Centre for Marine Science and Technology
Curtin University

PORT HEDLAND
SEA NOISE LOGGER PROGRAM,
FIELD REPORT MARCH-2011 to JULY-2011

By:

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PROJECT CMST 979 and 981d

REPORT R2011 - 48

Abstract

Two seabed mounted noise loggers located 21.6 km apart recorded for a three month period in inshore and offshore waters from Port Hedland, Western Australia from the 29-March to 30-June 2011. A preliminary analysis of the data quality and sources revealed noise sources of: vessels underway and holding location nearby for extended periods; humpback whales; a plethora of unidentified fish calls and choruses; mooring noise artefacts attributable to the high tidal regime; and variations in ambient noise levels at different frequencies on a tidal cycle. Humpback whale calling was common towards the end of the deployment with calling periodically each day in the last week of June.

Contents

1. Introduction

In 2011 RPS Metocean contracted the Centre for Marine Science and Technology of Curtin University (CMST) to supply and analyse data from two sea noise loggers in the Port Hedland area for environmental monitoring purposes, under contract quotes CMST 979 and 981d. The sea noise loggers were intended to:

- Define the natural ambient noise regime including wind, fish and vessel noise, for inshore (proposed wharf area) and offshore (20 m depth contour) areas.
- Estimate the density of great whales in the listening area of the respective noise logger.
- Compare whale densities inshore and offshore.

On 29-March-2011 two sea noise logger moorings were deployed on the seabed by RPS Metocean staff and on 30-June-2011 these were recovered and two replacement noise logger moorings were deployed, again by RPS Metocean. The full work program is for a 15 month period of data collection, with service intervals every three months. A report of data collected for the first three month period is presented here. This is not a thorough analysis but rather defines what data has been collected to July-2011 and identifies the major sea noise sources present without any elaboration. In the initial contract CMST 979 a full analysis as per the objectives listed above was to be completed on retrieval of the 3 month data set, but contract CMST 981d makes that requirement superfluous. A more detailed analysis of this data set has been requested to be completed in Sept-2012.

2. Equipment deployed and recovered

Two Curtin CMST_DSTO sea noise loggers were deployed on the seabed by RPS Metocean staff on the 29-Mar-2011 and turned over on the 30-June-2011 at the locations 21.6 km apart shown on Figure 1. The deployment details are listed in Table 1. These moorings were recovered on the 30-June-2011 and replacement noise loggers deployed at the locations listed in Table 1 (*in water* locations). The locations have been termed PH_O (2972 on Figure 1) and PH_I (2973) for the offshore and inshore locations respectively, with numbers after the site name referring to the CMST deployment number at that site.

The noise loggers PH_O and PH_I sampled 400 s and 320 s of sea noise every 15 minutes respectively, at 6 kHz sampling rate using a 2.8 kHz anti-aliasing filter and a low frequency roll-off applied to flatten the naturally high levels of low frequency sea noise (to improve system dynamic range).

The frequency response in V/μPa of each noise logger was calibrated before deployment by inputting white noise of known level in series with the hydrophone. The frequency response of both noise loggers are shown in Figure 2. The difference in responses in the low frequencies (< 100 Hz) are due to the impedance match between the particular hydrophone and pre-amplifier plus the low frequency roll-off applied. The gain with frequency curves shown on Figure 2 along with the appropriate hydrophone sensitivity are used to correct noise levels in processing.

