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CONFIDENTIAL

Prepared for: **Chancery Green on behalf of Refining New Zealand**

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Title: **Short-term Passive Underwater Acoustic Survey of Whangarei Harbour Entrance and Marsden Point: Preliminary Investigation**

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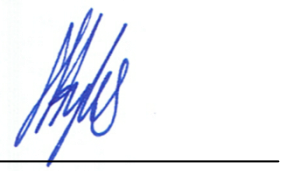

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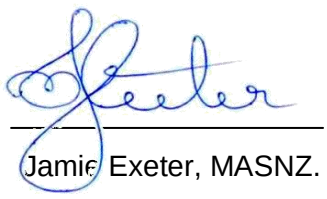

Jamie Exeter, MASNZ.

Executive Summary

Styles Group has been engaged by Refining New Zealand (RNZ) to undertake a passive acoustic survey of the ambient underwater soundscape within and around Calliope Bay at the entrance to Whangarei Harbour as part of an investigative phase 1 study. This survey addressed three separate objectives: the first was to establish the temporal and spatial variability of background sound levels over the two week study period; the second was to determine the received sound pressure levels from several vessels, particularly a suezmax vessel, entering and departing the Marsden Point Oil Refinery; and the third was to confirm the presence of marine mammals over the study period.

Up to eight passive acoustic loggers were deployed within Calliope Bay and Bream Bay at four separate survey sites (Lort Point, Mair Bank, Busby Head and Bream Bay). Ambient sound levels varied within each survey site with spectral analyses revealing variances up to 47 dB for frequencies below 10 kHz. Measured sound levels were highest within the Lort Point survey site (average 119 ± 0.08 dB_{rms} re 1 µPa) and decreased with increasing distance from the Marsden Point industrial area (averages of 113 ± 0.07 dB_{rms} re 1 µPa, 108 ±, 0.46 dB_{rms} re 1 µPa, and 105 ± 0.10 dB_{rms} re 1 µPa from within the Mair Bank, Busby Head and Bream Bay survey sites, respectively). Between survey sites, the ambient soundscape was largely characterised by frequencies below 2 kHz. Unique within the Lort Point survey site (within the boundary of a Marine 1 (Protection) Management Area) was a consistent low frequency signal (103 - 121 dB_{rms} re 1 µPa between 0.1 and 1 kHz) of various harmonics. This low frequency signal did not demonstrate any biological characteristics and appeared typical of an already existing mechanical source. In the absence of any operating vessels, the broadband sound levels within the Whangarei Harbour entrance were comparable with many other nearshore environments around New Zealand and the soundscape within Calliope Bay was spectrally similar to other busy harbours where vessels are common (as spectral analyses reveal peaks in spectral density below 1 kHz).

Received broadband sound levels from vessels showed considerable variation depending on the type of vessel as well as being a function of speed and distance. The highest broadband (0.05 - 70 kHz) received level measured from any vessel was 150 dB_{rms} re 1 µPa (Torea, IMO 9274082); a considerable increase from the lowest measured level of 128 dB_{rms} re 1 µPa (Anatoki, IMO 8864153). There was no apparent relationship between the tonnage of a vessel and the received broadband sound levels as the largest suezmax vessel (Jag Lagshita, IMO 9208057) had a received broadband level of 135 dB_{rms} re 1 µPa; a phenomenon previously measured by Styles Group at other locations.

Dolphins (species unidentified) were detected within all survey sites, with most detections occurring outside Calliope Bay. No whales were detected during the survey period. In total, dolphins were detected on 13 separate occasions between all four survey sites and vocalisations were mostly detectable for approximately 30 minutes a time. The longest duration

for which vocalisations were detected during a single occurrence was 1.5 hours. These data provide evidence that dolphins do frequent this area, however care should be taken when inferring any conclusions regarding their abundance or habitat use because the data is limited in sample size and methodology.

The data from this survey shows the ambient sound levels within and around Calliope Bay are comparable with other nearshore environments around New Zealand, however average and median levels were lower compared to very busy harbours such as the Waitemata Harbour and inner Hauraki Gulf.

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Introduction

Styles Group has been engaged by Refining New Zealand (RNZ) to undertake a passive acoustic survey of the ambient underwater soundscape within and around Calliope Bay at the entrance to Whangarei Harbour to accompany an application to deepen the channel at Whangarei Heads to allow suezmax vessels to operate at a higher capacity than at present, as well as ease the navigational difficulty during the channel approach. Currently, these large ships carry cargo to and from the oil refinery but are under-loaded so as to successfully navigate the channel between Whangarei Heads and Marsden Point.

The overall aim of the survey was to investigate the ambient underwater soundscape and achieve the three following objectives:

1. To establish background sound levels;
2. To determine the received levels from several vessels, particularly oil tankers, entering and departing the Marsden Point Oil Refinery;
3. To confirm any presence of marine mammals over the survey period.

This report will outline the survey methodology and results for each of the above three objectives. Potential impacts on marine life from undersea dredging or any acoustic modelling of undersea dredging noise have not been undertaken as part of this report.

Materials and Methods

Survey Sites

In order to establish background underwater sound levels within the Whangarei Harbour entrance, Styles Group was asked to design a suitable survey methodology. It was identified that potential underwater noise arising from the proposed dredging activity may propagate into four separate Marine 1 (Protected) Management Area zones in accordance with NRC Map C13 (Figure 1). Thus, eight calibrated SoundTrap (ST) acoustic loggers were deployed to assess the current background sound levels within Calliope Bay and Bream Bay; including within the Marine 1 (Protected) Management Area Lort Point and next to Mair Bank. The four survey sites (each with two individual acoustic loggers) were (1) Lort Point (S 35° 49.856' E 174° 30.223'); (2) Mair Bank (S 35° 51.091' E 174° 31.125'); (3) Busby Head (S 35° 52.449' E 174° 32.757'); and (4) Bream Bay (S 35° 53.147' E 174° 31.326'). A map showing the location of each survey site is provided in Figure 2. The location of each site was selected based on field-accessibility, depth, currents and the purpose of that particular ST logger in the scheme of the overall survey.

