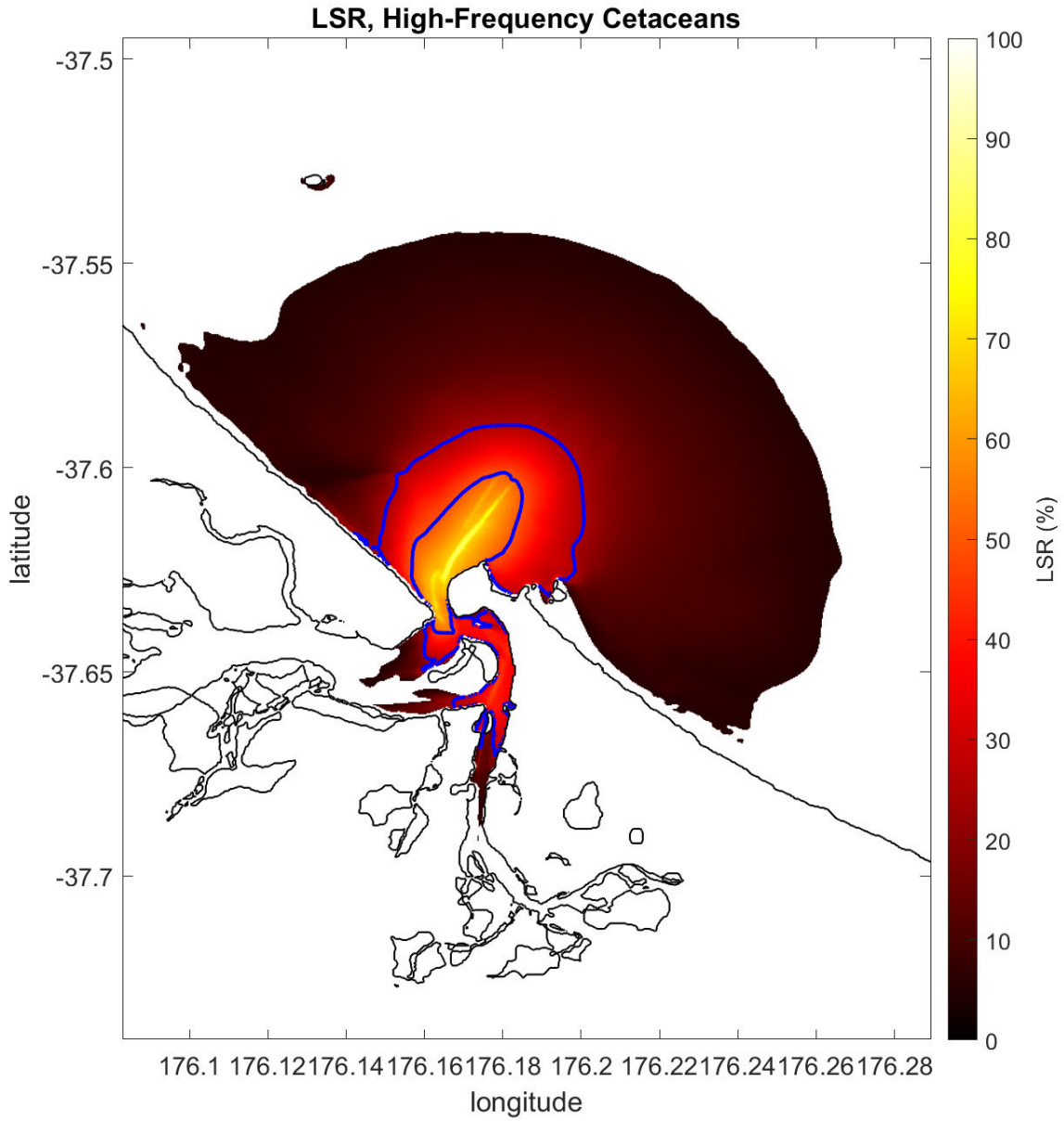


Figure 25 Map showing the spatial extent of listening space reductions for odontocete species (NMFS (2024) functional hearing group HF) from the TSHD *Albatros* actively dredging, averaged over a single 24-hour period. The blue contours represent 50% and 25% LSR.

Note the map shows the average over a whole day and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

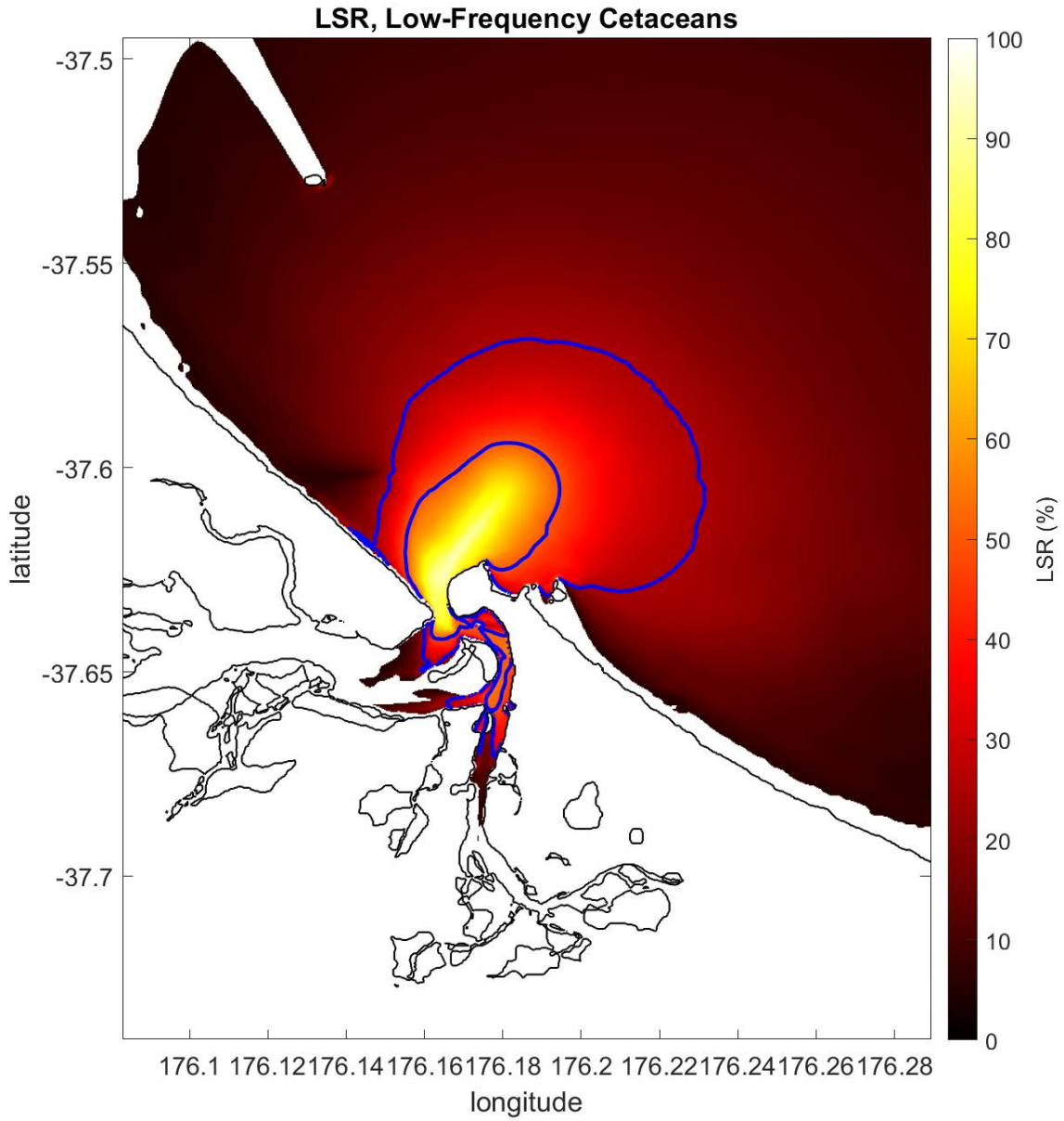


Figure 26 Map showing the spatial extent of listening space reductions for baleen whales (NMFS (2024) functional hearing group LF) from the TSHD *Albatros* actively dredging, averaged over a single 24-hour period. The blue contours represent 50% and 25% LSR.

Note the map shows the average over a whole day and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

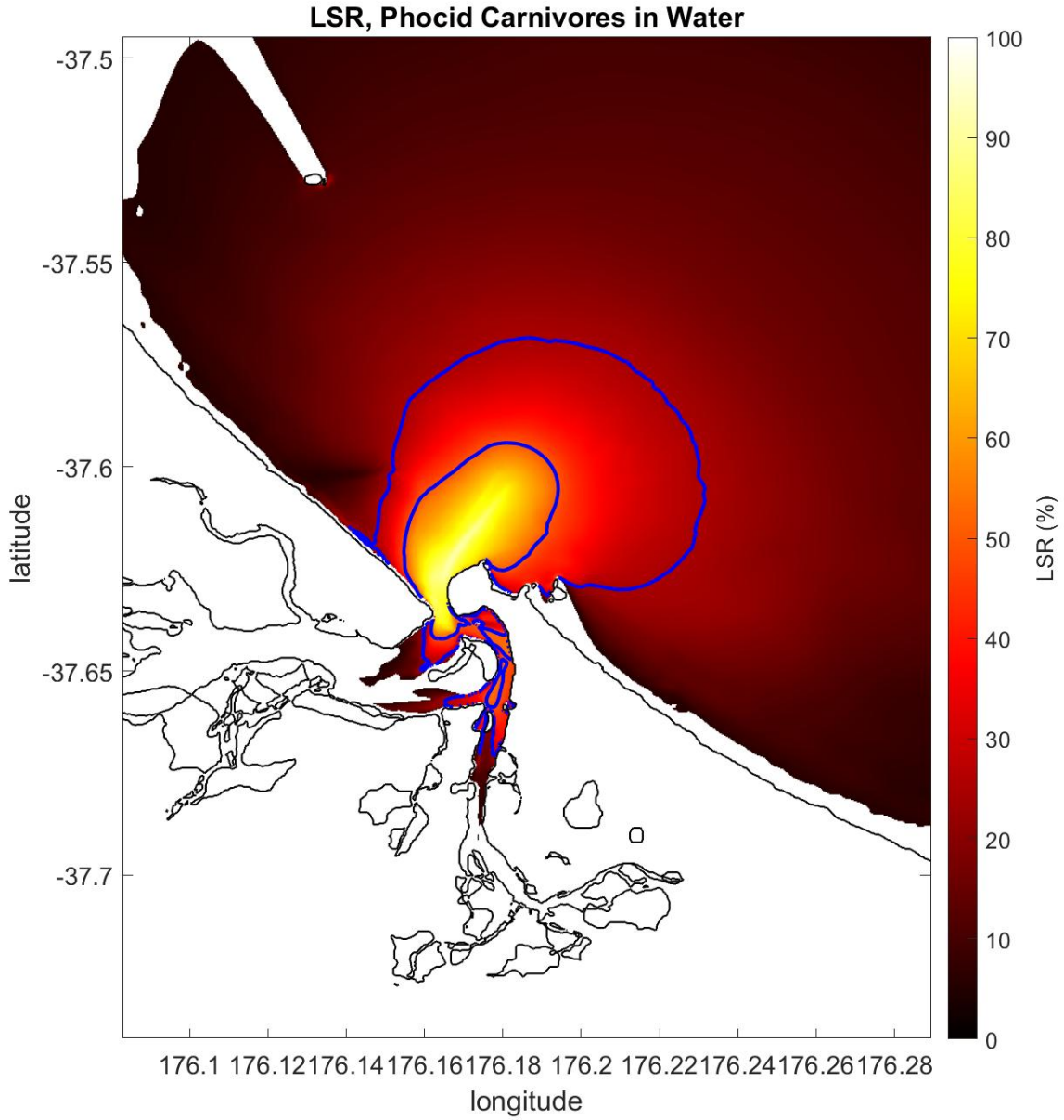


Figure 27 Map showing the spatial extent of listening space reductions for phocid pinnipeds underwater water (NMFS (2024) functional hearing group PCW) from the TSHD *Albatros* actively dredging, averaged over a single 24-hour period. The blue contours represent 50% and 25% LSR.