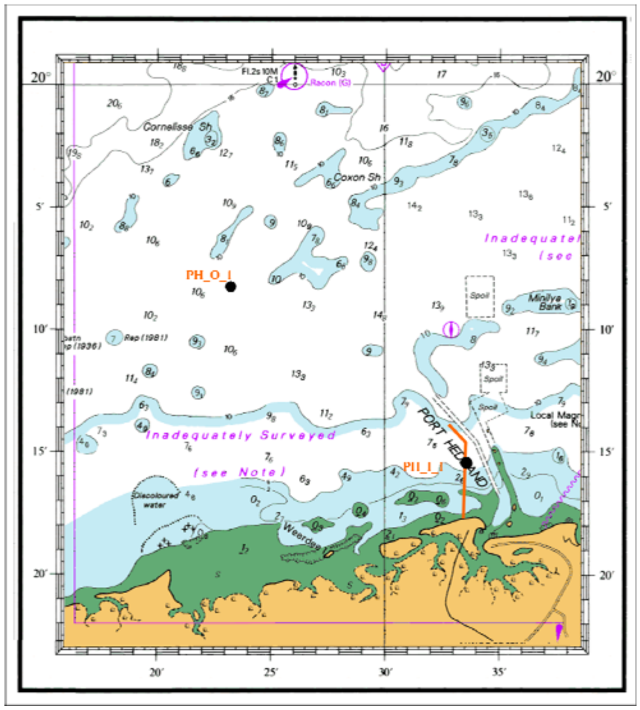

Figure 1: Location of sea noise loggers deployed.

Table 1: Summary of sea noise logger deployments. Locations use WGS84 datum. The fields are: **site**, abbreviations used throughout for the location; the Curtin set number for each recording; latitude; longitude; **D (m)** – water and receiver depth in metres; the start and end of sampling in the water with days sampled (gear recovered only); and equipment details. Times are UTC.

Site	**Set**	**Latitude (S)**	**Longitude (E)**	**D (m)**	**Start / end good data (days recorded)**	**Electronics Hydrophone**
PH_I-1	2973	20°15.428’S	118°33.379' E	10.0	29-Mar-2011 12:00 to 30-June-2011 15:15 (93.2)	SNR Revenge HTI 454 047
PH_O-1	2972	20°08.317’S	118°23.570’E	18.0	29-Mar-2011 13:15 to 30-Jun-2011 10:45 (93)	SNR Lancelot HTI 454 006
PH_I-2		20°15.427’S	118°33.357’E	10.0	30-June-2011 15:50 to In water	SNR25
PH_O-2		20°08.304’S	118°23.524’E	18.0	30-June-2011 11:35 to In water	SNR 28

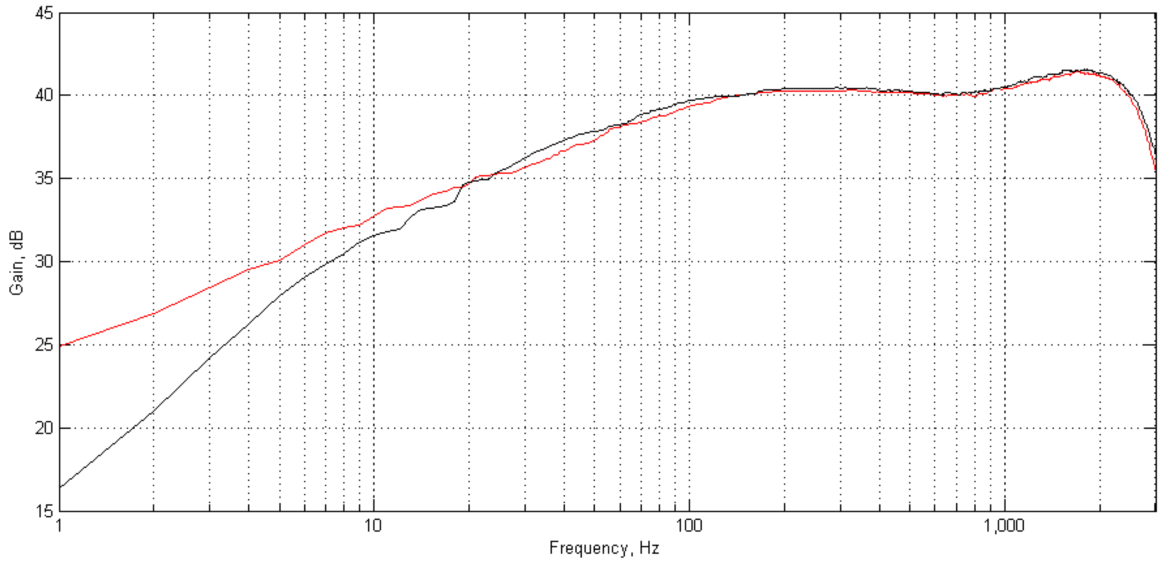

Figure 2: System gain (dB with frequency as determined from white noise calibration before deployment) for dataset 2972 (red) and 2973 (black).