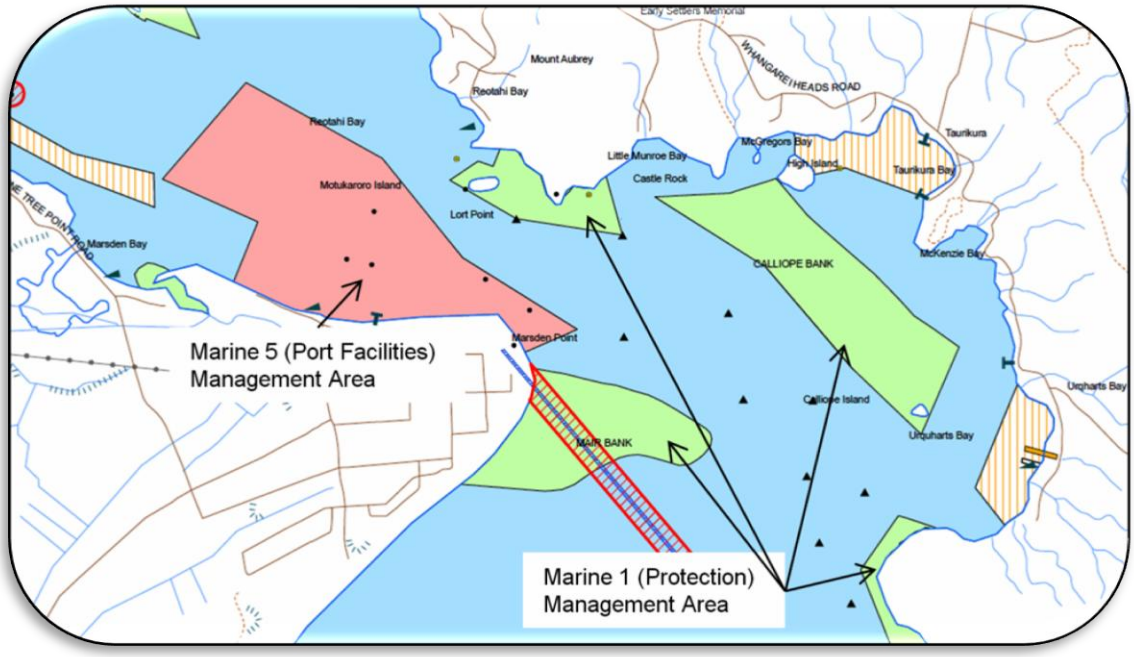


Figure 1: NRC C13 Map. Arrows show main Marine Management Areas.

Figure 2: GPS location of each survey site where SoundTrap loggers were deployed.

Underwater Recording Systems

Ambient sound recordings were made using SoundTrap (ST) 201 (288 kHz sampling rate), 202 (288 kHz sampling rate), and 202HF (576 kHz sampling rate) laboratory grade underwater acoustic loggers secured between 1 m and 2 m off the seabed and at a depth between 6 m and 20 m at MLWS. See Appendix A for a schematic diagram of the deployment apparatus. Two loggers were deployed at each survey site and set on alternating duty cycles to conserve memory and battery life during the survey. Acoustic data were obtained between the 26th March and 6th of April 2015.

Calibration

The hydrophone component of the ST acoustic logger was calibrated by the manufacturer and field-calibration checks before and after deployment were undertaken using a calibrated pistonphone (GRASS Type 42AA, SPL 114 dB re 20 µPa, nominal frequency 250 kHz), a calibrated (using a Brüel & Kjaer Type 4231 Sound Calibrator) sound level meter (Brüel & Kjaer 2250 Type 1 SLM with a Brüel & Kjaer 1/2 inch Condenser Microphone Type 4189) and specialist acoustic software. Electronic calibration of the recorder component was done at the

start of each 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 and verified using the pistonphone. The calibrated range of the hydrophones was 20 Hz to 144 kHz (ST 201, 202 recorders) or up to 200 kHz (ST202HF recorders) before sensitivity begins to decrease. The distances at which an animal would need to be before being detected is highly variable and depends on the vocalisation amplitude and frequency. Consequently, we are unable to identify a scientifically defined range for which marine mammals may be detected.

Data analysis

Each sound recording was examined for extraneous noise contamination from wind, waves, or precipitation to ensure accurate calculation of ambient pressure levels, as well as received levels from commercial vessels. Recordings which did contain considerable contamination were not analysed.

A descriptive statistical analysis was undertaken on 1200 thirty-minute recordings made between the 26th March and 6th April over the four survey sites. Power spectra, third-octave band levels, the spectral probability density (SPD) and broadband sound pressure level (SPL) for each survey site over the deployment period were calculated. Note the 1200 recordings were made up of systematically selected 30min recordings which did not contain extraneous noise contamination (from weather). Selection was based on every hour or half-hour period depending on the degree of contamination, if any.

Ship arrival and departure times at the oil refinery during the survey period were provided by North Tugz Limited and were used to identify passing ships in the acoustic data. Broadband received levels of each passing ship were calculated and plotted against time, along with the corresponding power spectra.

Acoustic data were analysed to determine the presence or absence of marine mammals using automated acoustic detectors and confirmed by visual inspection of the corresponding spectrogram. Vocalisations were not characterised or specifically analysed as this type of analysis was outside the survey's scope.

Survey Results and Discussion

Due to the high tidal currents within Calliope Bay, a single ST logger at Lort Point was physically compromised by mud and contained too much extraneous noise contamination to be used. The second ST logger at Lort Point that was closer to the surface was not affected. Therefore, analysis was carried out on the remaining seven acoustic loggers.

Objective 1: Background sound levels

Broadband (50 Hz - 48 kHz) ambient SPLs measured passively over a 24 hour period (28th March 2015) are shown in Figure 3, while percentile plots of both power spectra and third-octaves over the entire survey period are given in Figure 4 and Figure 5, respectively. The 28th March 2015 was selected because the least number of ships were logged coming in or out of Marsden Point on that day and therefore provided the best opportunity to obtain a representative measure with minimal noise contamination. Simple descriptive statistics of the broadband SPLs over the survey period are provided in Table 1.

Ambient sound levels varied within each survey site with spectral analyses revealing variances up to 47 dB for frequencies below 10 kHz (due to consistent vessel activity). Consistent between survey sites was the soundscape being characterised by frequencies below 2 kHz; indicated by the power spectra (Figure 4) and third-octave (Figure 5) percentile plots. Sound levels measured from the Lort Point survey site were largely controlled by large vessels arriving and departing Marsden Point (characterised by a greater noise-floor at frequencies below 2 kHz compared to Busby Head and Bream Bay where sound levels below 200 Hz are >10 dB less). With the exception of the Lort Point survey site, in the absence of any vessels the ambient soundscape could be considered similar to other nearshore environments, such as the outer Hauraki Gulf (~109 - 118 dB re 1 µPa[1]), Rotoroa Island (~112 - 117 dB re 1 µPa[2]) or the Kaipara Harbour (~114 - 118 dB re 1 µPa, respectively (Pine et al. 2015)). However, at the Lort Point survey site only, a continuous low frequency signal (~103 - 121 dB_{rms} re 1 µPa between 0.1 and 1 kHz) of various harmonics was recorded below 1 kHz (Figure 6) on most days. Peak frequencies and SPLs of the signal did vary in time, although showed no consistent pattern (Figure 7). The source of this low frequency signal is not biological but appears mechanical. Notwithstanding this, average background sound levels (broadband) from all four survey sites were lower compared to the inner Hauraki Gulf where average sound levels measured from within the Waitemata Harbour, Rangitoto Channel and Waiheke Channel range between 116 and 127 dB re 1 µPa[3]. The gradual increases in sound energy residing in frequencies above 10 kHz were controlled by snapping shrimp, which are the most ubiquitous species within New Zealand's temperate habitats (Pine et al. 2015; Radford et al. 2008; Radford et al. 2010), such as those around Whangarei Heads and within Calliope Bay.

[1] Pine, MK. Unpublished data, August 2011. Leigh Marine Laboratory, Institute of Marine Science.
[2] Pine, MK, Styles JR. Unpublished data from passive acoustic survey, July - October 2014. Styles Group Acoustics and Vibration Consultants.
[3] Pine MK., Styles JR. Unpublished data from passive and active surveys between May 2013 and October 2014. Styles Group Acoustics and Vibration Consultants.

Survey Site	Mean ± SE (dB_{rms} re 1 µPa)	Median (dB_{rms} re 1 µPa)	Max (dB_{rms} re 1 µPa)	Min (dB_{rms} re 1 µPa)	Range (dB_{rms} re 1 µPa)
Lort Point	119 ± 0.08	117	147	111	36
Mair Bank	113 ± 0.07	111	146	108	38
Busby Head	108 ± 0.46	107	142	98	44
Bream Bay	105 ± 0.10	104	132	96	36

Table 1: Basic statistics for ambient broadband sound (50 Hz - 48 kHz) measured at each survey site between 26th March and 6th April 2015 based on 7,043 randomly selected 60-sec samples per site.