Note the map shows the average over a whole day and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

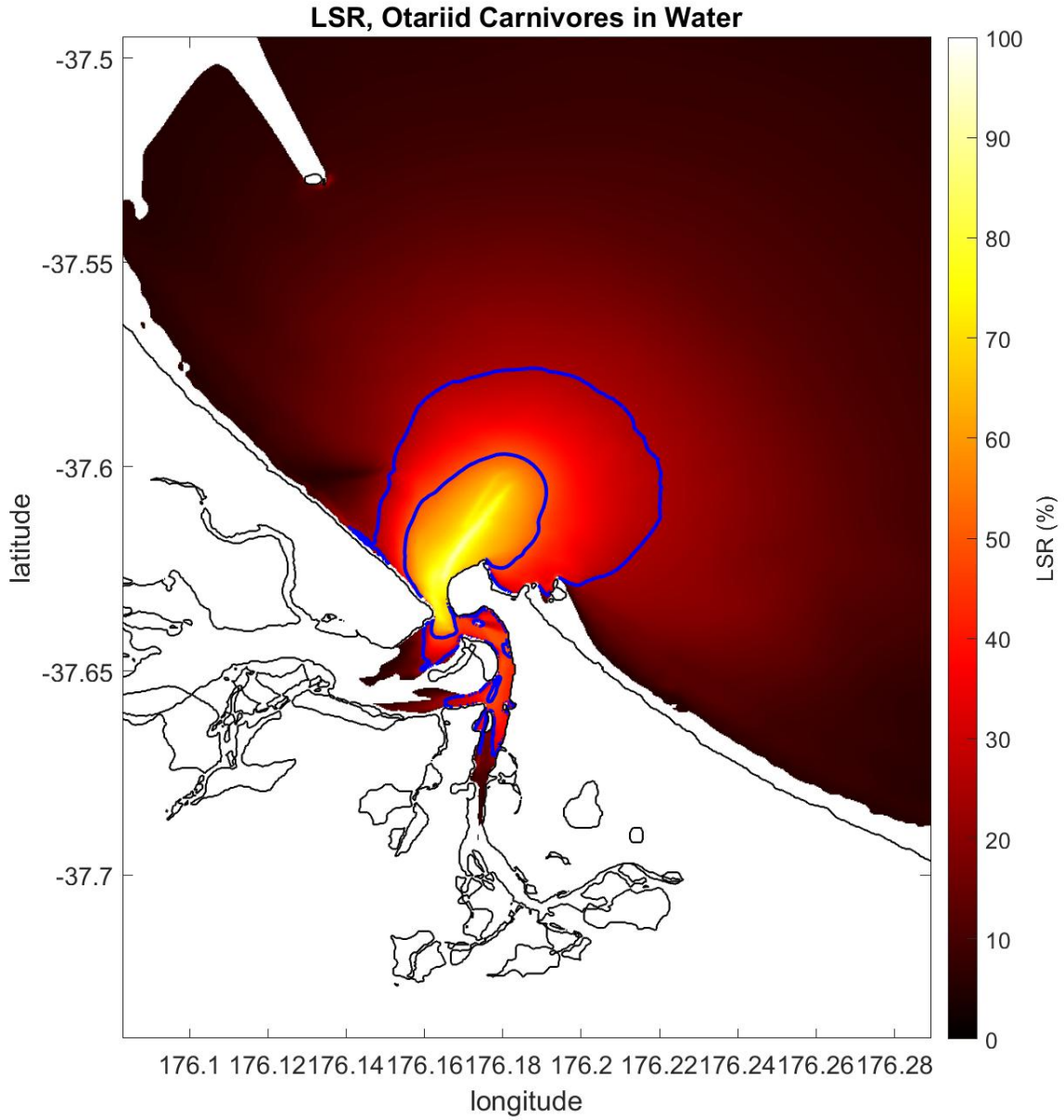


Figure 28 Map showing the spatial extent of listening space reductions for otariid pinnipeds underwater water (NMFS (2024) functional hearing group OCW) from the TSHD *Albatros* actively dredging, averaged over a single 24-hour period. The blue contours represent 50% and 25% LSR.

Note the map shows the average over a whole day and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

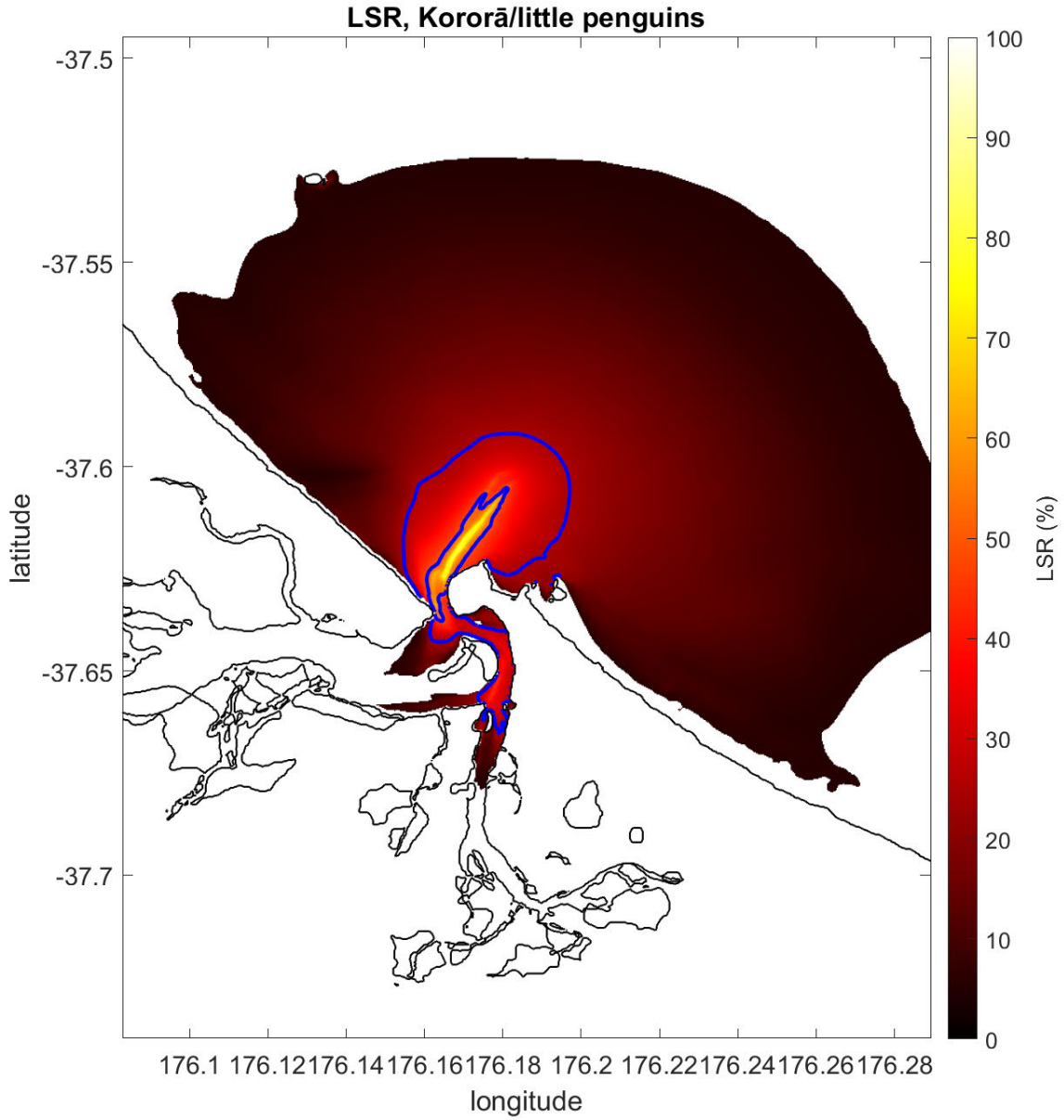


Figure 29 Map showing the spatial extent of listening space reductions for little penguins/kororā from the TSHD *Albatros* actively dredging, averaged over a single 24-hour period. The blue contours represent 50% and 25% LSR.

Note the map shows the average over a whole day and is not the acoustic footprint or effect at a single point in time (as provided in the effects tables within the report).

Appendix G Vessel and dredging noise models

AIS Traffic

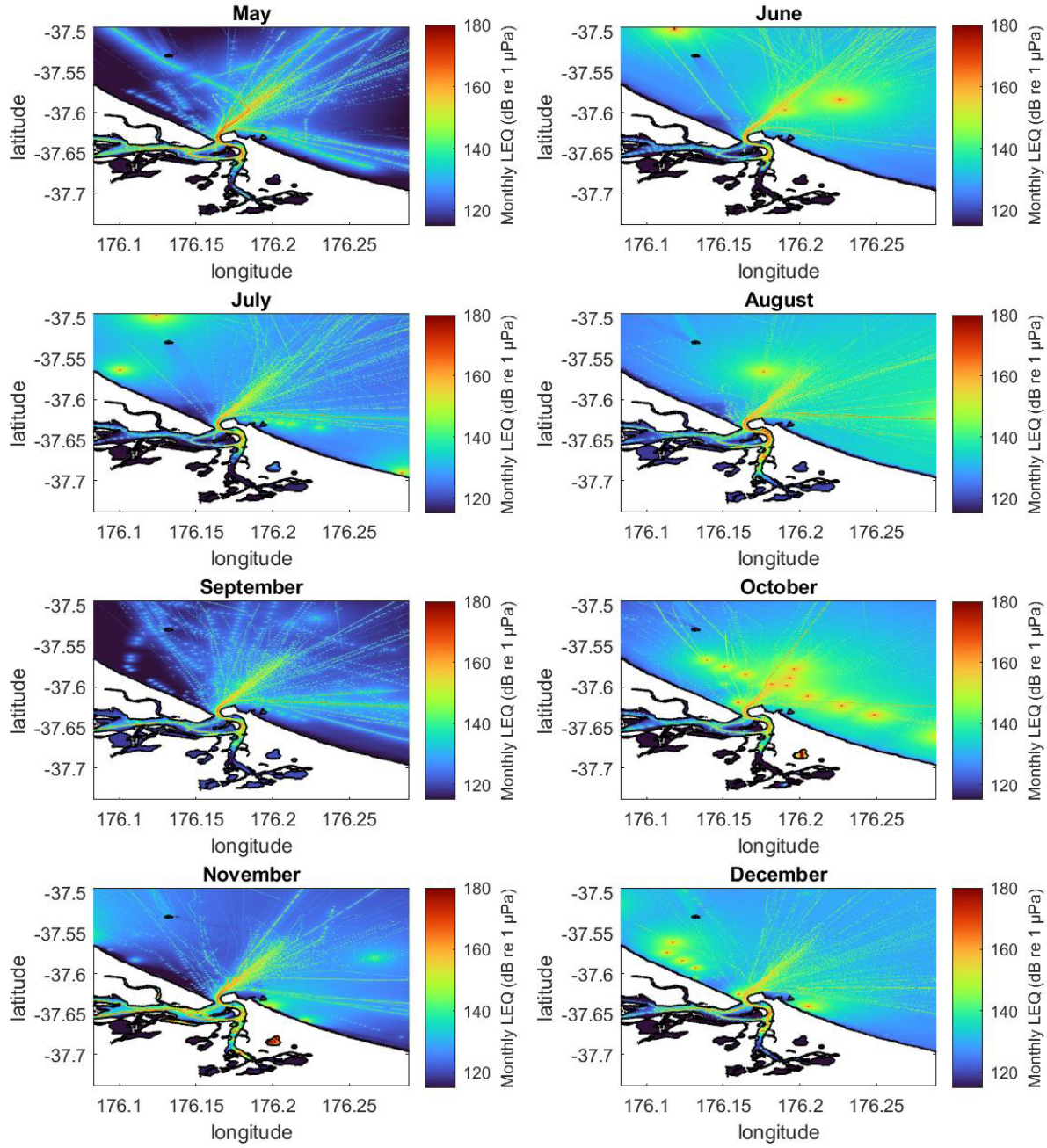


Figure 30 Monthly Leq (dB re 1 µPa) map of all AIS vessels for each month modelled in 2022, representing the minimal existing anthrophonic noise levels in the area.

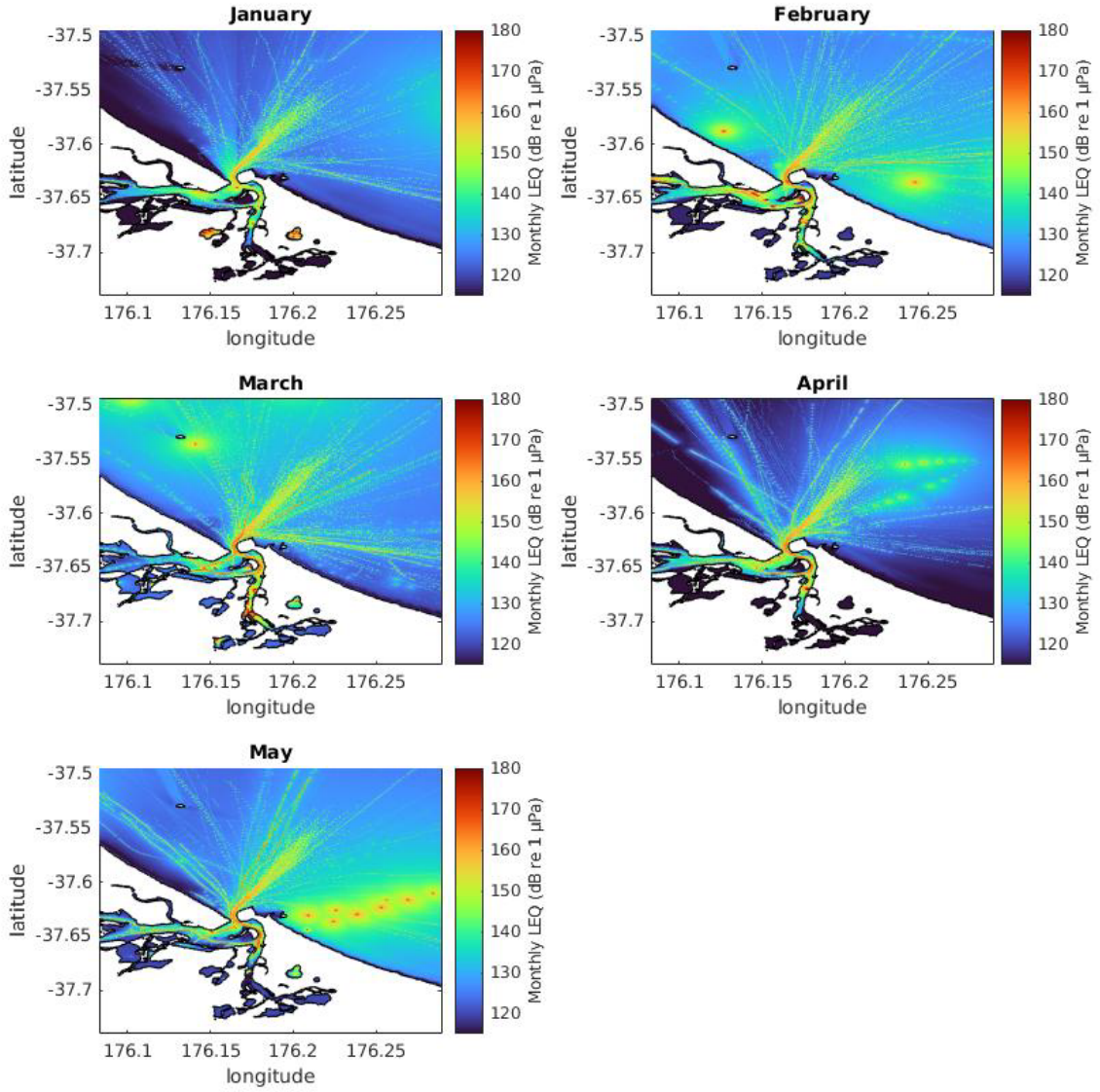


Figure 31 Monthly Leq (dB re 1 µPa) maps of all AIS vessels for each month modelled in 2023, representing the minimal existing anthrophonic noise levels in the area.

