Survey Report for:
Royal Boskalis Westminster N.V.

Project:
HMNB Devonport Capital Dredge Site Investigation

Description:
Noise Monitoring Results Report

Survey Date:
28-Nov-2021 to 06-Dec-2021

Project Number:
11748

Report Status:
Final

REPORT AUTHORISATION AND DISTRIBUTION

Compilation	Acoustics	R Lee
Authorisation	Checked	Isobel Carr .... I Carr
	Approved	Gillian Allen. .... G Allen

Revision	**Date**	**Title**
0	11-Feb-2022	Draft
1	31-May-2022	Final

Distribution

pdf

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For attention of

Richard Cope

EXECUTIVE SUMMARY

- Gardline conducted noise monitoring during geotechnical drilling operations at Her Majesty's Naval Base Devonport on behalf of Royal Boskalis Westminster N. V. between 28-Nov-2021 and 06-Dec-2021.
- Two static mooring arrays were deployed, each housing two autonomous recording units (ARUs) at two water depths: approximately 6m and 1m above the seafloor.
- Four drilling locations were monitored over four days and a total of 21 hours and 30 minutes of recordings were included in the back propagation modelling. The recordings from Recorder MWAR 0009 did not save correctly and were excluded from analysis.
- Peak sound pressure level, sound exposure level (SEL) and frequency were measured after any inherent direct current offset was removed.
- The mean SEL was calculated to be 133.0 dB re. 1μPa^2·s (± 10.8SD) during periods of drilling activity and 134.3 dB re. 1μPa^2·s (± 11.7SD) during ambient periods. An analysis of variance test showed no significant difference between the two periods.
- Various forms of anthropogenic noise, such as vessel traffic, may have a greater impact than drilling and may have contributed to the recordings from the current survey.
- When compared to previous noise monitoring of coring activity, drilling produced a lower mean SEL. This is likely a result of the drill machinery being mostly above water and the sea surface reflecting most of the noise.

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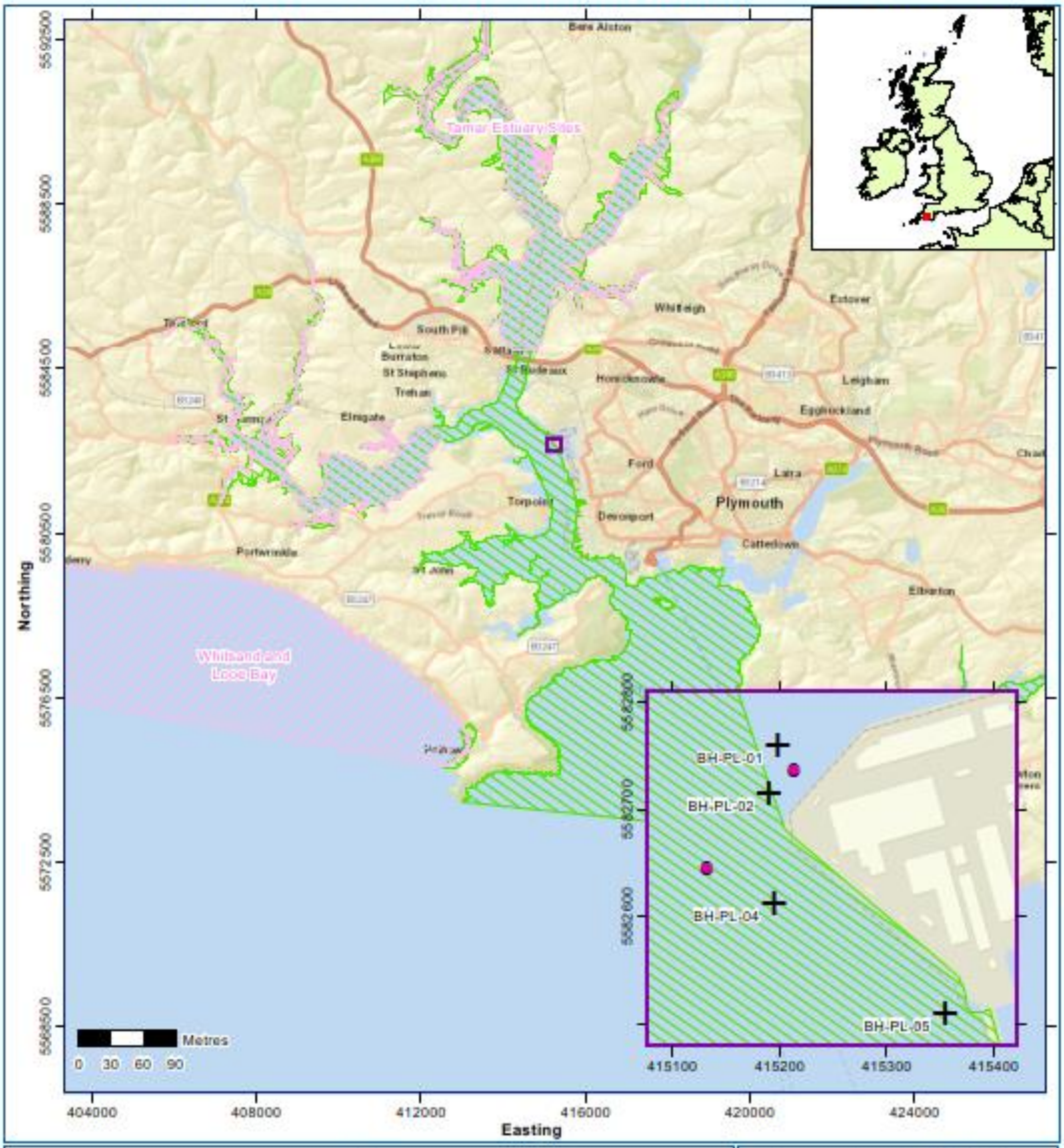
LOCATION MAP