Despite the lower broadband sound levels, the soundscape within the Whangarei Harbour entrance was spectrally similar to other harbours where vessel activity is high as the root mean squared and 5th percentile spectrum was characterised by frequencies below 1 kHz, while the outermost survey site, Bream Bay, demonstrated spectra closer resembling those of soft sediment habitats.

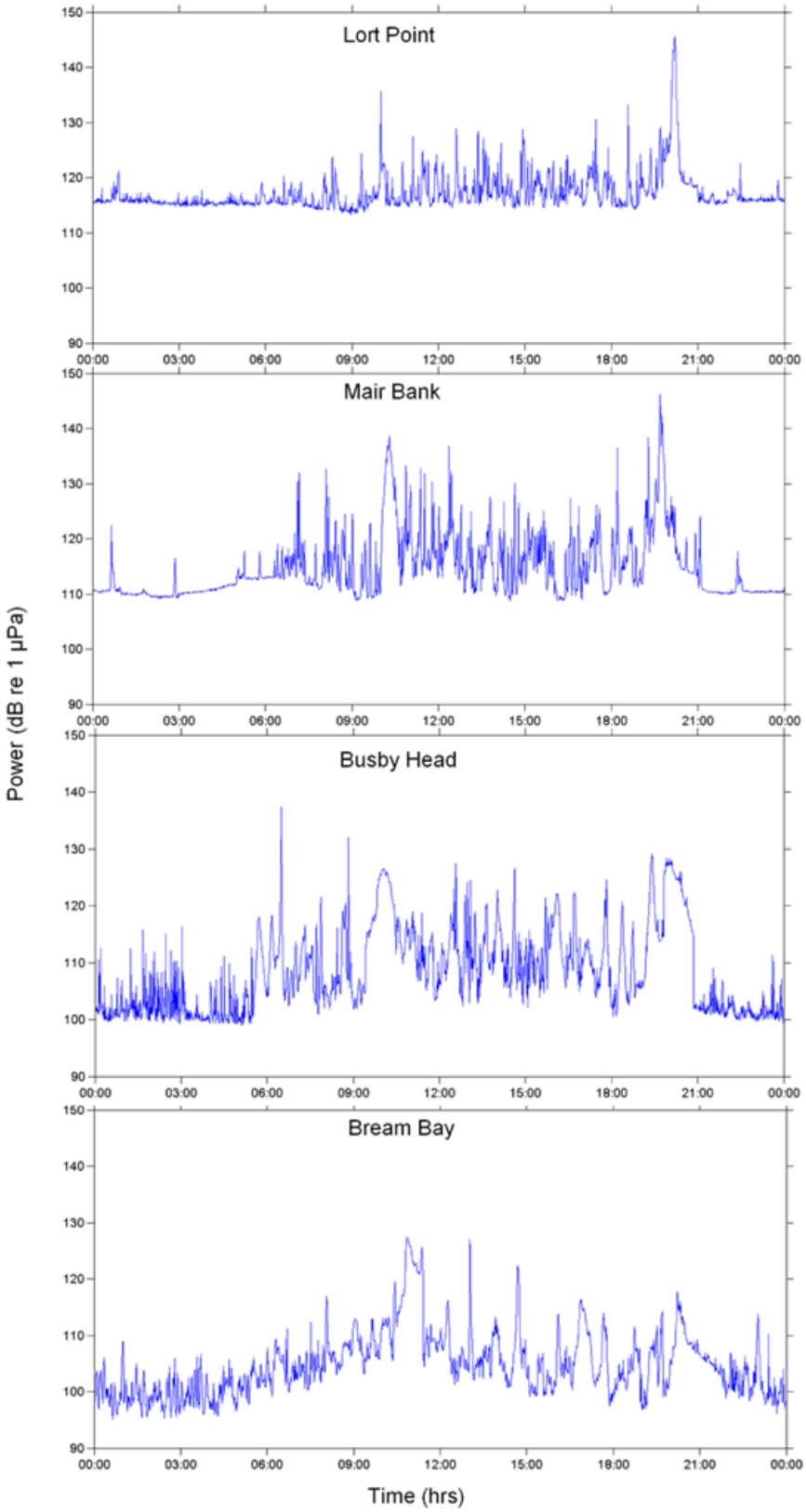


Figure 3: Broadband (50Hz - 48kHz) ambient SPLs measured over a 24 hour period (28th March 2015) at each survey site (n=2161).

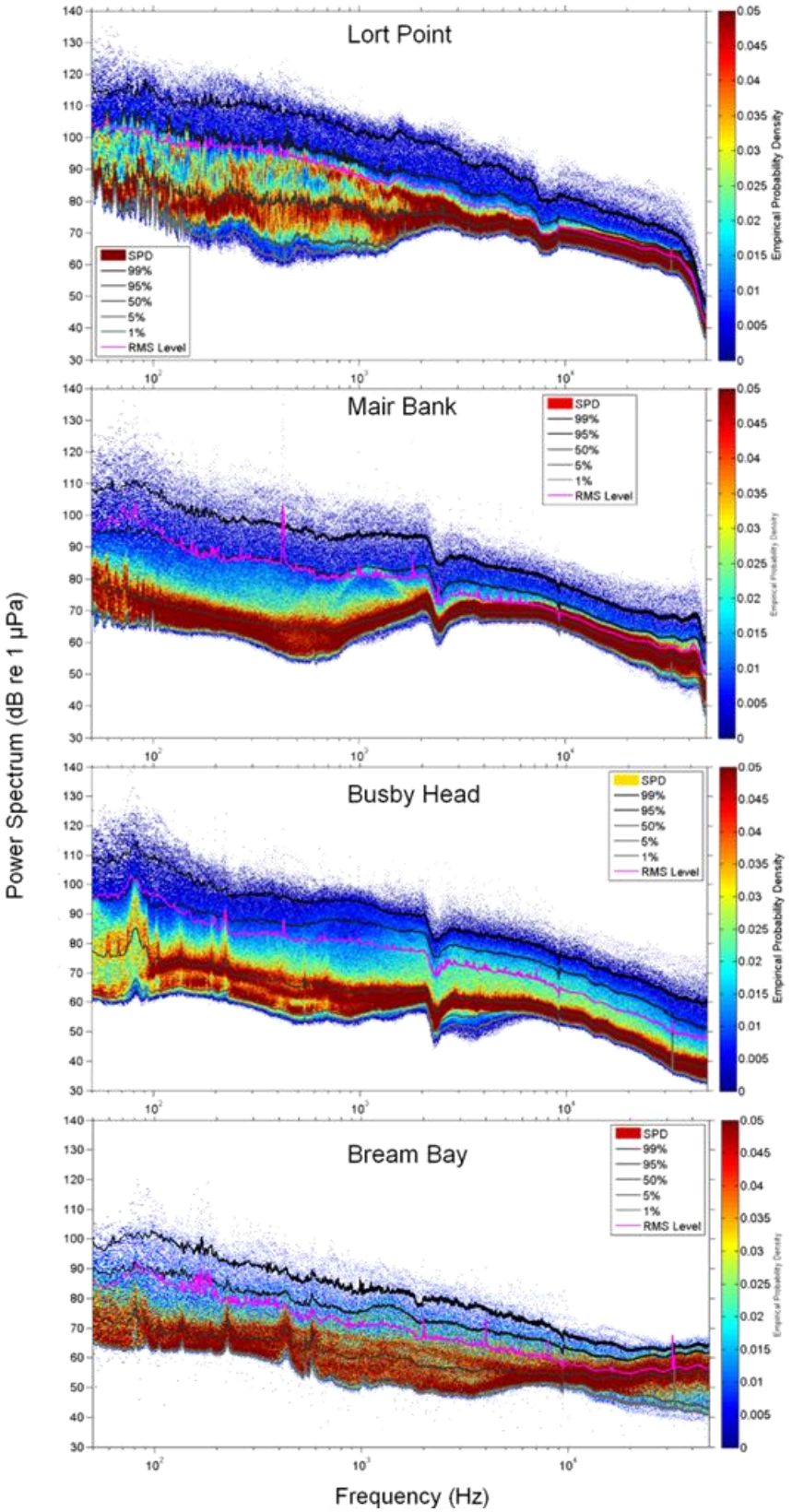


Figure 4: Power spectra plots showing RMS spectrum, percentiles and SPD measured over the survey period.