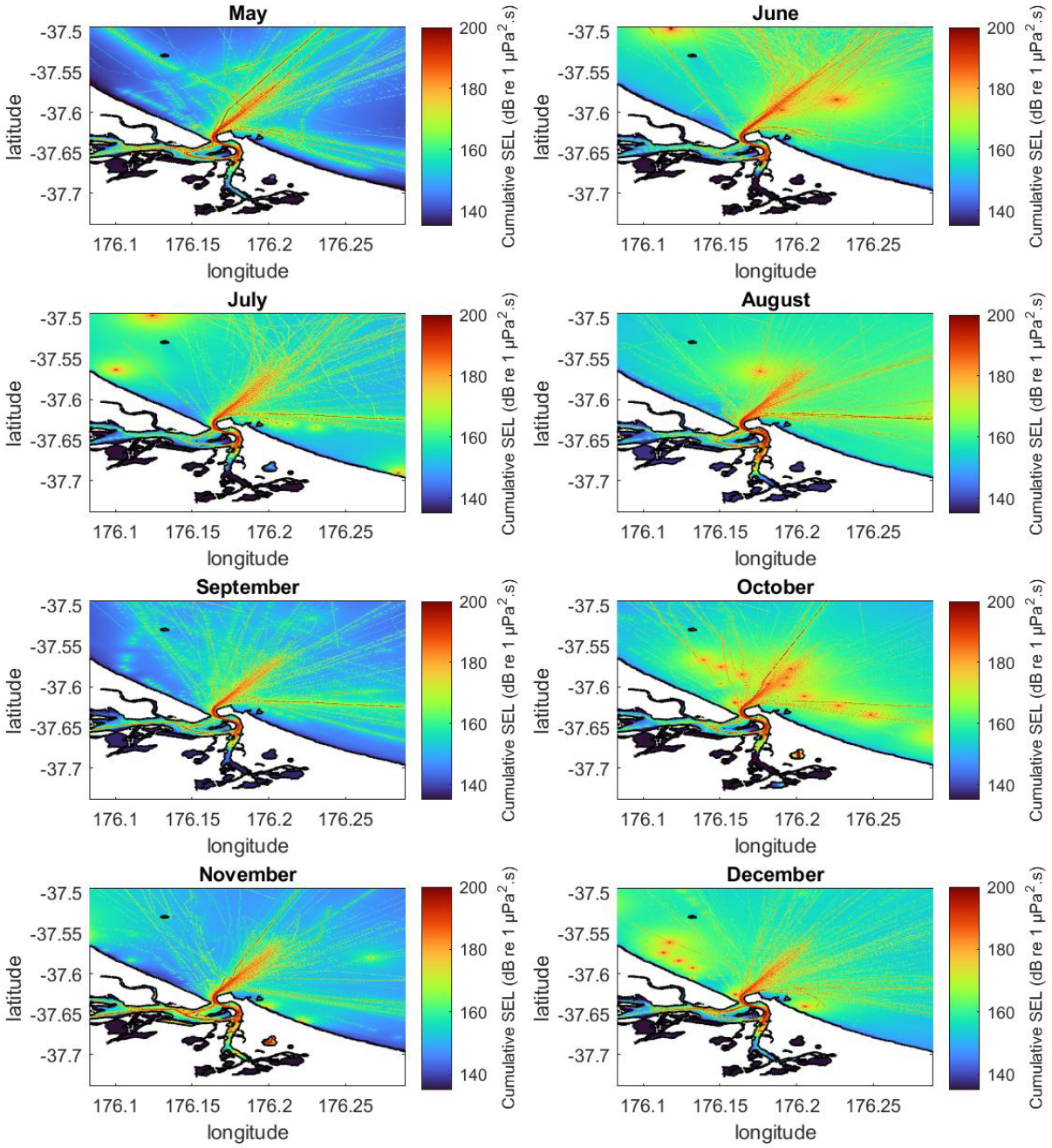


Figure 32 Monthly cumulative sound exposure level (L_E) map of all AIS vessels for each month modelled in 2022, representing the minimal existing anthrophonic noise levels in the area.

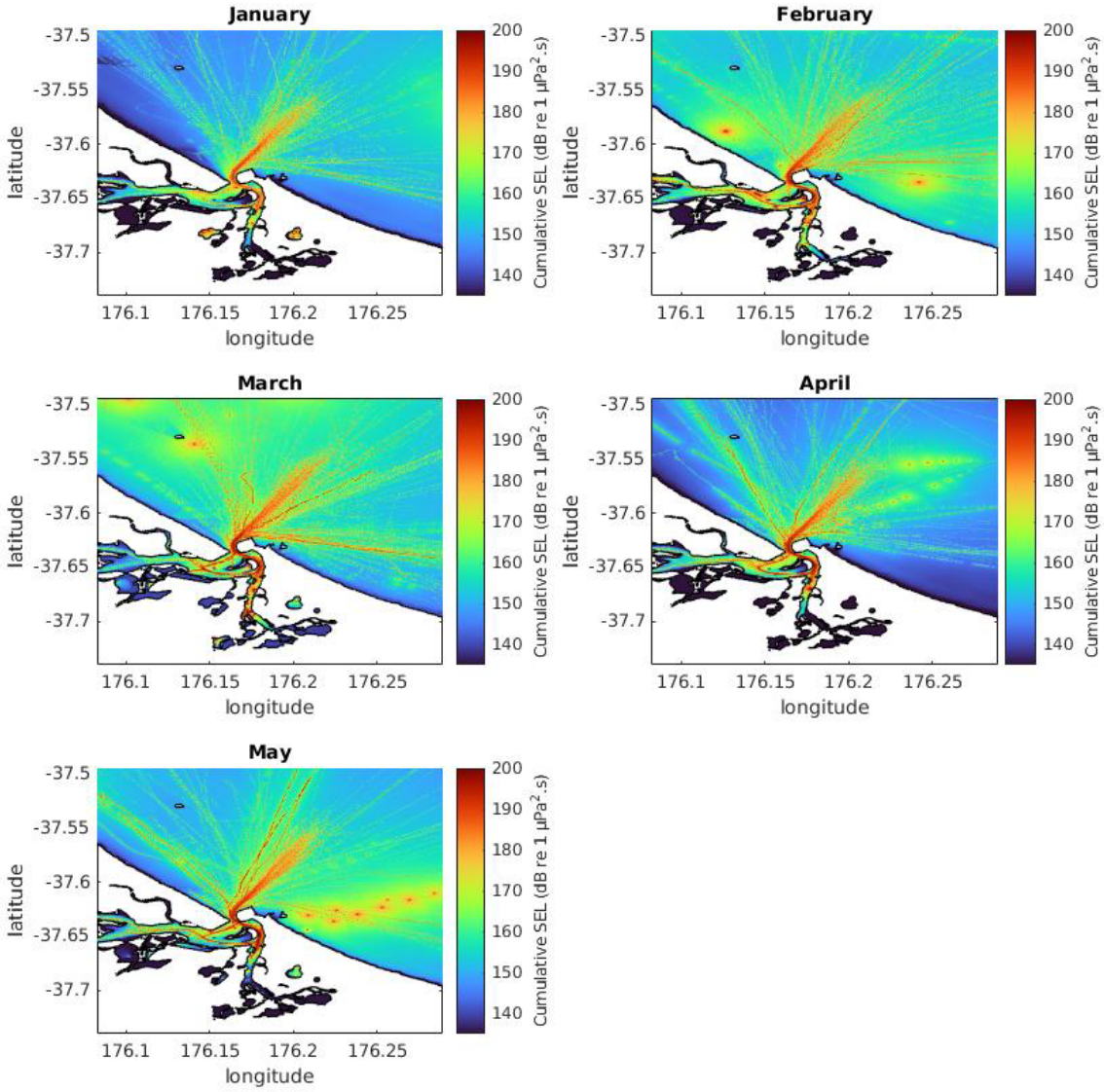


Figure 33 Monthly cumulative sound exposure level (dB re 1 µPa²•s) map of all AIS vessels for each month modelled in 2023, representing the minimal existing anthrophonic noise levels in the area.

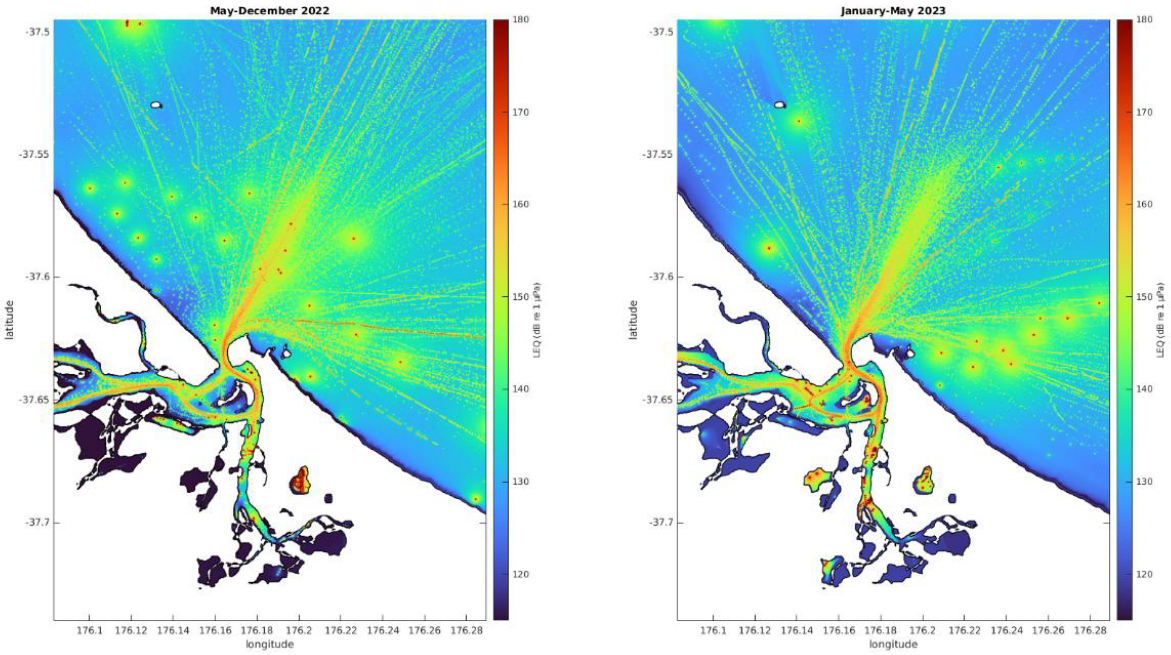


Figure 34 Six-monthly Leq maps of all AIS vessels between May-December 2022 (left panel) and January-May 2023 (right panel).

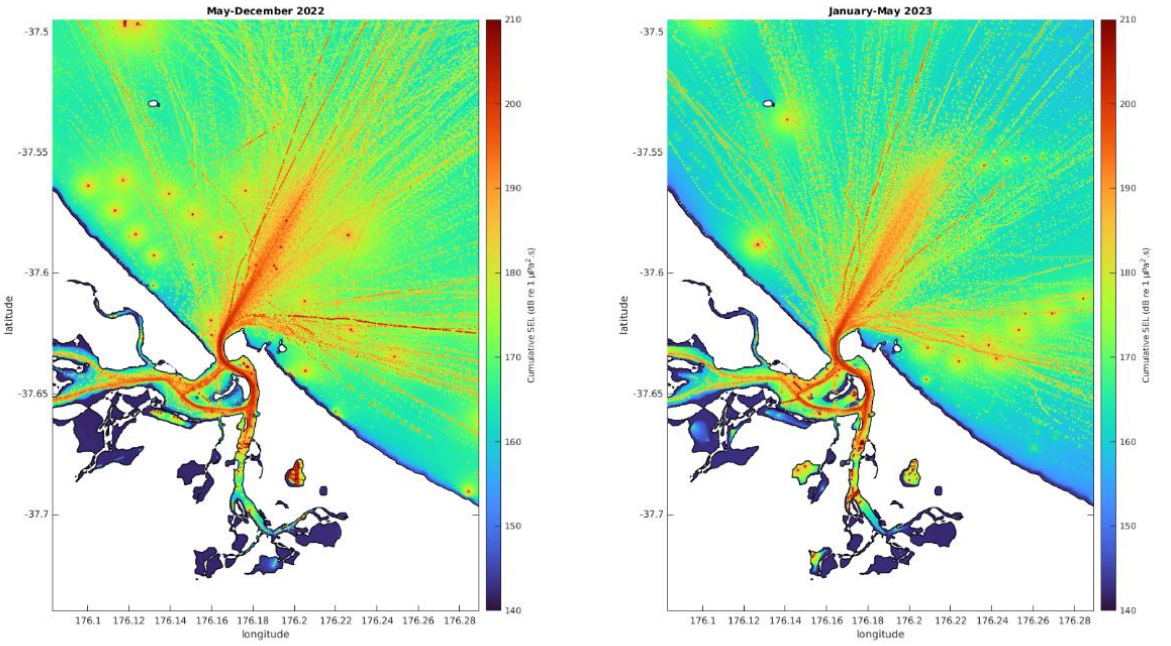


Figure 35 Six-monthly cumulative sound exposure level (dB re 1 µPa^2•s) maps of all AIS vessels between May-December 2022 (left panel) and January-May 2023 (right panel).