11748 - Boskalis - Naval Base Noise Monitoring Location Map (Stage 2)



Key

- Borehole Locations
- ARU Locations
- Marine Conservation Zones (NE, 2020)
- Inshore SPAs with Marine Components (JNCC, 2020)
- Special Areas of Conservation (NE, 2021)

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Kilometers
0 1 2 3 4

Coordinate System:
Name: WGS 1984 UTM Zone 30N
Projection: Transverse Mercator
Datum: WGS 1984
Central Meridian: -3.0°E

N

Compilation: I Carr
Revision: Draft
Date: 09 Feb 2022

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GLOSSARY OF TERMS AND ABBREVIATIONS

ANOVA	Analysis of variance
ARU	Autonomous Recorder Unit
dB re. 1µPa	Decibels relative to one micro-Pascal, used as a unit for SPL
dB re. 1µPa^2·s	Decibels relative to one micro-Pascal square per second, used as a unit for SEL
Hz	Hertz
kHz	Kilohertz
RMS	Root Mean Squared
SAC	Special Area of Conservation
SEL	Sound Exposure Level
SPL	Sound Pressure Level

1 PROJECT SUMMARY

1.1 Scope of Work

On behalf of Royal Boskalis Westminster N. V., Gardline conducted noise monitoring during borehole operations; the second stage of a dredging program aimed at deepening a berth pocket at Her Majesty's Naval Base Devonport at Wharf 8 and Wharf 9. Noise monitoring operations were conducted between 28-Nov-2021 and 06-Dec-2021, with all drilling work carried out between 02-Dec-2021 and 05-Dec-2021.

1.2 Environmental Survey Strategy

In total, four boreholes were acquired for geotechnical analysis. Noise monitoring during drilling operations was conducted using autonomous recording units (ARUs) at two pre-determined locations.

1.3 Background - Plymouth Sound and Estuaries SAC

The site investigation shall take place within the Plymouth Sound and Estuaries Special Area of Conservation (SAC), which is listed on both Annex I and Annex II of the Habitat Directive (1992). The fish species *Alosa alosa* (allis shad) is listed on Annex II of the Habitats Directive (1992) and is a qualifying feature of the SAC.

Alosa alosa are a member of the clupeid family and relatively little information is available on the habitat requirements in freshwater (JNCC, 2020). They are an anadromous species, growing in coastal water and estuaries and migrating inland up streams to spawn. The only known confirmed spawning site for *A. alosa* in the UK is the Tamar Estuary in Plymouth Sound (JNCC, 2020). Members of the clupeid family have a swim bladder and inner ear structures, suggesting they have specialised hearing capabilities (Popper *et al.*, 2004). Furthermore, *A. alosa* have been found to show a response to ultrasonic pulses of both 70kHz and 120kHz, with a response threshold between 161 and 167 dB re. 1 µPa (peak to peak; Wilson *et al.*, 2008)

1.4 Sound Characteristics and Sound Metrics Used

By convention, underwater sound levels are measured in decibels (dB) relative to a reference pressure of 1µPa. The two most employed sound level metrics are peak sound pressure level (SPL) and sound exposure level (SEL). Peak SPL (also known as zero-to-peak) is defined as the maximum instantaneous sound pressure level attained by an impulse, *p(t)*:

$$_{peak}SPL = 20log_{10}\max\left(|p^2(t)|\right)$$

Due to the variety of pulse shapes emitted by different equipment, peak SPL is used as worst-case scenario rather than mean (RMS) values.