The on-board clock of each logger was time synchronised to UTC time transmitted by GPS before deployment and the clock drift read after deployment, with estimated clock accuracies at any point in time of the order of ± 250 ms. The clock drifts were:
Set 2972 gained 0.024 s/day
Set 2973 gained 0.009 s/day

3. Results

3.1 Data summary

To visually display the majority of data collected by each noise logger, summary stacked sea noise spectra have been calculated in 32 day periods starting from 29-Mar-2011. These plots were made by taking the time averaged power spectra of each sample at three frequency resolutions, averaging these across 10 samples and stacking a combination of the averaged spectra through time on a colour plot. A technique was applied to remove noise spikes produced by any hydrophone movement. The resulting figures are displayed with a logarithmic frequency scale from 10 Hz to the upper calibrated limit of the recording system using a fixed colour scale with bounds from 50 to 110 dB re 1 $\mu Pa^2/Hz$. The colour scale bounds are fixed to standardise the plots and optimise the colour dynamic range. Extreme values are set to the colour bounds. These plots are shown on Figure 3 to Figure 5 with the offshore site plotted on the top panel and the inshore site on the lower panel for overlapping time periods. The moon phase has been shown on each of Figure 3 to Figure 5 with full and new moons represented by white and black circles, respectively.

These figures show broad scale temporal patterns and because of the averaging involved (within a sample and across the consecutive averaged samples) can miss, or not display well, signals which are short in relation to the sample length. The plots tend to highlight signal types which are either intense or which persist across the sample length either through a long signal duration or multiple signals within a sample. Vessel noise, machinery noise, fish choruses and humpback whale calls show up well in the plots.

The long time stacked sea noise plots highlight various noise sources. Significant features observed include:

- **Vessels** – There were records of passing vessels although these were not frequent. A transiting vessel produces a noise spike which typically increases and decreases over a 2-6 hour period. An example of a passing vessel can be seen on the 22-Apr-2010 at the inshore site (bottom panel) of Figure 3. There were several instances of vessels operating near to the receivers for long periods, where constant tones associated with engine room machinery were present. One example of a stationary vessel can be seen on the 29-Mar-2010 at the offshore site (top panel) of Figure 3. An example of a vessel staying near to a receiver for a short period is highlighted at the inshore site on Figure 4. Evidence of machinery noise was observed as single tone noise, an example of which can be seen on Figure 5 at approximately 50 Hz
- **Mooring related noise artefacts** appear in some records. Since hydrophones are pressure-sensitive devices, anything which moves them, touches them or which creates pressure fluctuations over the hydrophone can create 'noise' signals which may not be real. To a lesser extent the same thing happens with the hydrophone cable, since it forms part of the circuit leading back to the pre-amplifier. Noise artefacts are common in sea noise records and can be difficult to remove entirely especially for deployments in areas of high current speeds. The sea noise records collected are reasonably free of mooring noise artefacts but instances of spikes from mooring noise were present. These were possibly produced by the hydrophone or hydrophone cable moving in the tidal stream. Sharp movements of the hydrophone translate to impulse signals in the sea noise records. There may have been instances of fish biting or rubbing the hydrophone cable, this is a common source of noise artefact in sea noise records. There was possibly also turbulent flow noise associated with periods of high current. Strong currents passing over protrusions upstream of a hydrophone can create eddy fields which drift down over the hydrophone, creating pressure fluctuations which translate to noise. Periods of either turbulent flow or sediment movement were seen which correlated with the lunar phase in Figure 3 to Figure 5, where higher levels of noise mostly < 30 Hz correlated with spring tides over periods of new or full moons. The six hourly tidal cycles were also evident in some plots. Periods with the mooring moving and this creating noise artefacts were also present, as shown on Figure 4 at the inshore site over 18-Apr-2011 to 24-Apr-2011 as evident by the strong spikes.
- Vocalisations produced by **humpback whales** were commonly present at the offshore site towards the end of June, as highlighted on Figure 5 between 150 and 1000 Hz with the major call energy within approximately 250-800 Hz.
- Several different **fish choruses** were present at each site as well as isolated fish calls. All fish choruses showed daily and seasonal patterns. Fish choruses are produced when large numbers of fish school and call *en-masse*, usually either for reproductive or feeding purposes. Periods with fish choruses of varying characteristics present are highlighted on Figure 3 at the offshore site although several fish choruses were present at the two sites over the full recording duration. On Figure 5 two fish choruses were easily evident, one recorded at both sites centred around 400 Hz (with harmonics at around 800 Hz) and one at the inshore site, centred at near 350 Hz. Examples of individual, or small numbers of fish calling can be seen at the offshore site, Figure 5, towards the end of June with one set centre around 400 Hz and one at 200 Hz.