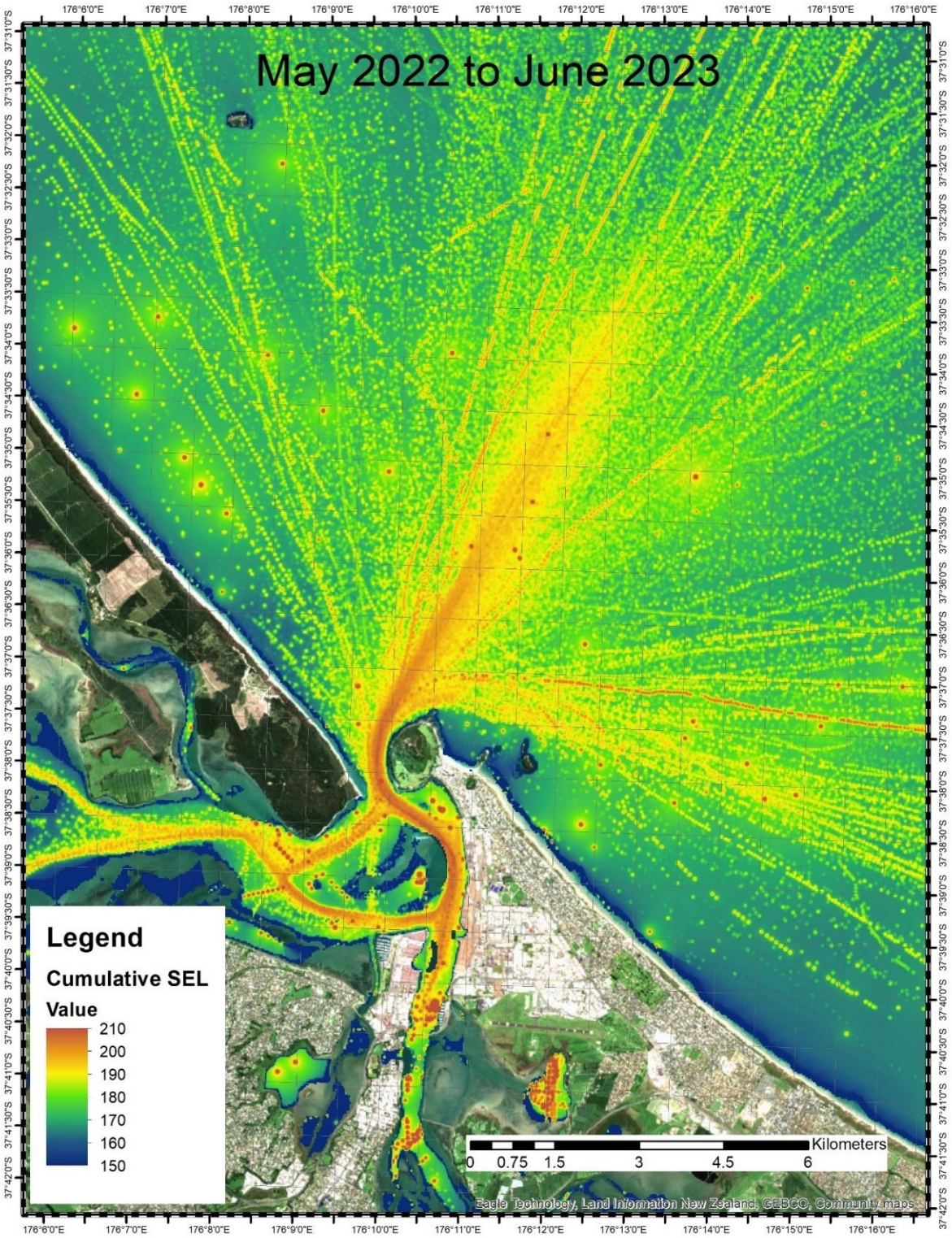


Figure 36 Cumulative AIS vessel noise inside and outside Tauranga Harbour, representing the region's minimal anthrophonic environment over 12 months in 2022-2023.

TSHD Dredging

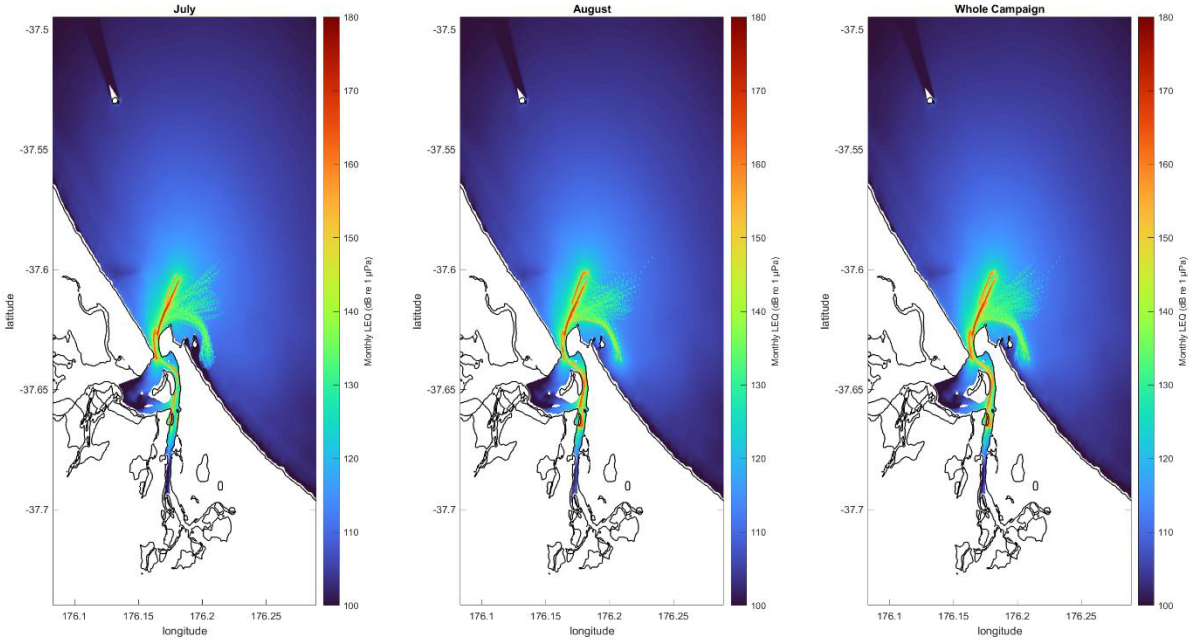


Figure 37 Monthly L_{eq} (dB re 1 µPa) maps of the 2023 maintenance dredging campaign (left and centre panels), and complete campaign (right panel).

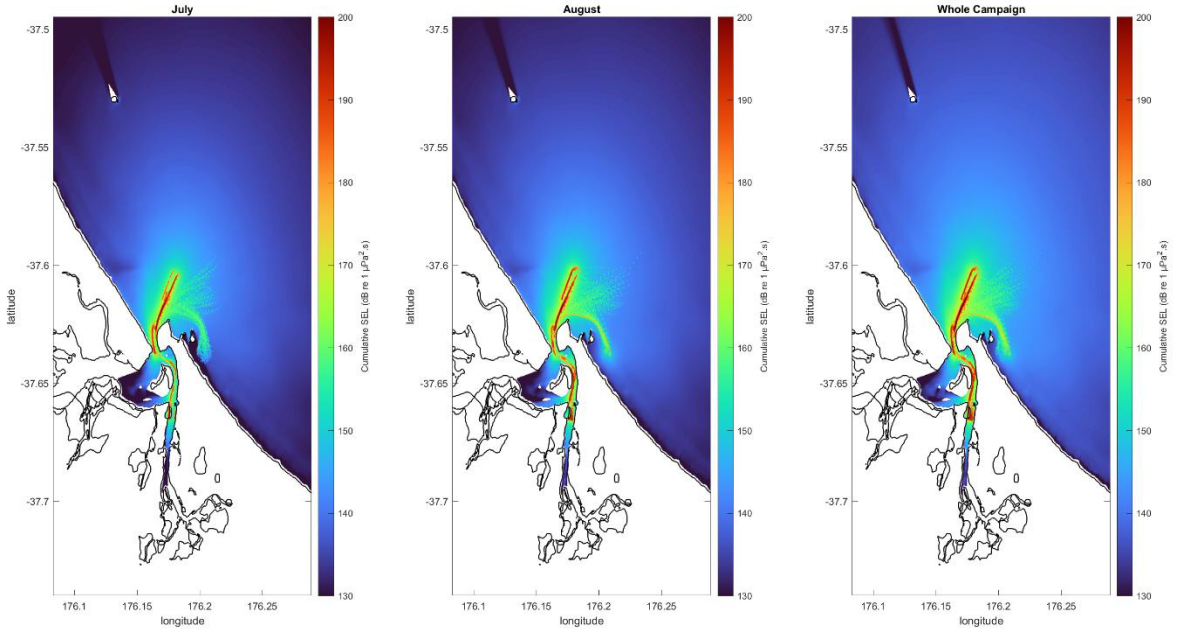


Figure 38 Monthly cumulative sound exposure level (dB re 1 $\mu Pa^2 \cdot s$) maps of the 2023 maintenance dredging campaign (left and centre panels), and complete campaign (right panel).

Cumulative noise models

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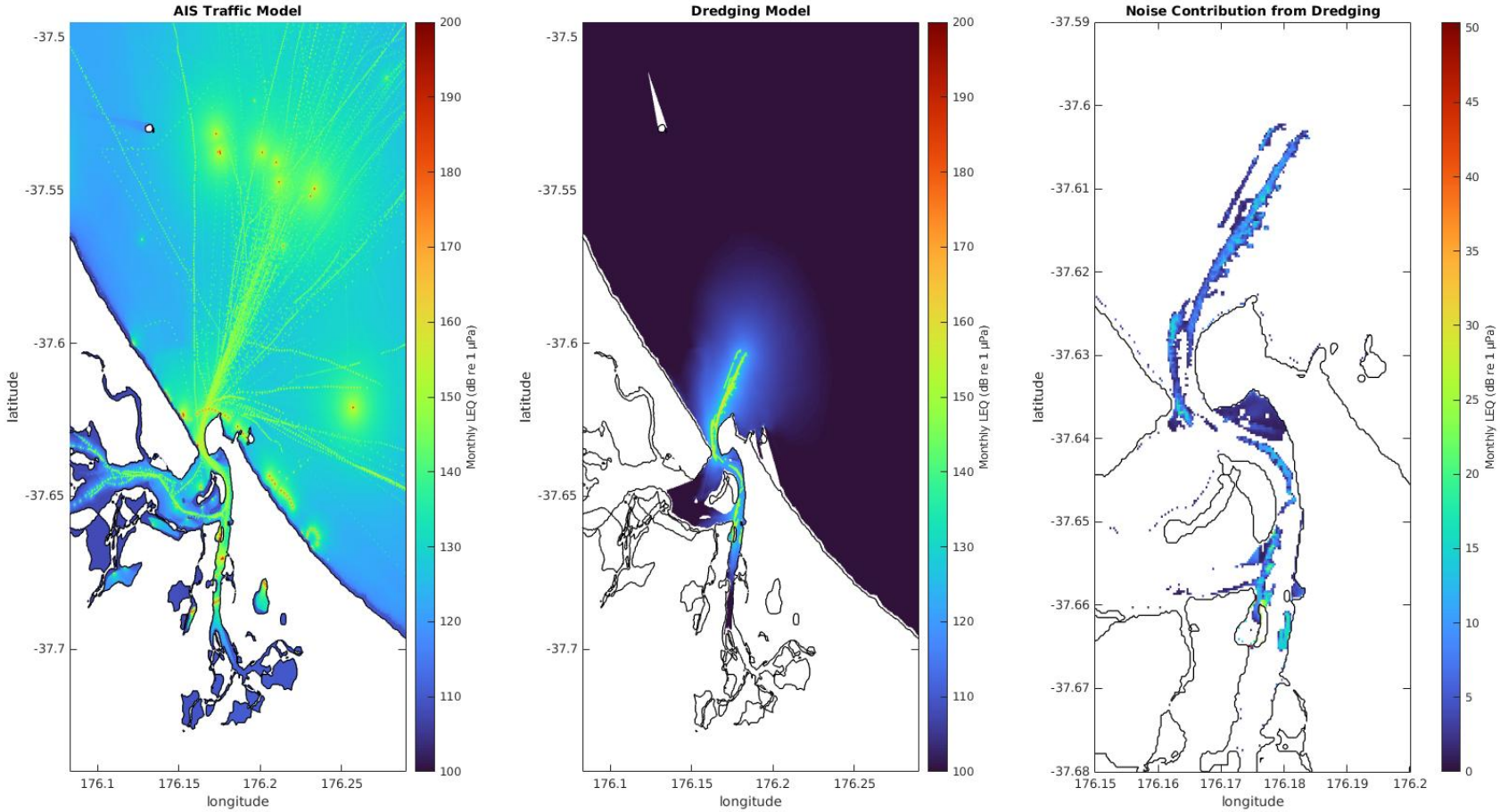


Figure 39 Monthly Leq levels (dB re 1 µPa) for July 2023 from the AIS traffic only (left panel), the TSHD active dredging during the same time (centre panel) and the difference between the two (right panel). The difference between the two represents the change to the background anthrophony directly from the dredging.