The SEL is the time-integral of the square pressure over a fixed time window long enough to include the entire pulse:

$$SEL = 10log_{10}\left(\int_T p^2(t)dt\right)$$

SEL has units of dB re. $1µPa^2 \cdot s$ and is a cumulative measure related to sound energy flux density rather than sound pressure.

2 DATA ACQUISITION AND PROCESSING

2.1 Noise Monitoring Acquisition

Two static mooring arrays were deployed, each housing two autonomous recording units (ARUs). At each mooring location the ARUs were deployed at two water depths: approximately 6m and 1m above the seafloor, as detailed in Table 2.1. The hydrophones were housed in the ARUs attached to a mooring line secured by a bottom anchor, with a subsurface buoy, as shown in Figure 2.1. The moorings were left in situ for the entirety of the geotechnical operations. Before and after the recorders were deployed a calibration tone was played using a pistonphone to ensure accuracy of the hydrophone measurements. This was completed in an office prior to work being conducted as calibrations can be affected by background noise, especially lower frequency noise such as the noise produced by vessel engines.

Each ARU was encoding lossless wav audio, comprising recording of two channels sampled at a rate of 96kHz with a 16-bit resolution. Two hydrophones with different sensitivities, were used per recording. Therefore, if the received sound produced was too intense for the more sensitive hydrophone, the second hydrophone with a larger dynamic range would still collect useful data. Sound levels did not exceed the limits of the sensitive hydrophone; therefore, the high dynamic range channel was not required and therefore will not be referenced at any point further in this report.

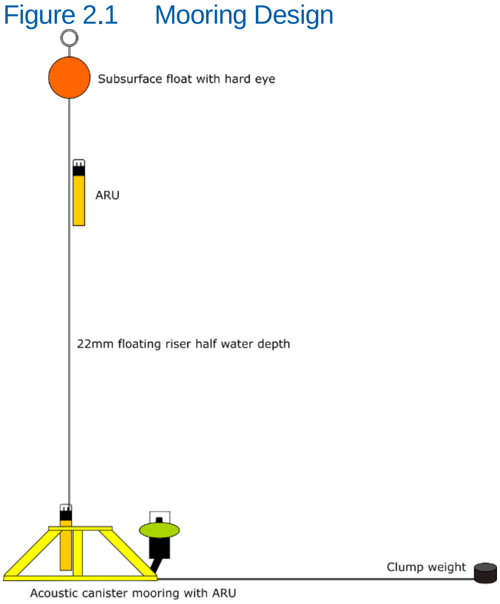
The entirety of the mooring was retrieved from the seafloor at the end of the survey using an acoustic release.

Full methods of data processing will be detailed in the subsequent full report.

Table 2.1 Autonomous Recorder Unit Details

Recorder ID	Sensitivity (dB 1V/µPa)	Vertical Distance from Seabed	Location During Recording	
			Easting	Northing
MWAR 0005	-166.80	6 m	415213	5582736
MWAR 0009	-166.06	1 m		
MWAR 0010	-171.26	6 m	415132	5582645
MWAR 0011	-166.44	1 m		