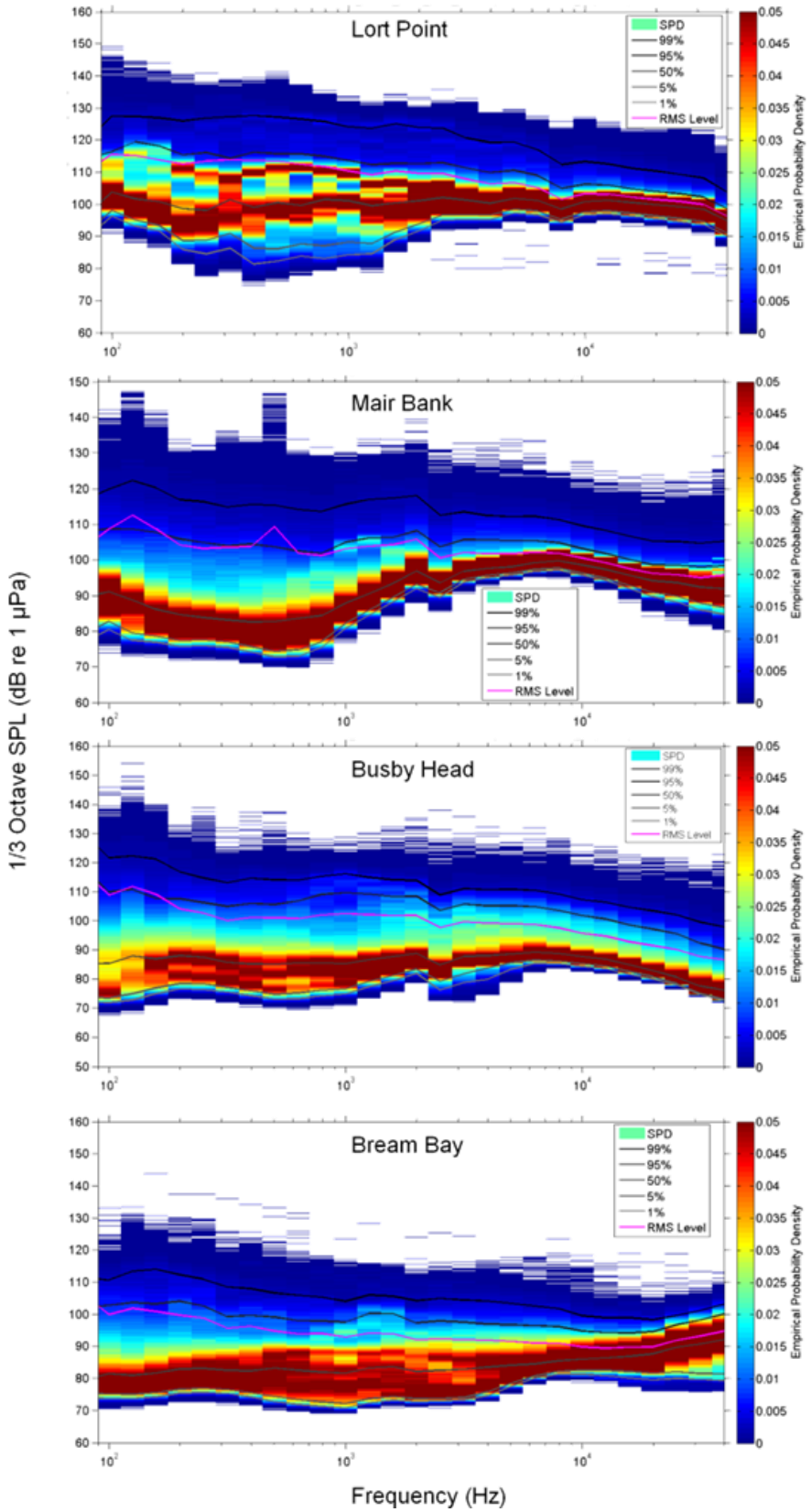


Figure 5: Third octave band plots showing RMS spectrum, percentiles and SPD measured over the survey period.