Wind driven noise and variation in intensity at a given frequency can be seen in Figure 13. The peaks in the frequency spectra are dependent on propagation of noise over the limestone shelf, a phenomenon known as notch frequency. Propagation at a specific frequency is dependent on water levels and thus changes with tidal pattern, producing the variations seen between 100 and 500 Hz in Figure 13.

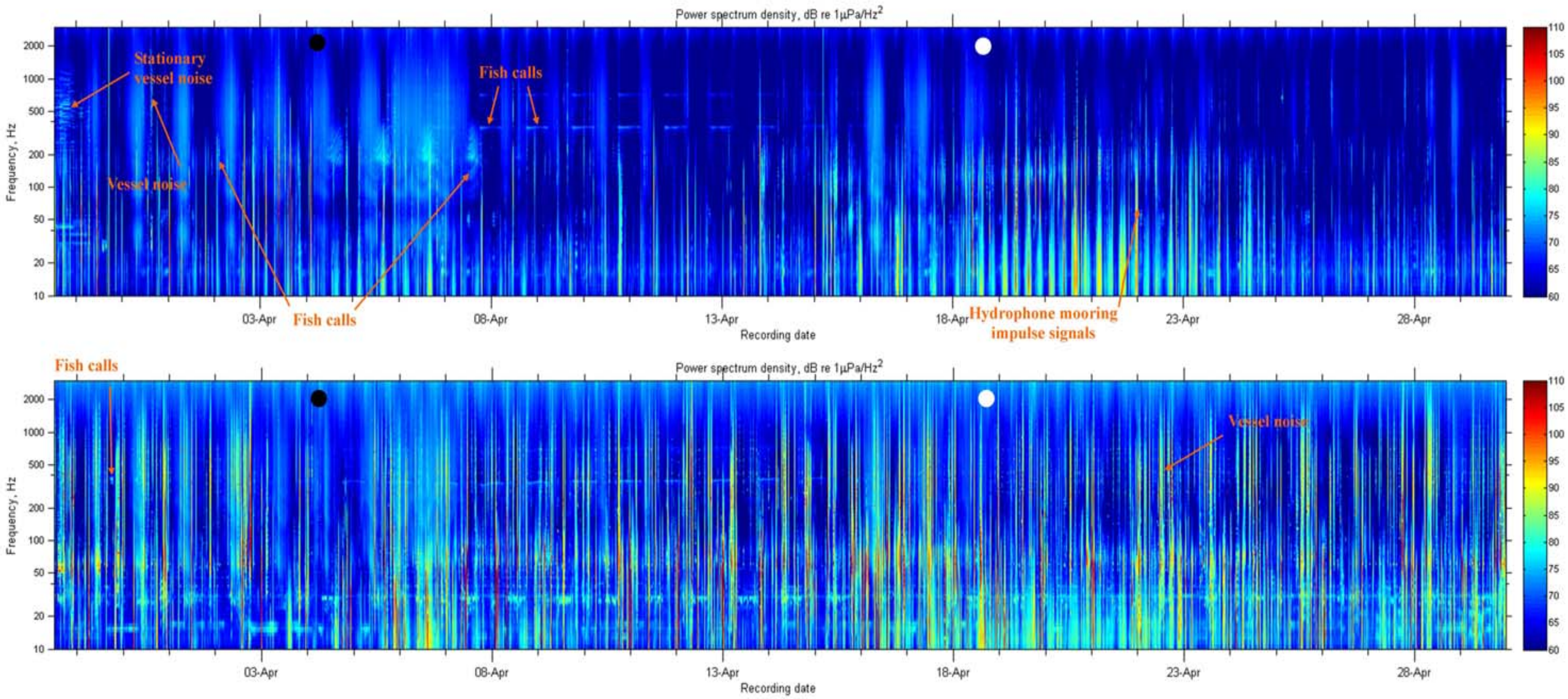

Figure 3: Stacked sea noise spectra in 32 day batches from 29-Mar-2011 for the offshore site (top) and the inshore site (bottom). Several features are highlighted. The white and black circles represent full and new moon periods respectively.