Figure 2.1 Mooring Design

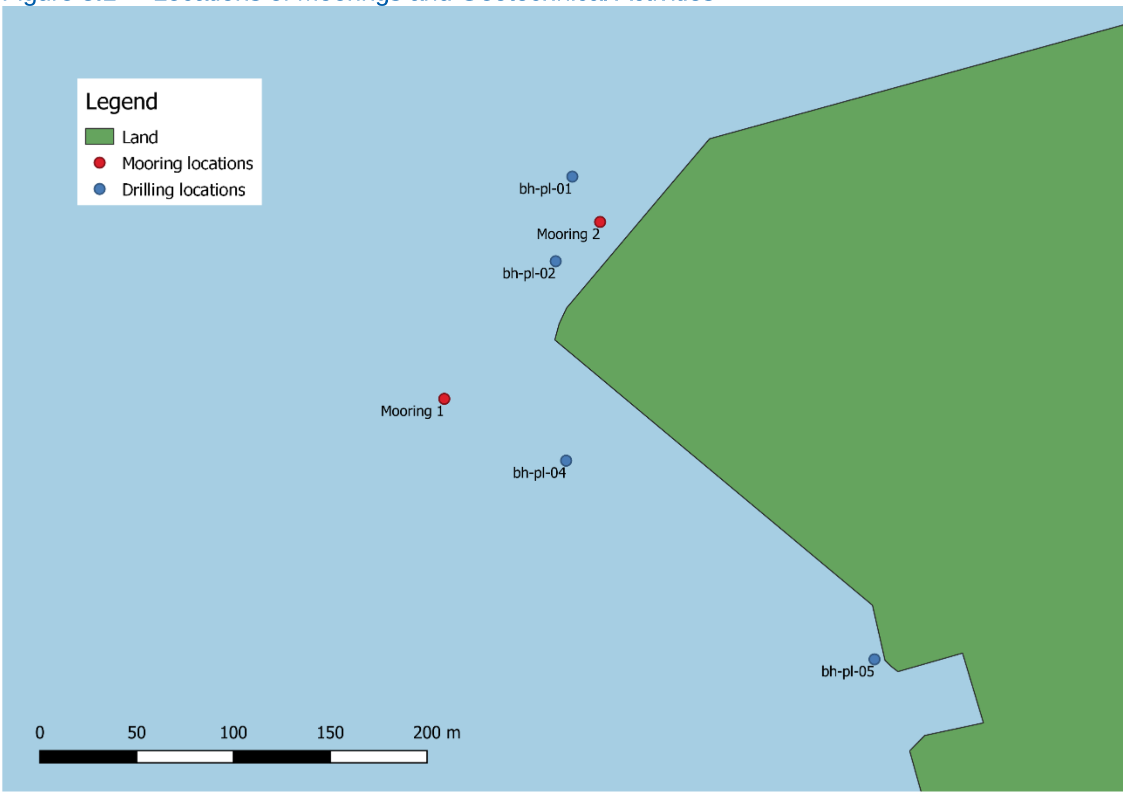


3 RESULTS AND DISCUSSION

3.1 Achieved Acquisition Overview

A total of four drilling locations (Figure 3.1) were monitored over four days. As the drilling took place over several hours, the peak SEL was calculated per audio file per location. To understand the ambient noise level, a peak sound exposure level (SEL) value was calculated in audio files with no drilling activity. If any file contained recordings of both drilling activity and pure ambient noise, the file was split with the ambient noise cut five minutes prior to the beginning of drilling activity.

Figure 3.1 Locations of Moorings and Geotechnical Activities



3.2 Back Propagation Modelling

Recorder MWAR 0009 did not correctly save the data and as such was excluded from the results. A total of 21 hours and 30 minutes of recordings were included in the back propagation modelling. This model does not take in to account any variability of bathymetry or potential differences in drilling intensity. Any inherent direct current offset was removed and peak sound pressure level (SPL), SEL and frequency was measured (Figure 3.2 to Figure 3.4). The peak SEL was calculated as the most intense one second period during any one period of geotechnical drilling activity. A scatter plot of received peak SEL against distance from the source for each recording is shown in Figure 3.5 however, the spread of sound levels illustrated in Figure 3.5 would not allow for a regression model to be applied as the drilling locations closest to the recorders showed a drop in SEL.