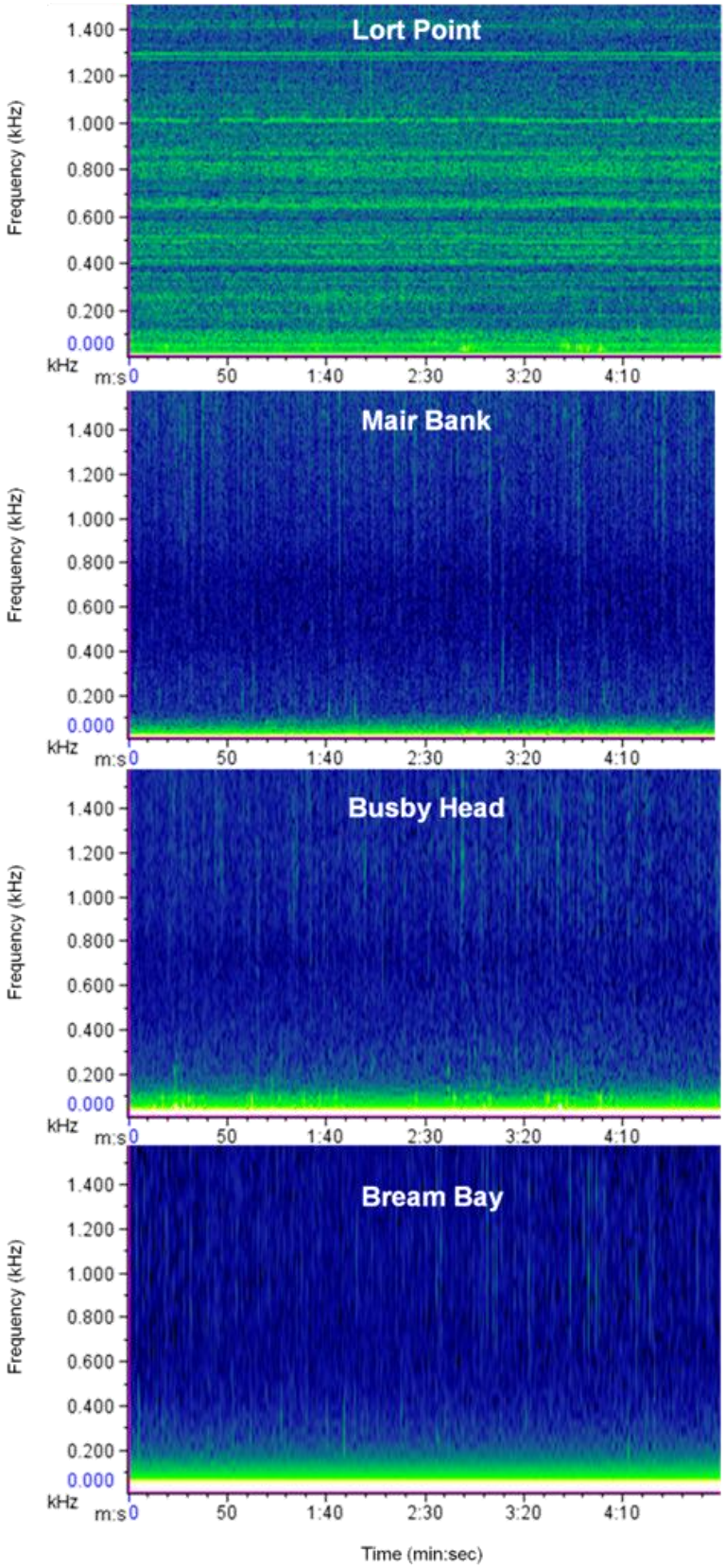


Figure 6: Acoustic spectrograms showing the low frequency signal composed of several harmonics within the Lort Point site only. Spectrograms based on five minute sample at 01:00hrs 26th March 2015.

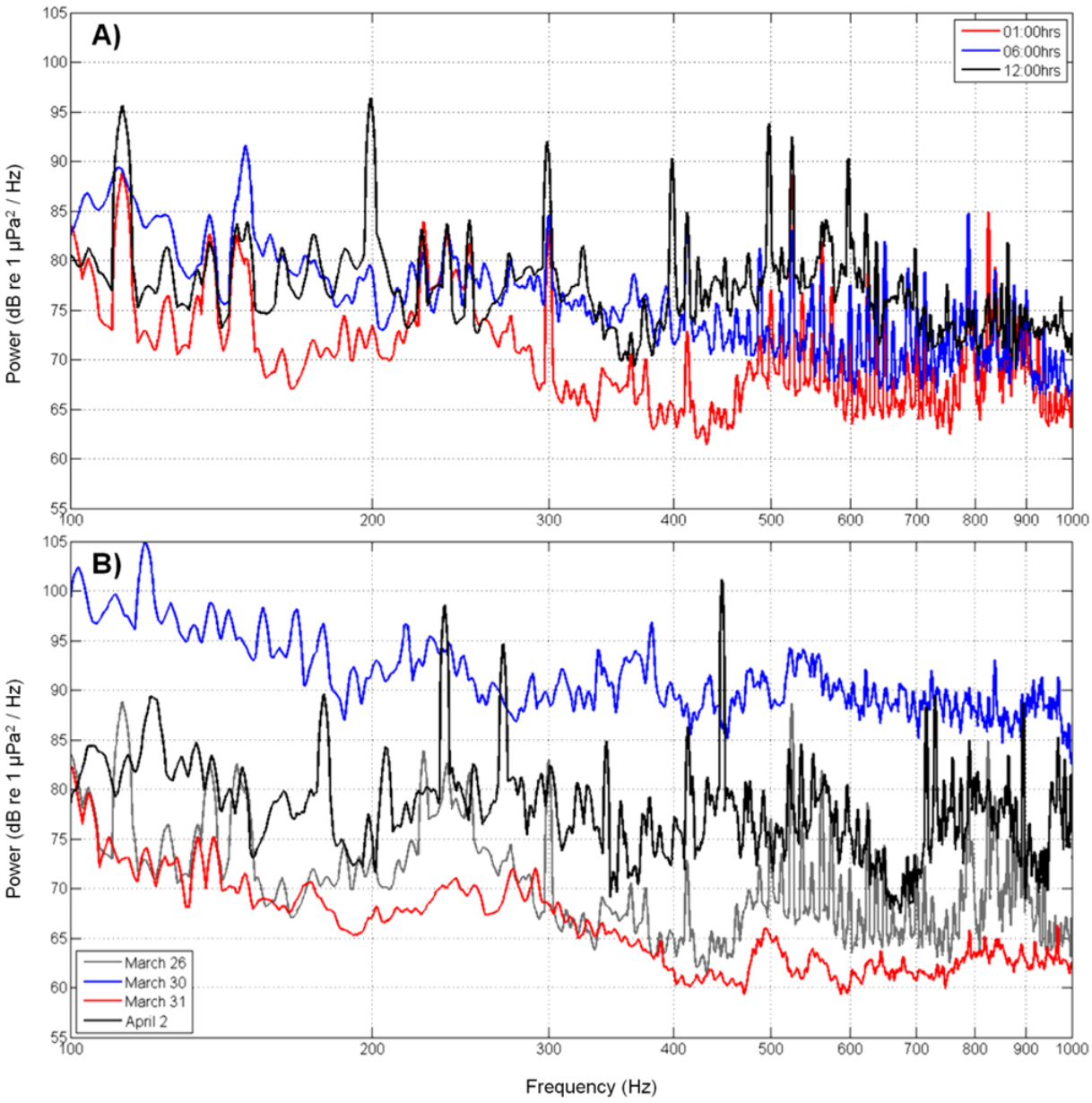


Figure 7: Power spectra plots of continuous low frequency signals within the Lort Point survey site: (A) 26th March 2015 at 01:00hrs, 06:00hrs and 12:00hrs; and (B) plots showing temporal variability in peak frequencies and SPL below 1 kHz between the 26th March and 2nd April. Samples were taken between 01:00hrs and 02:30hrs where no vessel noise (commercial and recreational) was present. Power spectra was calculated using a randomly selected 10min recording. The continuous low frequency harmonics suggest source is mechanical.

Objective 2: Vessel noise

A total of 15 identifiable vessels were recorded both arriving and departing Marsden Point. Of those 15 vessels, five were oil tankers (four out of the five were smaller coastal product vessels). Details of all 15 vessels, including the received SPLs are given in Table 2. Broadband SPL plots of each oil tanker passing through the Mair Bank or Lort Point survey site (identified in Table 2) and the corresponding spectral plots are provided in Figure 8.

Vessel Name	IMO Number	Type	Speed (km h^{-1})	Distance (m)	Received SPL (dB_{rms} re 1 µPa)	Survey Site
Awanuia	9458042	Bunker Tanker (Coastal)	17	257	143	Mair Bank
Maritime Victory	9550292	Log	17	287	141	Mair Bank
Ningpo	9134658	Veneer	NA*	NA*	136	Mair Bank
Pacific Princess	7806271	Fishing	NA*	NA*	142	Mair Bank
Amsel	9076387	Log	15	300	141	Mair Bank
Jag Lagshita	9208057	Suezmax	12	277	135	Mair Bank
Kakariki	9158305	Coastal Tanker	19	248	137	Mair Bank
Anatoki	8864153	Cement	20	314	143	Mair Bank
Yangtze Grace	9584231	Log	19	293	142	Mair Bank
Matsumae	9401336	Triboard	17	270	136	Mair Bank
Baltic Hare	9397236	Log	18	249	143	Mair Bank
Southern Trader 3	9167459	Cement	23	286	141	Mair Bank
Torea	9274082	Coastal Tanker	22	313	150	Mair Bank
High Endurance	9272929	Small Tanker	10	508	133	Lort Point
Maritime Fidelity	9528861	Log	16	284	143	Mair Bank

*Data unavailable.