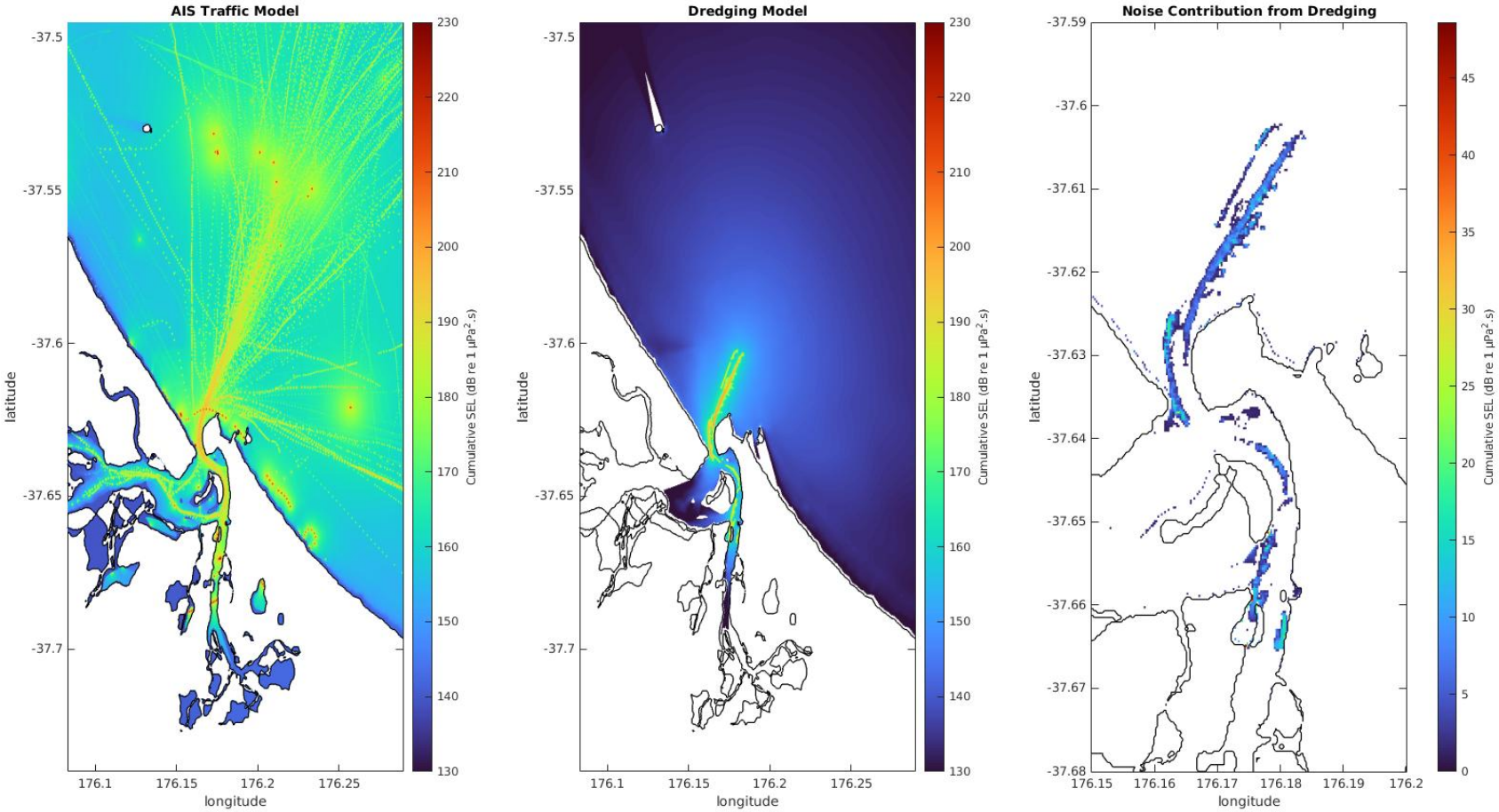


Figure 40 Monthly cumulative sound exposure levels (dB re 1 µPa²•s) for July 2023 from the AIS traffic only (left panel), the TSHD active dredging during the same time (centre panel) and the difference between the two (right panel). The difference between the two represents the change to the background anthrophony directly from the dredging.

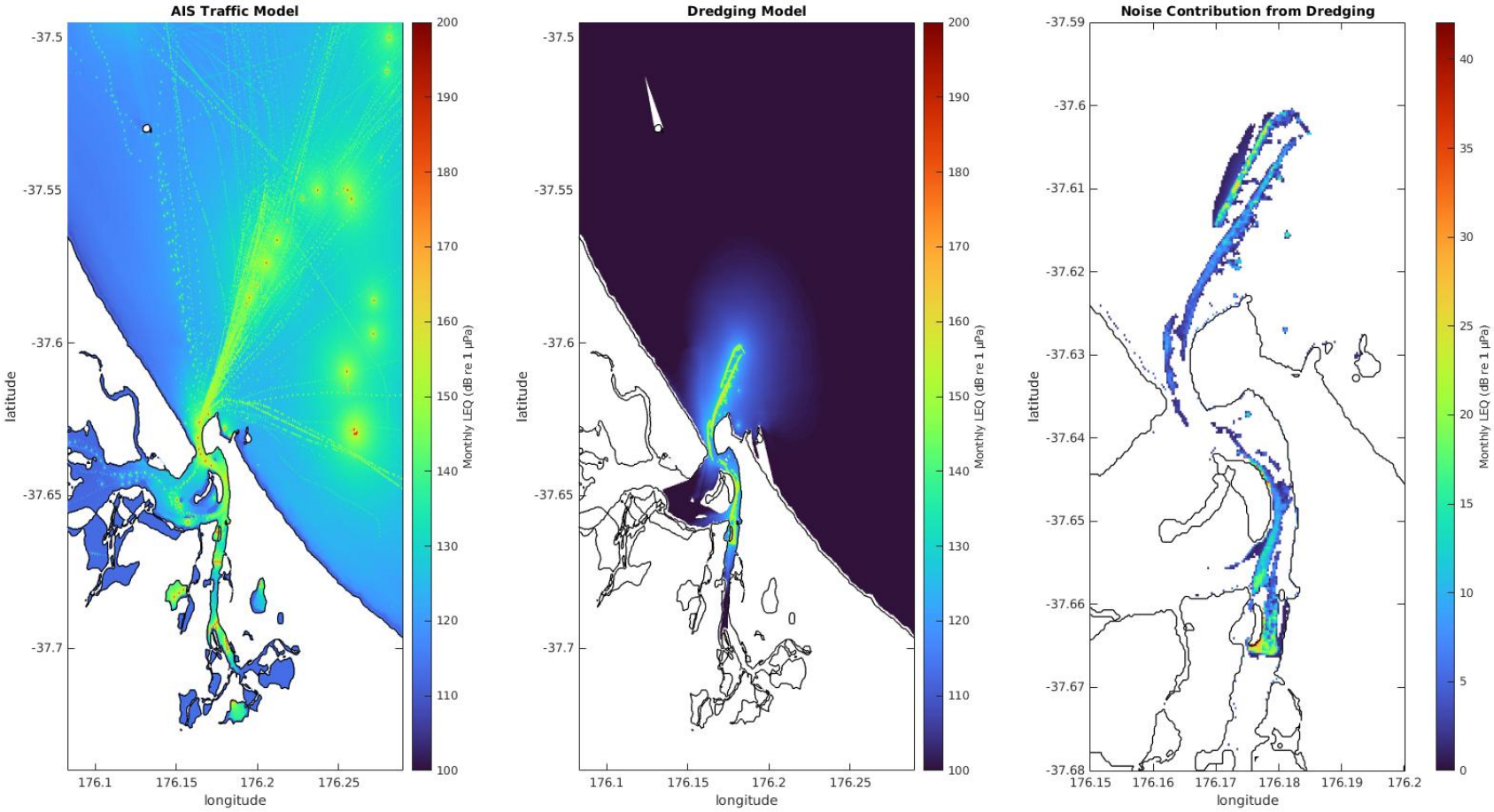


Figure 41 Monthly Leq levels (dB re 1 µPa) for August 2023 from the AIS traffic only (left panel), the TSHD active dredging during the same time (centre panel) and the difference between the two (right panel). The difference between the two represents the change to the background anthrophony directly from the dredging.

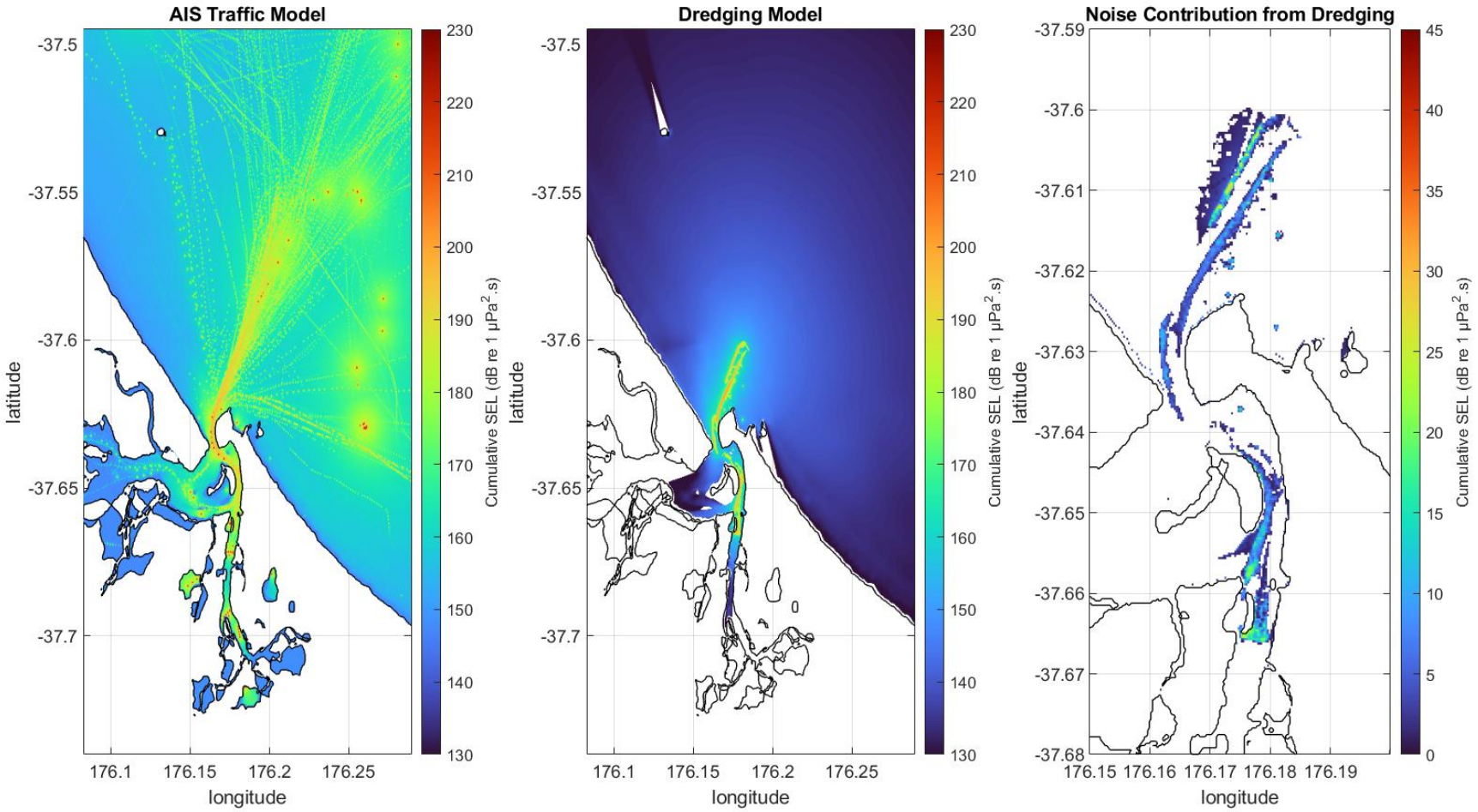


Figure 42 Monthly cumulative sound exposure levels (dB re 1 µPa²•s) for August 2023 from the AIS traffic only (left panel), the TSHD active dredging during the same time (centre panel) and the difference between the two (right panel). The difference between the two represents the change to the background anthrophony directly from the dredging.