Figure 3.2 Example Waveform from Recorder MWAR 0005

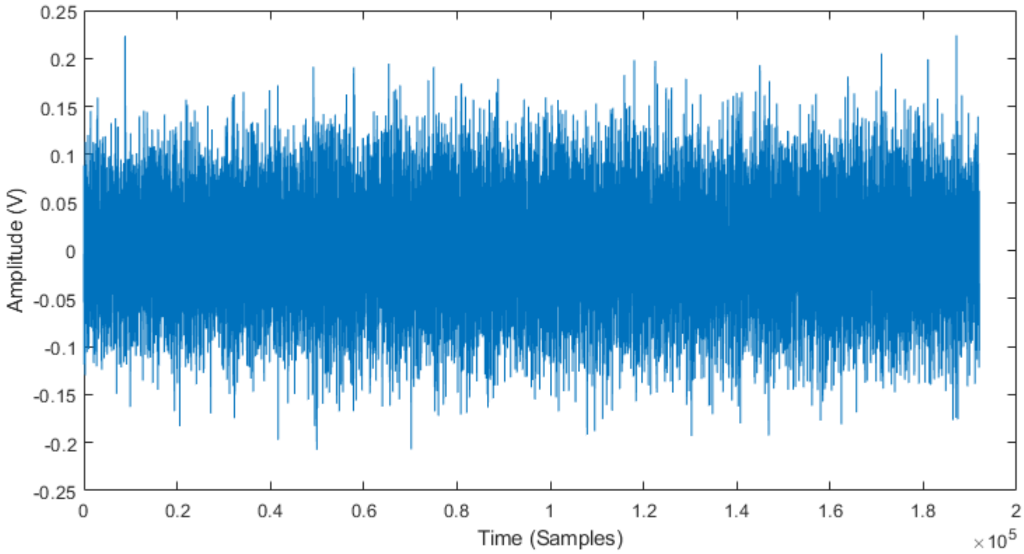


Figure 3.3 Example Fast Fourier Transform from Recorder MWAR 0005