Table 2: Details of each commercial vessel arriving/departing the oil refinery and the received broadband SPLs (50 Hz - 70 kHz).

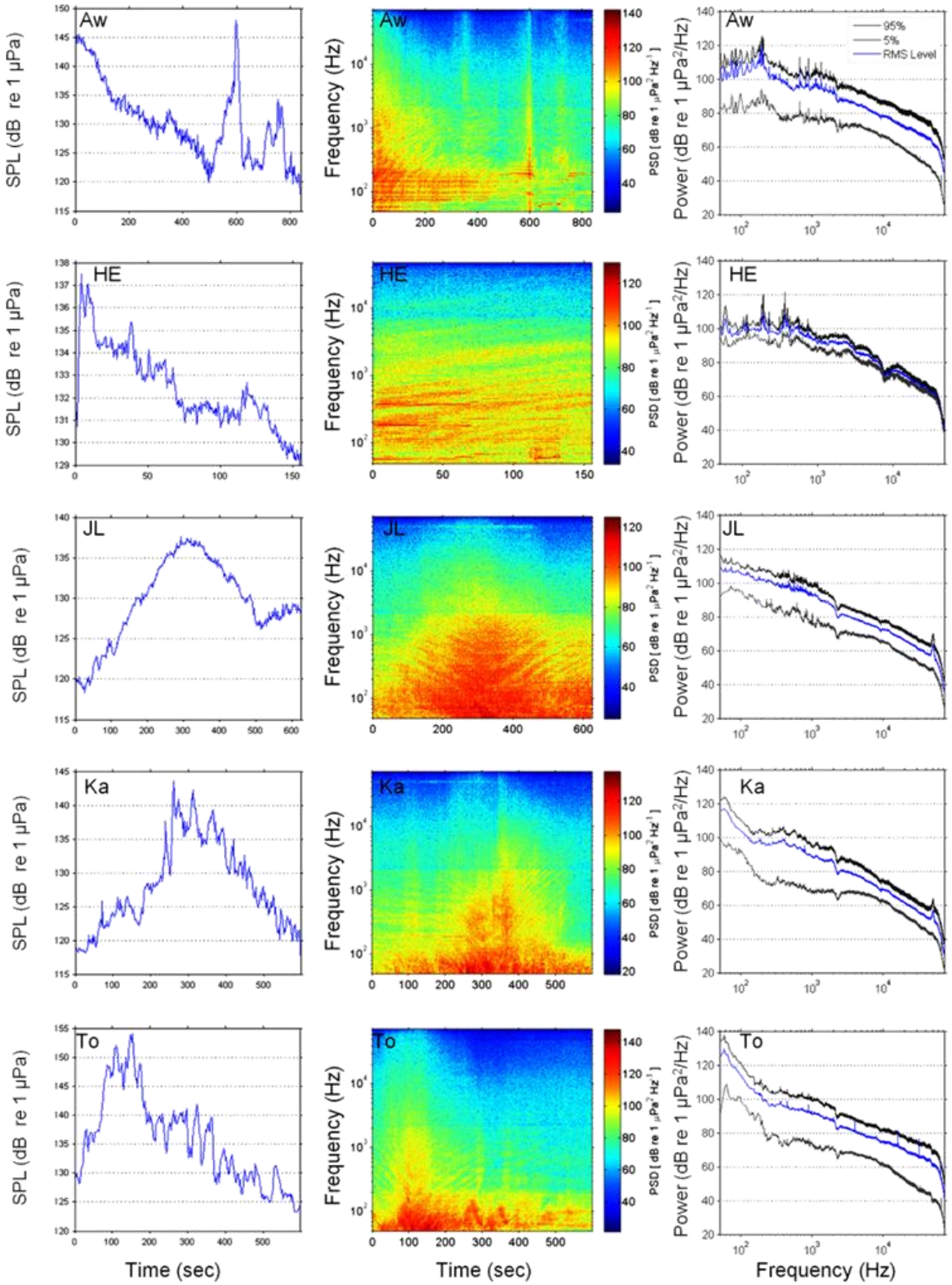


Figure 8: Broadband SPLs (left column) and corresponding acoustic spectra for five oil tankers arriving or departing the Marsden Point oil refinery (Aw=Awanuia; HE=High Endurance; JL=Jag Lagshita; Ka=Kakariki; To=Torea).

The broadband SPL of the larger suezmax tanker is not the highest, with many of the smaller coastal tankers showing greater received SPLs. It is important to note, however, that this difference may be caused from reduced speed, differing distances or engine configurations and the relationship between vessel speed and received SPLs are plotted in Figure 9.

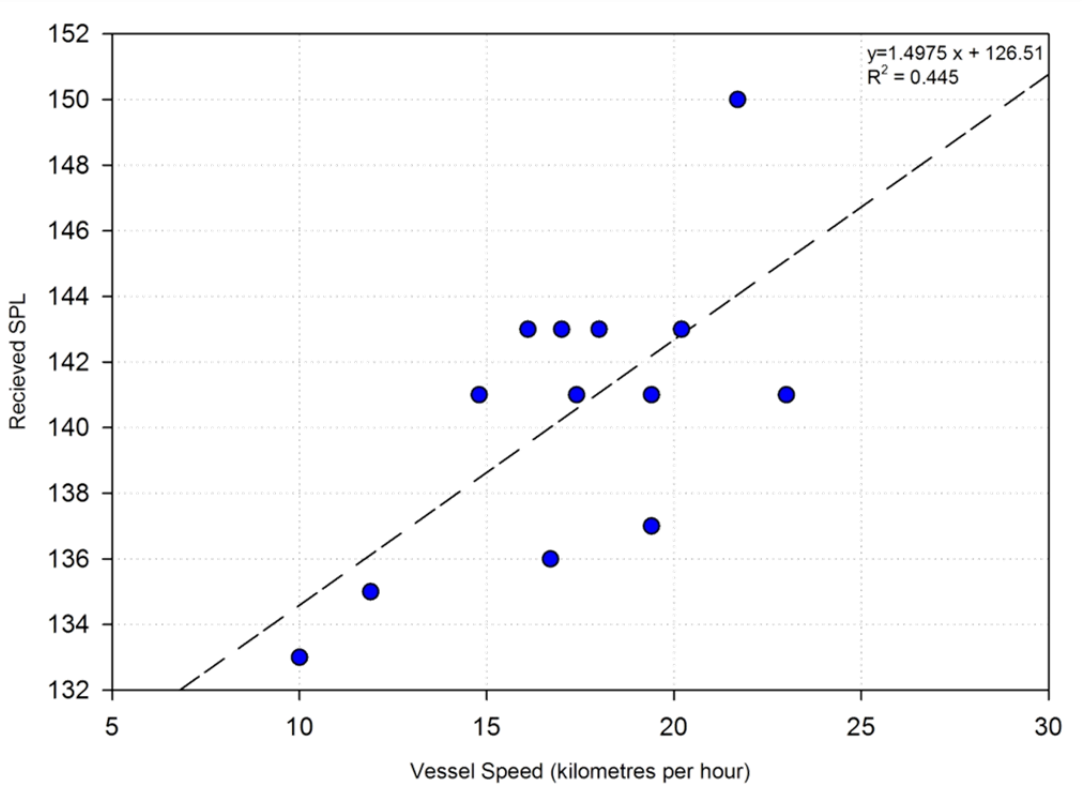


Figure 9: Relationship between received SPL (dB re 1 µPa) and vessel speed (km h^{-1}). Dotted line represents the regression line showing a statistically significant positive relationship (y = 1.4975x + 126.51; R^2 = 0.445; Regression ANOVA $F_{1,12}$ = 8.833, P = 0.013). ANOVA was performed after confirming the data met the assumptions for normality and homogeneity. Note these are based on received SPLs and have not been controlled for distances or spectral variability between vessels' acoustic outputs.