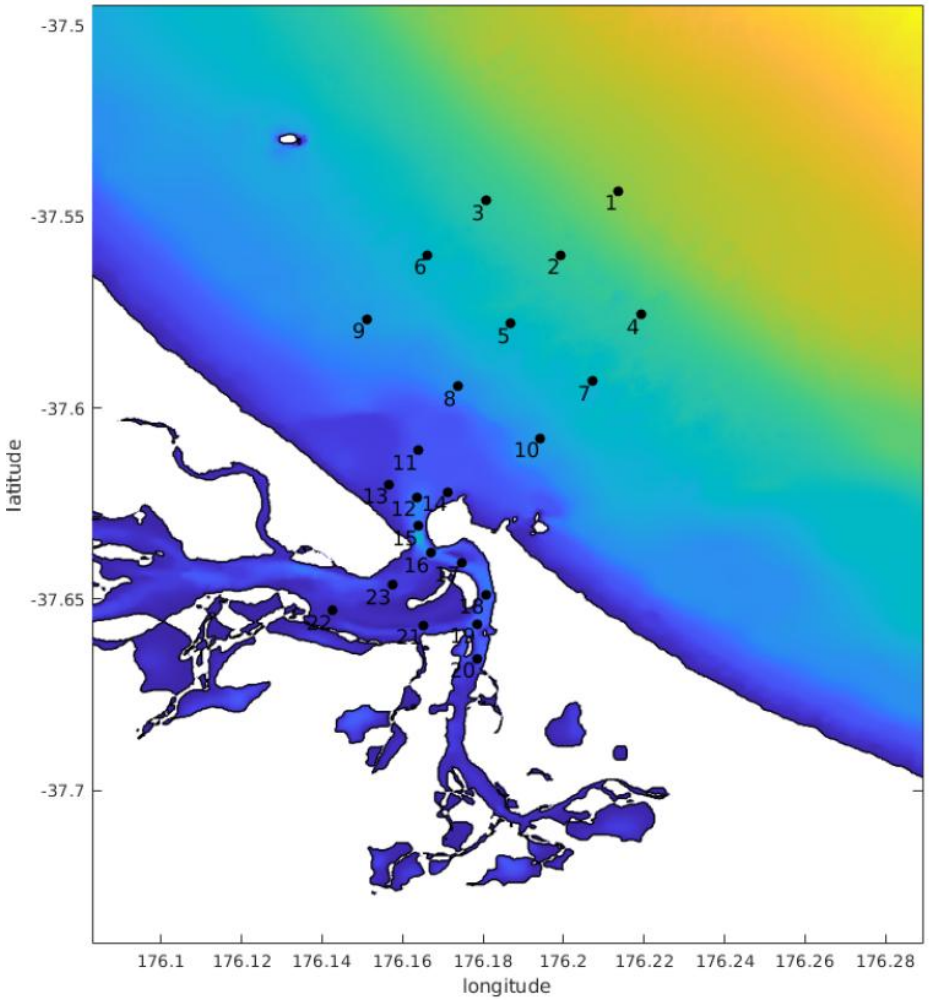


Figure 43 Map showing the positions of each 'measurement position' used to calculate the average soundscape changes from active dredging within the Port Zone.

Model: Jul-Aug 2023 Active Dredging, TSHD Only.

			Frequency Bands (1/1 Octaves) Daily Leq (dB re 1 µPa)									
Position Number	Position Latitude	Position Longitude	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	176.2135698	-37.54335089	124.66	123.25	122.70	121.99	119.48	116.39	112.45	107.94	101.22	93.98
2	176.1992434	-37.56009733	128.50	127.12	126.40	125.18	122.61	119.66	116.09	112.32	106.44	100.35
3	176.1807783	-37.54569539	113.75	116.78	117.78	118.14	116.08	113.19	108.82	103.87	93.60	79.30
4	176.2193004	-37.57550406	120.93	120.77	121.12	119.89	117.73	114.93	110.98	106.92	99.38	89.95
5	176.1868272	-37.57784856	122.16	123.78	123.78	122.97	120.62	117.94	114.32	110.98	104.43	96.28
6	176.1661336	-37.56009733	106.22	114.76	117.02	117.93	116.58	113.99	109.71	105.18	94.24	74.52
7	176.2072025	-37.59292036	118.59	121.00	122.00	120.86	119.03	116.58	112.99	109.86	102.78	91.75
8	176.1737743	-37.59426007	109.99	119.16	122.05	123.04	121.23	119.06	115.45	113.26	107.33	97.08
9	176.1511705	-37.57684377	96.29	111.78	115.50	116.33	115.36	113.23	109.27	105.72	96.14	75.04
10	176.1941496	-37.60799215	112.97	120.60	123.24	122.93	121.38	119.27	115.82	113.70	108.17	98.53
11	176.163905	-37.61100651	88.80	108.11	122.24	126.56	125.84	124.25	120.93	119.56	115.15	108.26
12	176.1635867	-37.62339888	129.99	132.22	135.24	134.46	132.03	130.09	126.80	126.16	123.31	120.28
13	176.1565827	-37.62004959	76.90	92.52	112.36	123.32	125.25	124.41	121.37	120.18	116.01	109.07
14	176.1712274	-37.62205916	126.01	134.16	136.89	136.30	134.82	132.94	129.86	128.53	125.45	122.00
15	176.163905	-37.63076731	155.39	155.21	154.50	151.89	148.86	145.90	142.80	140.12	137.10	134.03
16	176.1670887	-37.63780082	153.65	151.30	150.50	148.35	145.44	142.51	139.47	136.61	133.39	129.84
17	176.1747294	-37.64048025	142.39	143.95	144.03	142.04	139.20	136.28	133.16	130.36	126.99	122.89
18	176.1807783	-37.64885347	145.85	144.47	143.79	141.41	138.71	136.24	133.21	130.96	127.78	124.83
19	176.1785498	-37.65655683	140.38	141.00	140.91	138.74	136.14	133.91	130.99	128.74	125.45	122.04
20	176.1785498	-37.66559991	120.41	125.33	127.12	129.81	128.98	127.52	124.51	122.50	118.89	114.11
21	176.1651785	-37.65689176	105.86	114.33	116.63	117.88	118.92	118.44	116.43	114.90	111.29	105.70
22	176.1425747	-37.65287261	76.31	90.99	95.53	98.78	103.81	110.56	109.99	108.36	103.21	91.29
23	176.1575378	-37.64617404	77.74	95.83	105.78	113.90	117.77	117.27	114.51	112.10	107.82	100.24

Model: Jul-Aug 2023 Active Dredging, TSHD Only

			Frequency Bands (1/1 Octaves) Daily Median (dB re 1 µPa)									
Position Number	Position Lon	Position Lat	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	176.2135698	-37.54335089	120.86	119.16	118.52	117.49	114.46	111.38	107.37	103.12	98.00	92.15
2	176.1992434	-37.56009733	126.19	126.19	125.41	123.98	120.85	117.74	114.35	110.80	105.86	101.04
3	176.1807783	-37.54569539	109.79	113.64	113.83	114.90	111.93	108.98	104.73	99.54	91.35	79.36
4	176.2193004	-37.57550406	119.56	117.91	117.64	116.98	113.99	111.13	106.35	102.69	96.92	88.75
5	176.1868272	-37.57784856	120.85	121.97	121.56	120.18	117.19	114.55	111.00	107.79	102.77	95.39
6	176.1661336	-37.56009733	101.76	113.45	113.62	115.38	114.55	110.72	104.84	100.61	90.78	71.07
7	176.2072025	-37.59292036	116.66	118.98	118.92	117.51	115.34	112.58	109.11	106.64	101.04	92.11
8	176.1737743	-37.59426007	108.33	117.27	119.50	119.86	117.64	115.40	111.13	110.82	105.85	96.70
9	176.1511705	-37.57684377	86.39	111.73	112.47	112.10	110.45	107.99	103.79	101.06	92.32	70.22
10	176.1941496	-37.60799215	114.03	120.10	120.80	120.16	118.17	115.82	112.02	110.98	106.66	98.82
11	176.163905	-37.61100651	85.31	108.35	119.91	121.79	120.41	118.66	115.31	115.45	111.70	106.08
12	176.1635867	-37.62339888	127.08	129.45	132.00	131.00	128.74	126.56	123.27	123.48	121.16	119.23
13	176.1565827	-37.62004959	66.32	89.63	109.33	120.31	120.08	118.82	115.08	115.18	111.40	105.06
14	176.1712274	-37.62205916	127.40	132.77	133.52	132.82	130.43	128.74	125.48	124.67	122.02	119.51
15	176.163905	-37.63076731	157.29	157.29	158.20	155.30	152.15	149.06	145.98	143.03	140.05	136.53
16	176.1670887	-37.63780082	152.03	148.60	148.78	150.68	148.02	144.92	141.84	138.87	135.83	130.55
17	176.1747294	-37.64048025	141.12	142.22	141.07	138.17	135.03	131.92	128.85	126.14	123.31	120.59
18	176.1807783	-37.64885347	143.36	141.18	140.32	138.00	135.01	132.44	129.55	128.24	125.29	122.17
19	176.1785498	-37.65655683	139.52	140.26	139.07	136.76	134.24	131.95	128.66	128.48	125.26	122.55
20	176.1785498	-37.66559991	116.30	124.11	125.30	124.76	122.31	121.71	118.58	116.01	112.79	107.97
21	176.1651785	-37.65689176	116.06	116.53	120.87	119.39	117.48	116.79	114.57	114.31	110.72	104.83
22	176.1425747	-37.65287261	65.86	82.24	90.65	100.38	106.32	109.72	108.02	107.00	102.95	96.16
23	176.1575378	-37.64617404	68.93	96.72	110.43	116.84	116.62	113.38	110.21	110.61	106.44	98.98

Model: Jul-Aug 2023 Active Dredging, TSHD Only

			Frequency Bands (1/1 Octaves) Daily Minimum (dB re 1 µPa)									
Position Number	Position Lon	Position Lat	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	176.2135698	-37.54335089	108.99	105.28	106.34	106.42	103.98	101.99	97.65	94.93	84.26	74.06
2	176.1992434	-37.56009733	112.16	107.73	108.71	109.81	107.72	105.47	100.81	98.74	89.16	79.45
3	176.1807783	-37.54569539	97.22	99.85	104.53	106.14	103.95	101.98	98.09	94.52	82.28	56.16
4	176.2193004	-37.57550406	108.15	106.66	108.57	110.03	107.39	104.17	100.69	96.63	89.58	78.33
5	176.1868272	-37.57784856	108.99	106.42	110.10	111.88	109.90	108.17	104.00	103.33	96.30	80.14
6	176.1661336	-37.56009733	88.47	97.27	104.84	107.06	104.64	101.41	97.48	92.09	83.25	59.15
7	176.2072025	-37.59292036	101.43	104.76	110.26	110.88	108.05	104.88	101.47	97.46	91.70	78.89
8	176.1737743	-37.59426007	93.93	103.73	114.34	114.88	112.12	109.08	105.86	102.29	97.71	88.40
9	176.1511705	-37.57684377	76.52	92.30	103.20	105.02	103.21	100.43	96.64	91.05	80.83	57.25
10	176.1941496	-37.60799215	94.09	105.23	113.63	114.37	111.71	108.67	105.43	101.77	96.55	86.74
11	176.163905	-37.61100651	59.42	85.38	113.95	116.37	114.90	112.20	109.13	105.71	101.27	94.40
12	176.1635867	-37.62339888	121.27	122.03	127.05	125.30	122.29	119.20	116.10	112.95	109.49	105.08
13	176.1565827	-37.62004959	58.64	73.23	103.30	113.64	113.54	111.44	108.49	105.00	100.05	91.01
14	176.1712274	-37.62205916	90.32	118.26	126.43	126.24	123.64	120.65	117.58	114.43	110.96	106.52
15	176.163905	-37.63076731	142.79	142.05	141.16	138.53	135.40	132.44	129.32	126.79	123.86	120.93
16	176.1670887	-37.63780082	141.28	136.68	135.42	132.68	129.51	126.30	123.13	120.08	116.99	113.76
17	176.1747294	-37.64048025	126.79	130.28	130.25	127.83	124.81	121.72	118.63	115.53	112.28	108.54
18	176.1807783	-37.64885347	137.87	135.31	133.87	131.03	127.90	124.78	121.71	118.66	115.60	112.44
19	176.1785498	-37.65655683	135.30	135.12	134.85	132.21	129.12	126.10	123.01	120.26	117.13	113.26
20	176.1785498	-37.66559991	97.78	104.90	107.19	108.50	107.73	104.80	101.70	98.29	93.95	86.34
21	176.1651785	-37.65689176	59.74	75.96	79.99	82.02	92.34	92.88	91.10	87.87	82.61	71.99
22	176.1425747	-37.65287261	58.01	72.57	76.07	75.50	79.63	94.75	94.28	92.36	84.35	64.80
23	176.1575378	-37.64617404	58.57	73.02	76.57	91.27	104.18	103.12	100.09	96.55	91.02	80.21