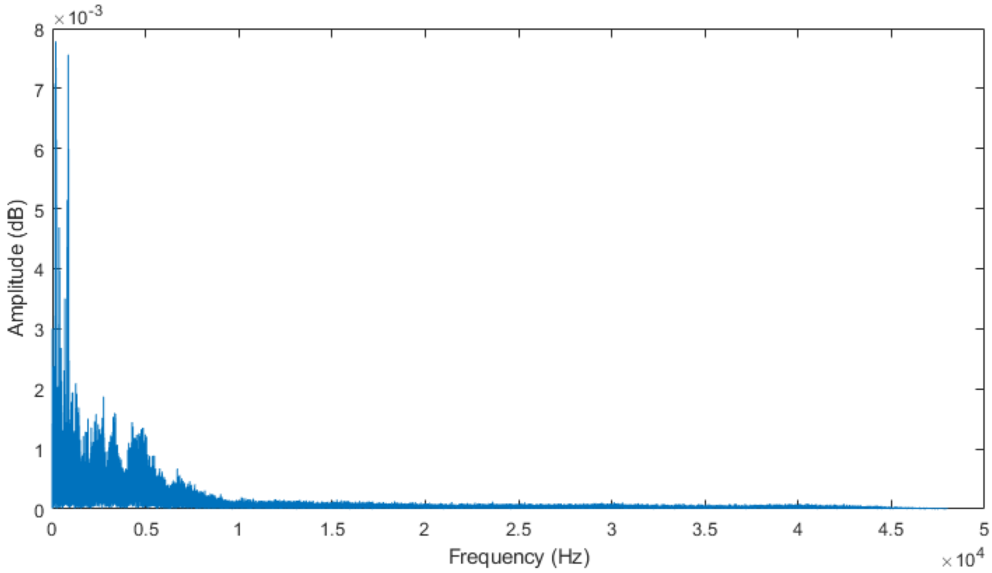


Figure 3.4 Example Spectrogram from Recorder MWAR 0010

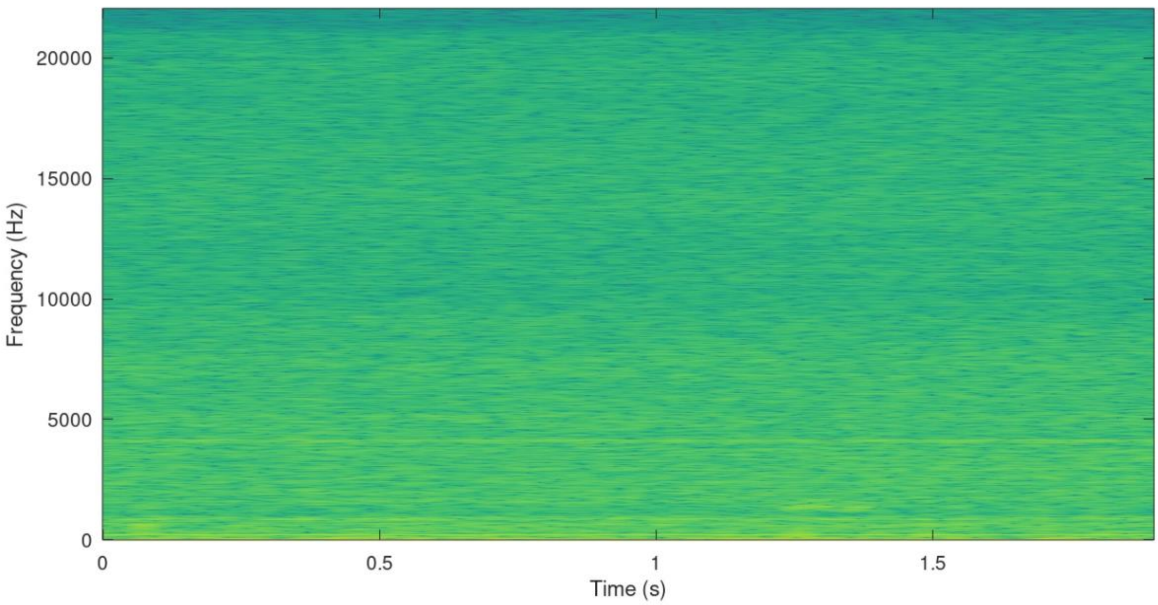
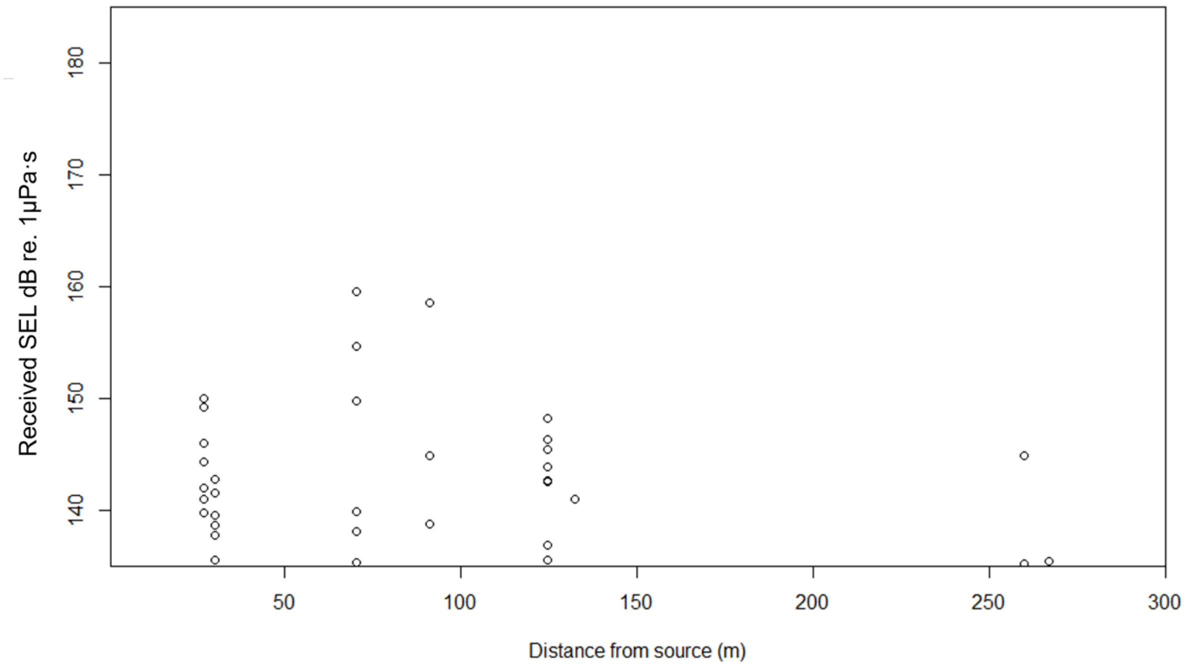