Objective 3: Marine mammal detection

Marine mammals were identified on several occasions during the survey. In total, marine mammals were detected 13 separate times between all four survey sites. Both echolocation clicks and whistles were detected and a typical example is shown in Figure 10. On most occasions, vocalisations were detectable for approximately 30 minutes at a time, with the longest occurrence lasting was approximately 1.5 hours.

Recorded whistles were consistently between 6 kHz and 20 kHz and clicks were broadband between 20 kHz and 100 kHz (characteristic of some dolphins). Due to the limited number of samples, identification of species was not possible. Whales and narrow-band high frequency cetaceans were not detected during the survey. The highest number of dolphin detections were within the Busby Head (6 separate detections) and Bream Bay (5 separate detections) survey site, followed by Mair Bank (2 separate detections) and Lort Point (1 detection). On one occasion, a group of dolphins were clearly detected during the passing of the ship Anatoki (IMO 8864153), at Mair Bank, as shown in Figure 11.

It is important to note that this survey does not serve as an accurate estimate of abundance or diversity, or the degree of affinity to a particular habitat or area. Dolphins vary their vocalisations depending on their behaviour and they are only detectable when they vocalise in proximity to the hydrophone, at sufficient levels to be detected over the background noise floor. Notwithstanding that, however, the results from this survey show that dolphins do frequent the general area. It is therefore our opinion that a noise management plan including passive acoustic monitoring may be required. This is, however, a matter that will be revisited in the future during the Phase 2 work.

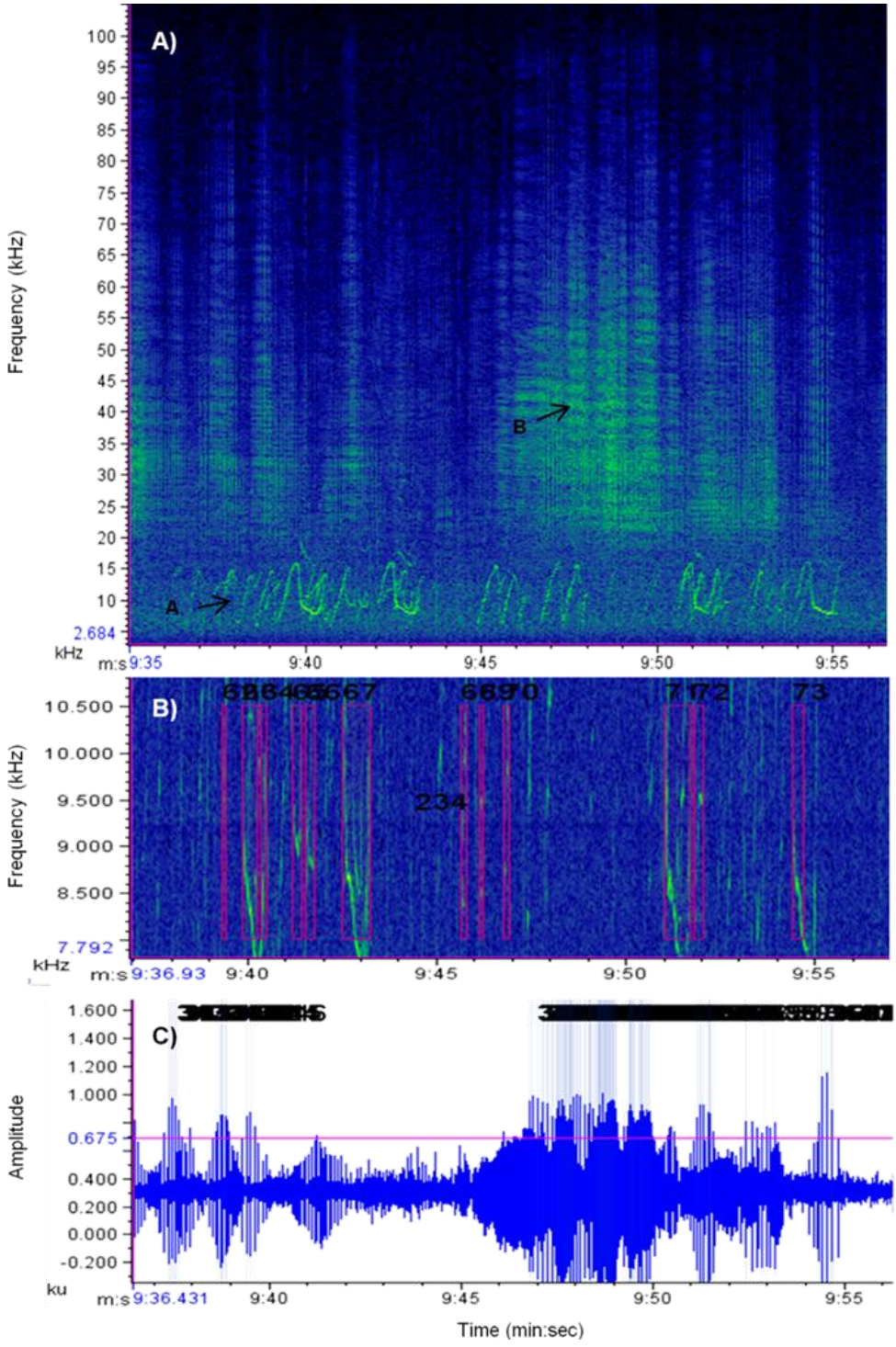


Figure 10: Acoustic spectrograms and waveform of dolphin vocalisations: (A) Echolocation clicks (shown by the arrow labelled B) and whistles (shown by arrow labelled A); (B) magnified section of whistles showing the auto-detection; and (C) waveform of vocalisations showing the amplitude auto-detection.