Model: Jul-Aug 2023 Active Dredging, TSHD Only

			Frequency Bands (1/1 Octaves) Daily Maximum (dB re 1 µPa)									
Position Number	Position Lon	Position Lat	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	176.2135698	-37.54335089	163.07	160.24	158.56	155.64	152.49	149.37	146.30	143.26	140.22	137.14
2	176.1992434	-37.56009733	161.13	161.88	160.20	157.28	154.13	151.01	147.94	144.91	141.89	138.87
3	176.1807783	-37.54569539	156.40	152.30	151.42	148.72	145.72	142.65	139.42	135.75	130.86	122.02
4	176.2193004	-37.57550406	154.19	150.60	150.02	147.36	144.23	141.05	137.81	134.16	128.83	118.32
5	176.1868272	-37.57784856	150.10	147.71	147.98	145.52	142.42	139.23	135.93	132.06	126.96	117.50
6	176.1661336	-37.56009733	141.54	143.46	144.39	142.27	140.01	137.32	133.90	128.98	120.37	101.60
7	176.2072025	-37.59292036	146.74	145.47	146.28	143.95	140.87	137.66	134.30	130.20	124.45	113.02
8	176.1737743	-37.59426007	129.45	140.50	142.50	140.88	140.77	139.20	135.95	130.55	120.47	106.98
9	176.1511705	-37.57684377	138.72	140.17	138.95	137.97	135.25	133.54	130.82	125.38	120.26	116.88
10	176.1941496	-37.60799215	128.85	139.31	141.44	140.66	138.89	137.25	134.54	129.45	121.70	107.74
11	176.163905	-37.61100651	169.41	170.16	168.48	165.56	162.41	159.29	156.22	153.19	150.17	147.15
12	176.1635867	-37.62339888	159.40	158.61	159.14	156.77	153.74	150.65	147.54	144.38	140.83	136.08
13	176.1565827	-37.62004959	116.73	118.50	133.10	145.04	149.63	150.30	148.71	145.79	141.91	135.82
14	176.1712274	-37.62205916	162.80	164.93	165.69	163.38	160.38	157.30	154.23	151.18	148.07	144.75
15	176.163905	-37.63076731	172.55	167.55	166.32	164.47	161.76	160.68	157.23	158.62	156.77	156.19
16	176.1670887	-37.63780082	166.35	167.12	166.12	165.13	162.36	161.06	157.65	158.77	156.88	156.26
17	176.1747294	-37.64048025	166.53	167.28	165.60	163.41	160.81	160.11	156.61	158.40	156.60	156.10
18	176.1807783	-37.64885347	162.25	163.16	163.63	163.87	161.27	160.38	156.91	158.50	156.66	156.12
19	176.1785498	-37.65655683	152.26	153.55	153.95	153.05	151.15	148.33	145.25	143.22	141.38	140.78
20	176.1785498	-37.66559991	156.20	154.81	163.00	163.40	160.84	160.15	156.67	158.42	156.61	156.10
21	176.1651785	-37.65689176	154.84	158.36	158.37	155.66	152.65	149.56	146.50	143.47	140.44	137.41
22	176.1425747	-37.65287261	116.02	118.20	121.65	122.47	120.81	142.65	144.48	142.93	139.09	132.07
23	176.1575378	-37.64617404	116.73	125.64	134.91	142.98	146.97	146.33	143.83	140.69	136.74	130.59

Model: Jul-Aug 2023 AIS Traffic Only

			Frequency Bands (1/1 Octaves) Daily Leq (dB re 1 µPa)									
Position Number	Position Lon	Position Lat	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	176.2135698	-37.54335089	124.66	123.25	122.62	121.76	119.21	115.94	112.05	107.32	101.15	93.98
2	176.1992434	-37.56009733	128.50	127.12	126.31	124.93	122.31	119.18	115.65	111.56	106.22	100.35
3	176.1807783	-37.54569539	113.75	116.78	117.51	117.55	115.39	112.09	107.74	101.86	92.85	79.29
4	176.2193004	-37.57550406	120.93	120.76	120.95	119.46	117.22	114.10	110.19	105.41	98.83	89.94
5	176.1868272	-37.57784856	122.16	123.77	123.55	122.42	119.98	116.92	113.37	109.16	103.22	96.07
6	176.1661336	-37.56009733	106.22	114.75	116.60	117.11	115.71	112.62	108.26	102.19	92.20	74.21
7	176.2072025	-37.59292036	118.59	120.98	121.61	119.99	118.07	115.12	111.59	107.25	100.69	90.95
8	176.1737743	-37.59426007	109.97	119.06	121.16	121.45	119.47	116.51	112.93	108.66	102.34	91.81
9	176.1511705	-37.57684377	96.29	111.77	114.98	115.28	114.12	111.31	107.21	101.37	91.79	72.40
10	176.1941496	-37.60799215	112.96	120.52	122.45	121.42	119.78	116.96	113.56	109.51	103.62	93.67
11	176.163905	-37.61100651	88.80	108.00	120.83	124.35	123.52	121.01	117.73	113.88	108.59	100.29
12	176.1635867	-37.62339888	129.71	131.94	133.69	131.89	129.35	126.40	123.27	120.00	116.35	111.57
13	176.1565827	-37.62004959	76.90	92.52	110.70	121.13	122.93	121.19	118.21	114.49	109.36	100.82
14	176.1712274	-37.62205916	125.29	133.90	135.68	134.36	132.95	130.35	127.38	124.15	120.51	115.66
15	176.163905	-37.63076731	155.36	155.19	154.32	151.57	148.52	145.42	142.35	139.28	136.13	132.80
16	176.1670887	-37.63780082	153.63	151.29	150.41	148.18	145.26	142.25	139.23	136.14	132.86	129.21
17	176.1747294	-37.64048025	142.01	143.62	143.41	141.28	138.40	135.34	132.26	129.11	125.67	121.45
18	176.1807783	-37.64885347	145.15	143.89	142.61	139.87	137.11	134.30	131.35	128.21	124.73	121.16
19	176.1785498	-37.65655683	140.26	140.90	140.41	137.92	135.27	132.75	129.90	126.77	123.15	118.77
20	176.1785498	-37.66559991	116.03	121.80	122.37	124.86	124.74	123.39	120.77	117.54	113.55	107.81
21	176.1651785	-37.65689176	105.86	114.33	116.63	117.48	117.66	116.44	114.31	111.45	107.75	102.33
22	176.1425747	-37.65287261	76.31	90.99	95.53	98.78	103.72	110.23	109.30	106.04	100.46	88.37
23	176.1575378	-37.64617404	77.74	95.83	105.78	113.58	117.08	115.99	113.13	109.53	104.95	96.90

Model: Jul-Aug 2023 AIS Traffic Only

			Frequency Bands (1/1 Octaves) Daily Median (dB re 1 µPa)									
Position Number	Position Lon	Position Lat	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	176.2135698	-37.54335089	120.86	119.16	118.45	117.46	114.36	111.20	107.10	102.62	97.95	92.15
2	176.1992434	-37.56009733	126.19	126.19	125.39	123.97	120.83	117.71	114.28	110.70	105.83	101.04
3	176.1807783	-37.54569539	109.79	113.64	113.66	114.51	111.45	108.18	103.95	98.13	90.90	79.36
4	176.2193004	-37.57550406	119.56	117.91	117.45	116.58	113.50	110.32	105.46	101.19	96.73	88.74
5	176.1868272	-37.57784856	120.85	121.96	121.47	119.89	116.81	113.97	110.42	106.41	102.08	95.38
6	176.1661336	-37.56009733	101.76	113.45	113.40	114.80	114.15	109.89	103.61	97.62	89.66	71.03
7	176.2072025	-37.59292036	116.66	118.96	118.61	117.01	114.61	111.34	107.96	103.61	98.96	91.95
8	176.1737743	-37.59426007	108.33	117.18	118.54	118.74	116.07	112.43	108.25	104.35	99.52	91.27
9	176.1511705	-37.57684377	86.39	111.73	112.02	111.11	109.30	105.86	101.55	96.04	88.22	66.21
10	176.1941496	-37.60799215	114.02	120.08	120.30	119.21	117.47	114.36	110.52	106.57	101.64	93.94
11	176.163905	-37.61100651	85.31	108.35	118.80	120.07	118.39	115.34	111.89	108.53	103.17	95.70
12	176.1635867	-37.62339888	126.87	129.25	130.54	128.13	125.74	122.63	119.54	116.12	112.85	108.63
13	176.1565827	-37.62004959	66.32	89.63	107.79	118.30	117.63	115.01	110.98	107.52	101.57	93.31
14	176.1712274	-37.62205916	127.40	132.75	132.61	131.32	129.99	126.94	123.88	120.53	116.67	113.26
15	176.163905	-37.63076731	157.29	157.29	158.19	155.28	152.13	149.01	145.94	142.90	139.88	136.33
16	176.1670887	-37.63780082	152.03	148.60	148.77	150.67	147.99	144.87	141.80	138.76	135.70	130.44
17	176.1747294	-37.64048025	141.08	141.98	140.84	137.93	134.79	131.67	128.60	125.56	122.53	119.50
18	176.1807783	-37.64885347	143.07	140.74	139.08	136.19	133.52	130.40	127.33	124.29	121.17	117.74
19	176.1785498	-37.65655683	139.42	140.20	138.81	135.98	133.18	130.07	127.00	123.95	120.87	117.50
20	176.1785498	-37.66559991	112.22	119.61	121.31	124.10	121.12	118.07	115.15	112.04	108.78	104.59
21	176.1651785	-37.65689176	116.06	116.53	120.87	119.35	117.29	115.42	112.47	110.22	106.88	102.22
22	176.1425747	-37.65287261	65.86	82.24	90.65	100.38	106.32	109.72	107.01	105.12	101.54	96.01
23	176.1575378	-37.64617404	68.93	96.72	110.43	116.83	116.44	113.08	108.99	105.40	100.78	91.74

Model: Jul-Aug 2023 AIS Traffic Only

			Frequency Bands (1/1 Octaves) Daily Minimum (dB re 1 µPa)									
Position Number	Position Lon	Position Lat	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	176.2135698	-37.54335089	108.99	105.23	104.99	103.42	100.77	97.30	93.27	88.49	82.97	74.06
2	176.1992434	-37.56009733	112.16	107.71	107.42	107.64	105.41	102.02	96.74	91.49	86.15	79.44
3	176.1807783	-37.54569539	97.22	99.80	101.88	101.11	98.78	95.42	91.18	84.97	74.37	55.95
4	176.2193004	-37.57550406	108.15	106.60	106.89	107.47	105.68	101.88	96.47	90.86	84.83	78.33
5	176.1868272	-37.57784856	108.99	106.28	107.34	107.86	106.03	102.30	97.16	91.97	85.86	77.10
6	176.1661336	-37.56009733	88.47	97.19	101.31	102.36	100.37	97.01	92.55	85.37	73.66	55.89
7	176.2072025	-37.59292036	101.43	104.45	106.92	107.05	104.26	101.04	97.02	91.51	83.52	69.83
8	176.1737743	-37.59426007	93.93	102.23	107.69	108.69	106.63	103.48	99.01	94.86	89.33	79.10
9	176.1511705	-37.57684377	76.52	92.28	98.49	101.40	99.97	96.87	92.49	85.89	75.18	54.22
10	176.1941496	-37.60799215	94.08	104.50	108.55	108.65	106.18	103.11	99.48	95.37	89.72	78.71
11	176.163905	-37.61100651	59.42	84.94	107.41	110.11	108.96	106.35	103.25	99.72	95.06	86.92
12	176.1635867	-37.62339888	120.33	120.76	121.01	118.69	115.68	112.59	109.49	106.33	102.86	98.51
13	176.1565827	-37.62004959	58.64	73.23	97.51	108.24	108.27	106.22	103.28	99.73	94.67	85.24
14	176.1712274	-37.62205916	81.09	116.46	121.55	120.86	118.28	115.30	112.23	109.07	105.59	101.09
15	176.163905	-37.63076731	142.74	141.99	140.54	137.68	134.55	131.43	128.36	125.31	122.24	119.07
16	176.1670887	-37.63780082	141.28	136.68	135.42	132.68	129.50	126.28	123.10	120.00	116.93	113.74
17	176.1747294	-37.64048025	126.79	130.28	130.25	127.83	124.81	121.72	118.63	115.53	112.28	108.54
18	176.1807783	-37.64885347	137.87	135.31	133.87	131.03	127.90	124.78	121.71	118.66	115.60	112.44
19	176.1785498	-37.65655683	135.30	135.12	134.85	132.13	129.01	125.89	122.82	119.77	116.72	113.26
20	176.1785498	-37.66559991	97.78	104.90	106.42	106.11	103.34	100.47	97.46	93.45	89.82	85.10
21	176.1651785	-37.65689176	59.74	75.96	79.99	82.02	92.34	92.88	91.10	86.51	81.25	70.73
22	176.1425747	-37.65287261	58.01	72.57	76.07	75.50	79.63	94.75	94.28	91.83	83.67	64.26
23	176.1575378	-37.64617404	58.57	73.02	76.57	91.27	102.64	102.07	99.88	96.55	91.02	80.21