Figure 3.5 Scatter Plot Displaying Distance from the Source Against the Received Peak SEL dB re. 1 µPa^2·s for Each Drilling Activity



To understand any variation between the measured SEL from each recorder, an analysis of variance (ANOVA) test was run for both periods of drilling activity (Figure 3.6) and periods when there was no drilling activity (Figure 3.7). This revealed no significant difference between recorders; although, there was slightly larger variability in MWAR 0005 than the other recorders. This is presumed to be because this recorder was located in a less sheltered position and closer to vessel traffic.

Figure 3.6 Peak SELs at each ARU during Drilling Activity

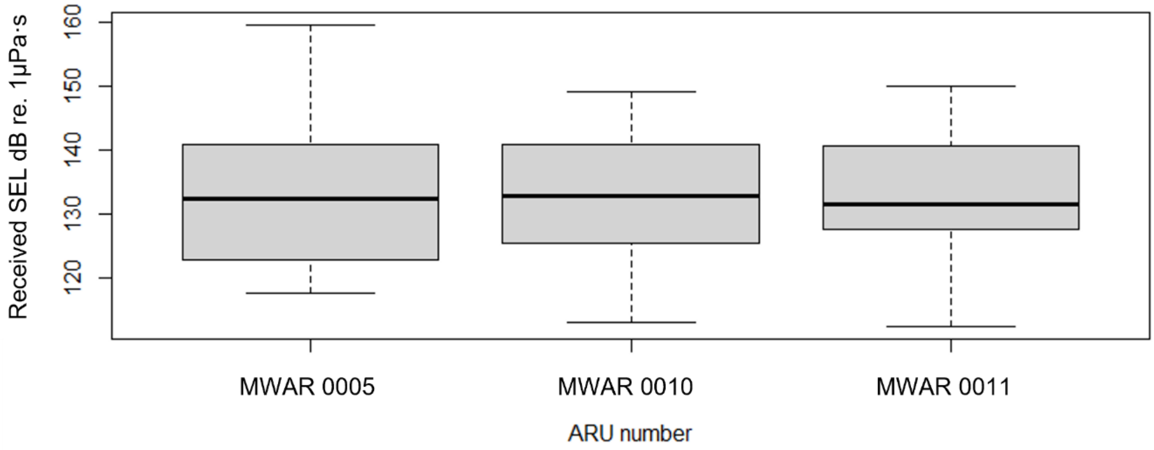
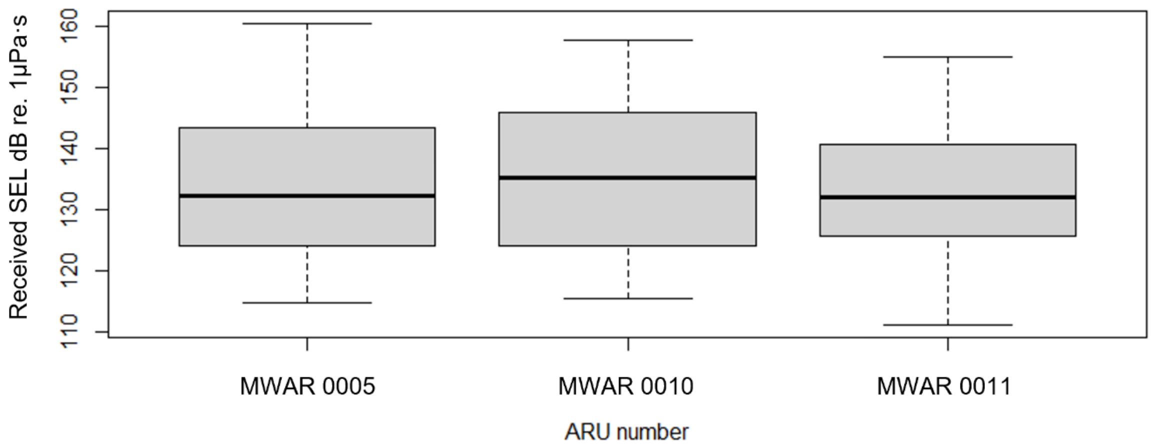