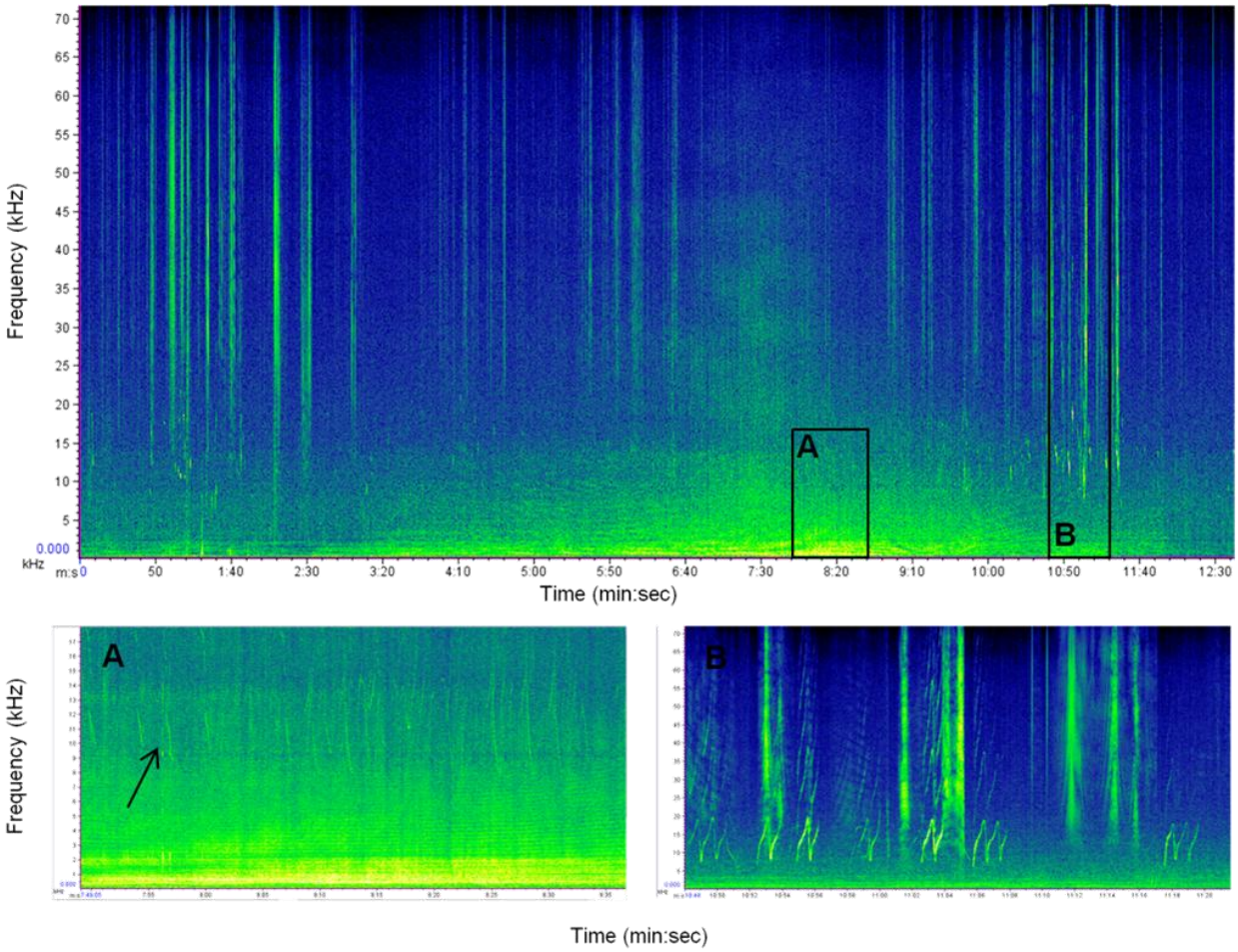


Figure 11: Acoustic spectrogram of the Anatoki (IMO 8864153) and dolphins at Mair Bank. The smaller windows labelled A and B are magnified sections corresponding to the boxes in the main spectrogram. The arrow identifies dolphin whistles over the top of the passing vessel noise.

Conclusion

Styles Group has been engaged by RNZ to undertake a passive acoustic survey of the ambient underwater soundscape within and around Calliope Bay at the entrance to Whangarei Harbour to accompany an application to deepen the channel at Whangarei Heads to allow suezmax vessels to operate at a higher capacity than at present. Currently, these large ships carry cargo to and from the oil refinery but are under-loaded so to successfully navigate the channel between Whangarei Heads and Marsden Point.

Background sound levels varied considerably between survey sites. The highest background sound levels were measured from Lort Point (average 119 ± 0.08 dB_{rms} re 1 µPa) followed by

Mair Bank (113 ± 0.07 dB_{rms} re 1 µPa), Bubsy Head (108 ± 0.46 dB_{rms} re 1 µPa) and Bream Bay (105 ± 0.10 dB_{rms} re 1 µPa). When compared to other New Zealand harbours, for example the Waitemata Harbour and around the inner Hauraki Gulf, the broadband background sound levels measured within the Whangarei Harbour entrance were lower. However, in the absence of any operating vessels, the ambient soundscape within the Whangarei Harbour entrance was comparable with many other nearshore environments around the New Zealand coastline, for example the outer Hauraki Gulf and Kaipara Harbour. Spectrally, the soundscape within the Whangarei Harbour entrance was similar to other harbours where vessel activity is high as the root mean squared and 5th percentile spectrum was characterised by frequencies below 1 kHz, while the outermost survey site, Bream Bay, demonstrated spectra closer resembling those of soft sediment habitats.

Received noise levels from vessels also varied considerably and ranged from 128 dB_{rms} re 1 µPa (Anatoki, IMO 8864153) to 150 dB_{rms} re 1 µPa (Torea, IMO 9274082). The received SPLs from the larger suezmax tanker was less than many of the smaller coastal tankers. However, the lower SPL from the suezmax may be because of her lower speed and differing distances from the receiving hydrophone.

Dolphins were detected at all survey sites, with most detections occurring outside Calliope Bay (Busby Head and Bream Bay). However, dolphins were detected within Calliope Bay on three separate occasions; once being detected as far as Lort Point. While these findings clearly show evidence that dolphins do frequent the general area, much care should taken when inferring any conclusions regarding their abundance or habitat use because the data is limited in sample size.

References

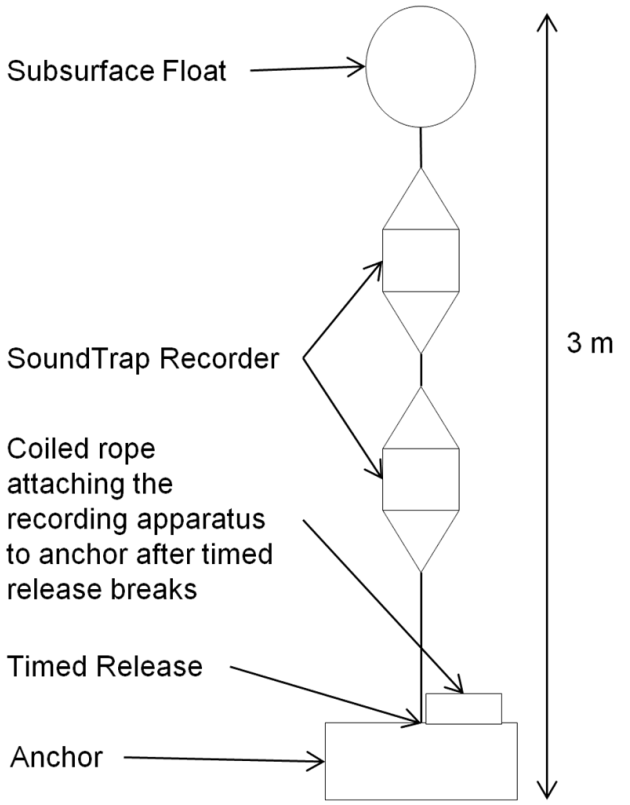
Pine, M.K., Radford, C.A., Jeffs, A.G. (2015). Eavesdropping on the Kaipara Harbour: characterising underwater soundscapes within a seagrass bed and a subtidal mudflat. *New Zealand Journal of Marine and Freshwater Research* 49(2): 247-258.

Radford, C.A., Jeffs, A.G., Tindle, C.T., Montgomery, J.C. (2008). Temporal patterns in ambient noise of biological origin from a shallow water temperate reef. *Oecologia* 156: 921-929.

Radford, C.A., Stanley, J.A., Tindle, C.T., Montgomery, J.C., Jeffs, A.G. (2010). Localised coastal habitats have distinct underwater sound signatures. *Marine Ecology Progress Series* 401: 21-29.

Appendix A

Schematic diagram of the SoundTrap acoustic logger apparatus and photograph of the apparatus being lowered during deployment.



Not drawn to scale