Model: Jul-Aug 2023 AIS Traffic Only

			Frequency Bands (1/1 Octaves) Daily Maximum (dB re 1 µPa)									
Position Number	Position Lon	Position Lat	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	16000Hz	32000Hz
1	176.2135698	-37.54335089	163.07	160.24	158.56	155.64	152.49	149.37	146.30	143.26	140.22	137.14
2	176.1992434	-37.56009733	161.13	161.88	160.20	157.28	154.13	151.01	147.94	144.91	141.89	138.87
3	176.1807783	-37.54569539	156.40	152.30	151.42	148.72	145.72	142.65	139.42	135.75	130.86	122.02
4	176.2193004	-37.57550406	154.19	150.60	150.02	147.36	144.23	141.05	137.81	134.16	128.83	118.32
5	176.1868272	-37.57784856	150.10	147.71	147.98	145.52	142.42	139.23	135.93	132.06	126.96	117.50
6	176.1661336	-37.56009733	141.54	143.46	144.39	142.27	140.01	137.32	133.90	128.98	120.36	101.60
7	176.2072025	-37.59292036	146.74	145.47	146.28	143.95	140.87	137.66	134.30	130.20	124.45	113.02
8	176.1737743	-37.59426007	129.45	140.50	142.50	140.88	140.77	139.19	135.95	130.54	120.45	106.91
9	176.1511705	-37.57684377	138.72	140.17	138.95	137.97	135.25	133.54	130.82	125.37	120.26	116.88
10	176.1941496	-37.60799215	128.85	139.31	141.44	140.66	138.88	137.25	134.53	129.42	121.59	106.64
11	176.163905	-37.61100651	169.41	170.16	168.48	165.56	162.41	159.29	156.22	153.18	150.17	147.15
12	176.1635867	-37.62339888	159.40	158.61	159.13	156.76	153.74	150.64	147.53	144.35	140.78	135.99
13	176.1565827	-37.62004959	116.73	118.50	133.09	145.04	149.63	150.30	148.71	145.79	141.90	135.81
14	176.1712274	-37.62205916	162.80	164.93	165.69	163.38	160.38	157.30	154.23	151.17	148.06	144.74
15	176.163905	-37.63076731	172.55	167.55	166.32	163.52	160.40	157.28	154.21	151.14	148.03	144.72
16	176.1670887	-37.63780082	166.35	167.12	165.46	162.54	159.39	156.27	153.20	150.17	147.14	144.12
17	176.1747294	-37.64048025	166.53	167.28	165.60	162.68	159.53	156.41	153.34	150.30	147.28	144.27
18	176.1807783	-37.64885347	162.25	163.16	162.37	159.91	157.09	154.05	150.99	147.89	144.64	141.03
19	176.1785498	-37.65655683	152.26	153.55	153.94	153.03	151.13	148.30	145.22	141.92	137.82	131.32
20	176.1785498	-37.66559991	148.23	148.89	147.25	144.34	147.49	146.86	144.38	141.24	137.26	131.01
21	176.1651785	-37.65689176	154.84	158.36	158.37	155.66	152.65	149.56	146.50	143.47	140.44	137.41
22	176.1425747	-37.65287261	116.02	118.20	121.65	122.47	120.81	142.65	144.48	142.93	139.09	132.07
23	176.1575378	-37.64617404	116.73	125.64	134.91	142.98	146.97	146.33	143.83	140.69	136.74	130.59

Appendix H TSHD *Albatros* source level measurement

Underwater recordings of the TSHD *Albatros* were undertaken on the 28 February 2024, during fine weather conditions (variable 10 knot winds, sea state 1 and no swell). A hydrophone array was deployed by Styles Group that consisted of six SoundTrap 300HF hydrophones (Ocean Instruments NZ). 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 the 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.

The array was deployed before 08:00hrs on the 28th February near the edge of the dredged channel. Each hydrophone was secured 5m below the surface and their positions marked by surface floats. The dredge channel has a steep ~5m drop off (from approximately 10m to 15m deep) and hydrophones were placed 10m from the edge of that drop off (confirmed using sonar after deployment) (Figure 44). Because the hydrophones were not able to be deployed inside the shipping channel due to gear safety (since these measurements were opportunistic during Lyttelton Port Company's maintenance dredging), the hydrophone array's geometry was in parallel to the channel, and therefore the dredge vessel's track, as it passed by (Figure 44). This produced several single-point replicates during the same environmental conditions, that could be back calculated to provide an estimate source spectrum used in the noise modelling.

Because of the challenges presented by the channel shelf, only certain passbys were used. Recordings of certain passbys were only used if the closest-point-of-approach (**CPA**) of the dredge vessel and corresponding sound pressure level showed good agreement. That is, that as the CPA decreases, the received SPLs increased. If the CPA was reached before the loudest received noise levels across several hydrophones, this suggested diffraction of the received sound level due to the channel shelf. When this occurred, those passbys were not selected for analysis.

Recordings were also checked for any contamination due to other vessels operating in the area.

The TSHD's positions were tracked using AIS and provided after the day by the dredging operator, Dutch Dredging Limited.

Data analysis

Time-series of the recorded power spectral densities (PSDs) were calculated and plotted to examine the quality of the data from all six hydrophones. The received third octave band levels

(TOLs) 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 PSDs and TOLs were calculated using a 1-sec Hamming window and 50% overlap with 10-sec averaging. The broadband (10Hz – 48 kHz) SPLs, as 1-sec and 10-sec averages, were calculated for each horizontal distance between the TSHD *Albatros* LAT/LON 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 *Albatros* and all hydrophones were inside 7km, the margin of error from assuming a perfect sphere is minimal. For each distance, the 10 second SPLs (both broadband SPLs and TOLs) were plotted, showing the finer-scale variations in the received sound pressures over distance as the TSHD passed the array (Figure 45).

For the purposes of the underwater noise modelling, the received sound pressures measured at the *Albatros*' CPA to each hydrophone (Figure 45) while actively dredging were back calculated to a reference distance of 1 metre. This was done using the sound propagation equations in Pine et al. (2014)[14] but modifying the spreading coefficient based on the empirical data collected in this study.

[14] Pine MK et al. 2014. The cumulative effect on sound levels from multiple underwater anthropogenic sound sources in shallow coastal waters. J. App. Ecol. 51: 23-30.

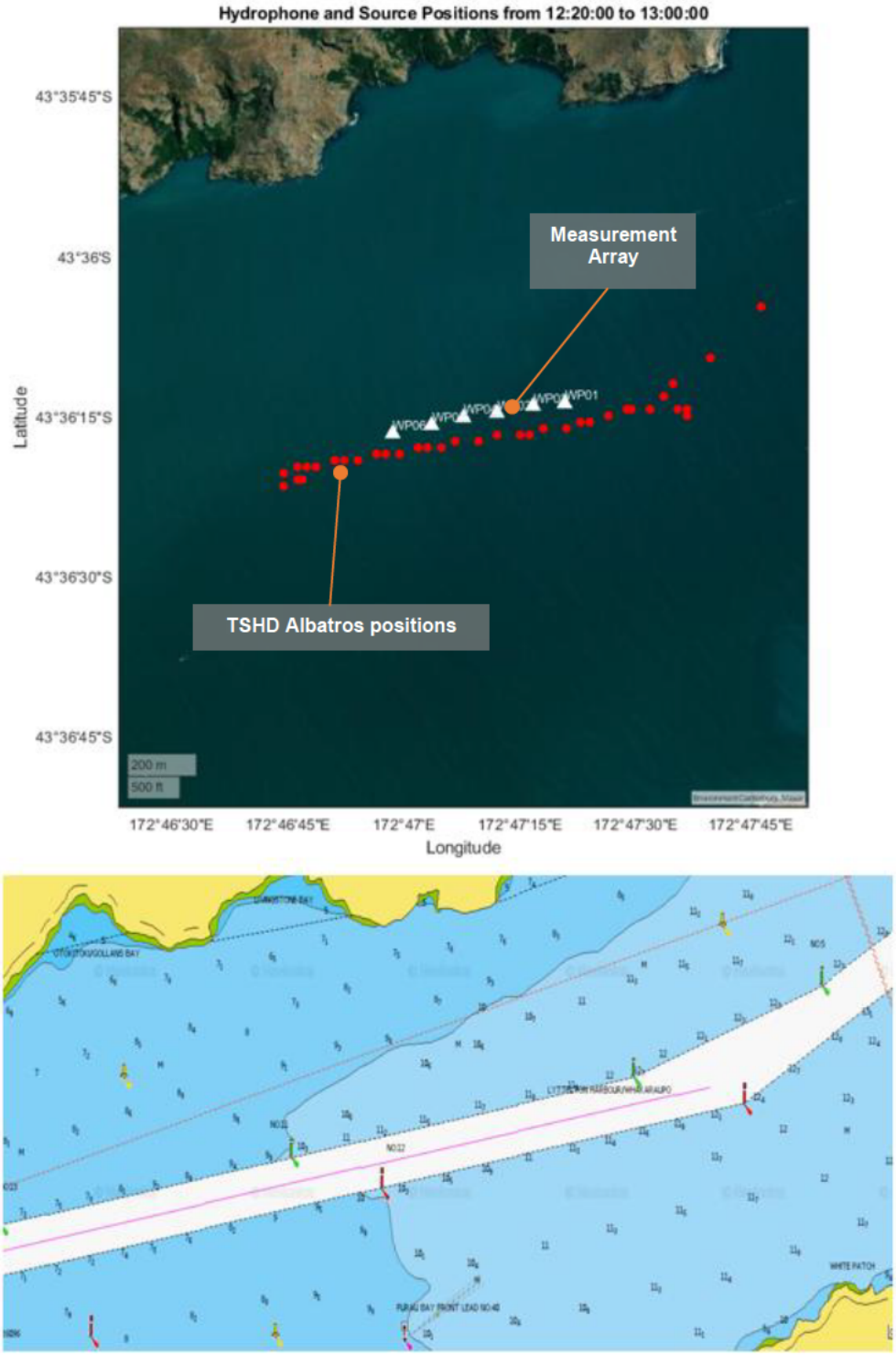


Figure 44 Map showing the hydrophone array position along the channel shelf (shown in the chart insert in the bottom panel). The red dots represent the TSHD *Albatros* positions between 12:20hrs and 13:00hrs (a single passby).

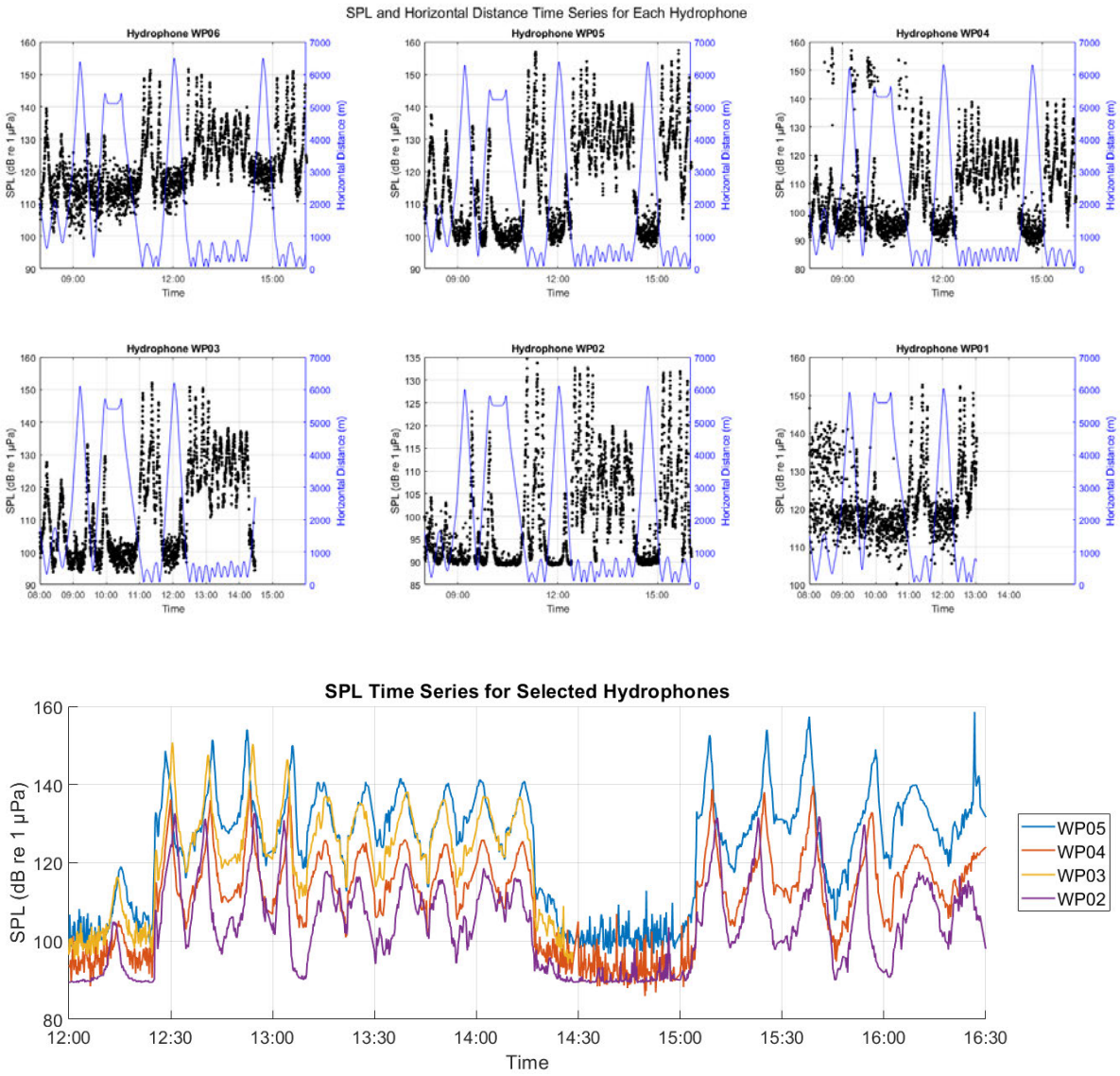


Figure 45 Received SPLs from each hydrophone during the 28th February 2024, as the TSHD *Albatros* undertook maintenance dredging.

Data from hydrophones WP06 and WP01 were not used to unreliable data.