Figure 3.7 Peak SELs at each ARU during no Drilling Activity



The mean SEL values were calculated for periods of pure ambient noise and for periods when drilling activity was taking place. This resulted in a mean SEL of 133.0dB re. 1µPa^2·s (± 10.8SD). Results were plotted on a histogram (Figure 3.8) and represent the expected distribution of sound levels. For ambient recordings, there was a mean SEL of 134.3dB re. 1µPa^2·s (± 11.7SD; Figure 3.9), which is comparable to the drilling periods. To understand if there was any statistically significant differences between ambient periods and drilling periods, an ANVOA test was completed. This showed no significant difference between the two periods ($p = 0.39$; Figure 3.10).

Figure 3.8 Peak Received SEL during Periods of Drilling Activity

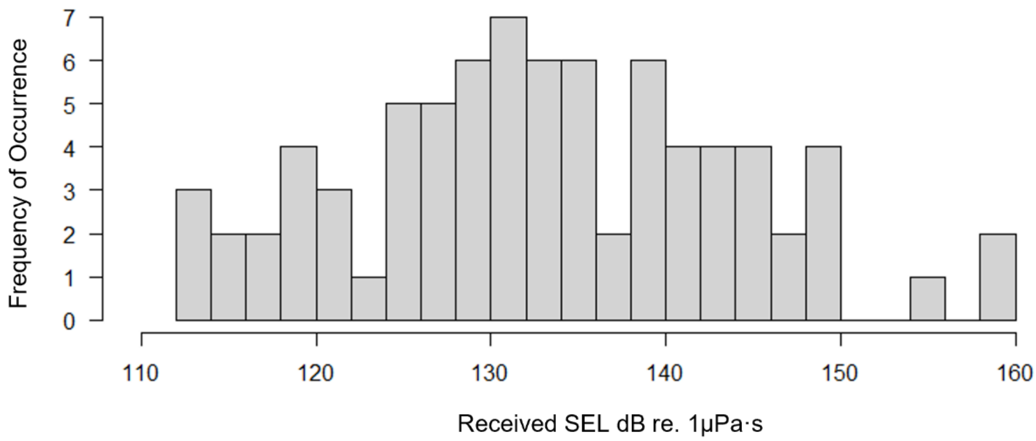


Figure 3.9 Peak Received SEL during Periods of Ambient Noise

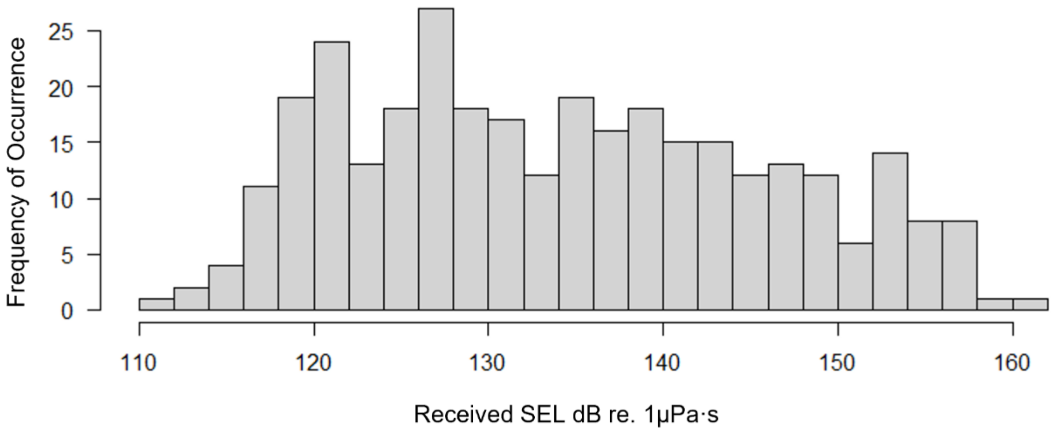
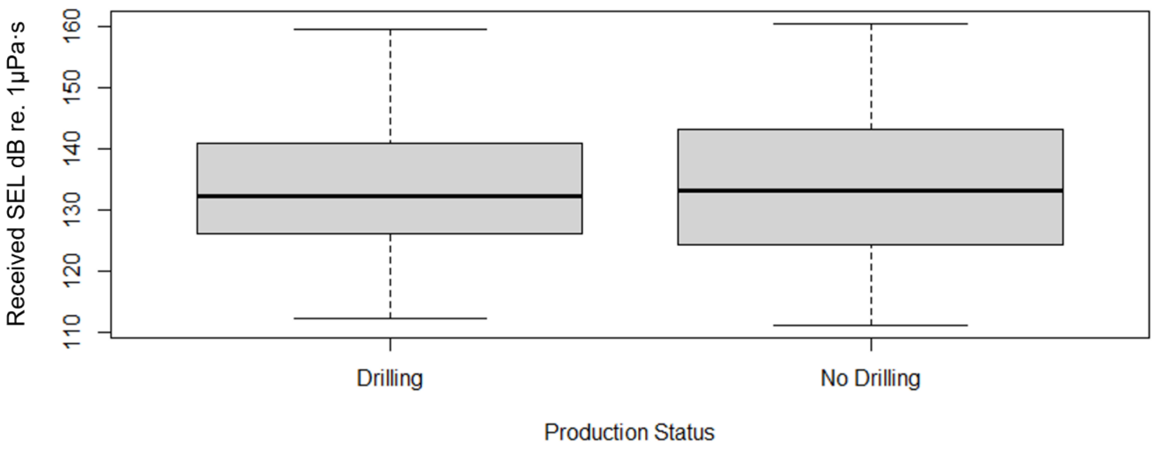


Figure 3.10 Peak received SEL of Drilling and Ambient Periods



3.3 Discussion

Although geotechnical activity is likely to contribute to the anthropogenic soundscape of the ocean, other forms of anthropogenic noise may have a greater impact than drilling. It is possible that vessel traffic passing through the area during the survey had a greater source level. For example, a selection of individual peak SELs were identified and actively listened to. Many of the peaks from drilling periods, especially those above the mean SEL, appeared to be a result of vessels transiting close to the survey area; however, it is difficult to be certain of the source. McKenna *et al.* (2021) calculated that a 54.6kGt container ship would record a SEL of 166.2dB re. 1μPa^2·s at a distance of 1km, exceeding all current survey recordings. Furthermore, at 5km, the same vessel would have a SEL of 148dB re. 1μPa^2·s (McKenna *et al.*, 2021). Additionally, the speed of vessels also has an impact on SEL, Wittekind (2009) found that a small vessel can produce the same level of noise as a vessel twenty times its size if it is travelling at twice the speed of the larger vessel. These factors may contribute to the recording from the current survey; however, without up-to-date local vessel track data for the period, it is not possible to compare the potential impact of the drilling to the ongoing vessel traffic transiting through the site.

In comparison to the previous noise monitoring of vibrocore activities (Gardline, 2021), the mean SEL is much lower (163 dB re. 1μPa^2·s during coring activity; Gardline, 2021). This is likely a result of the positioning of the machinery required for the geotechnical drilling activity; unlike coring, most machinery, with the exception of the drill string, are above the water. In flat, calm conditions, the sea surface acts as a mirror and can reflect almost 100% of the sound energy away from the ocean (Ulrick, 1983). However, it can be assumed that a larger drill with greater force of penetration will cause sound levels to increase and therefore, may exceed the ambient noise levels. Additionally for this survey, an anchor was used to keep the drilling platform at location. If this was replaced with dynamic positioning thrusters then the noise of the vessel itself would likely exceed that of the drilling activity.

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