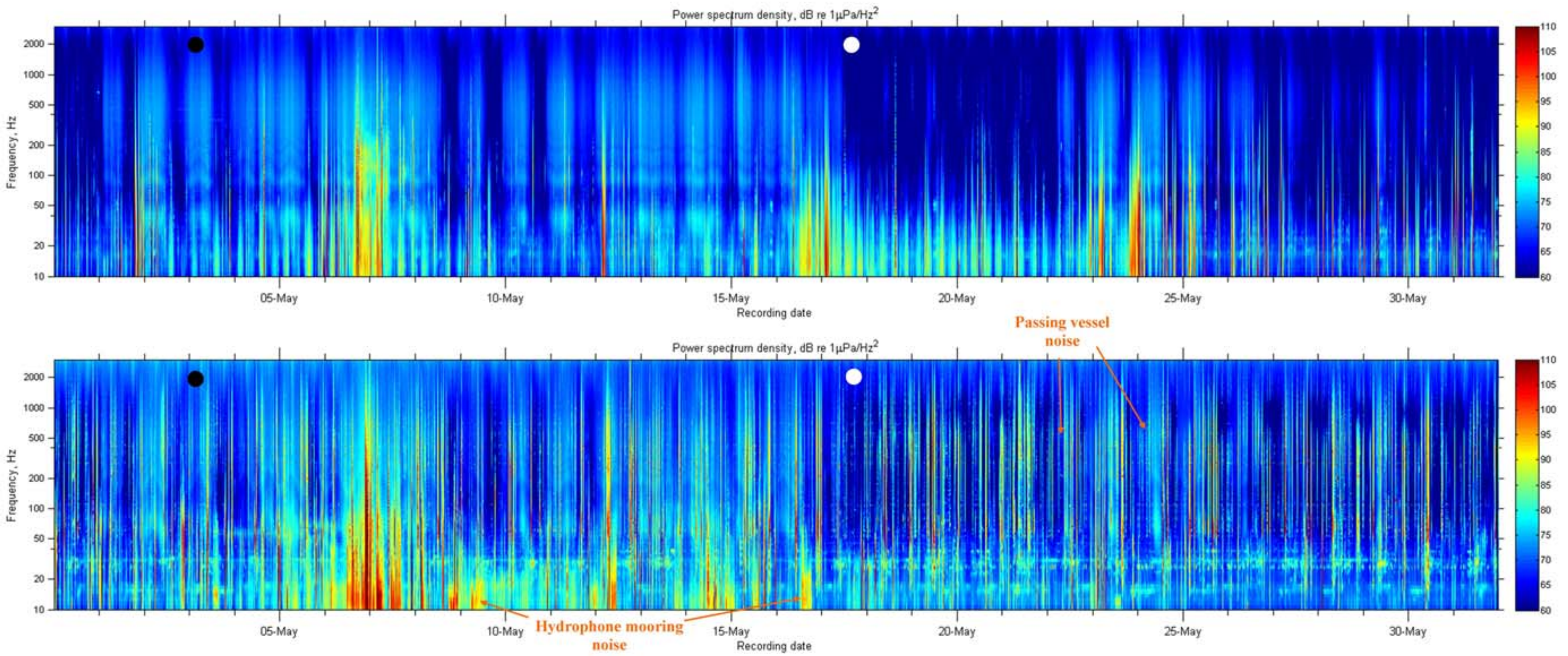

Figure 4: Stacked sea noise spectra in 32 day batches from 30-April-2011 for (top) the offshore site and (bottom) the inshore site. The white and black circles represent full and new moon periods respectively.

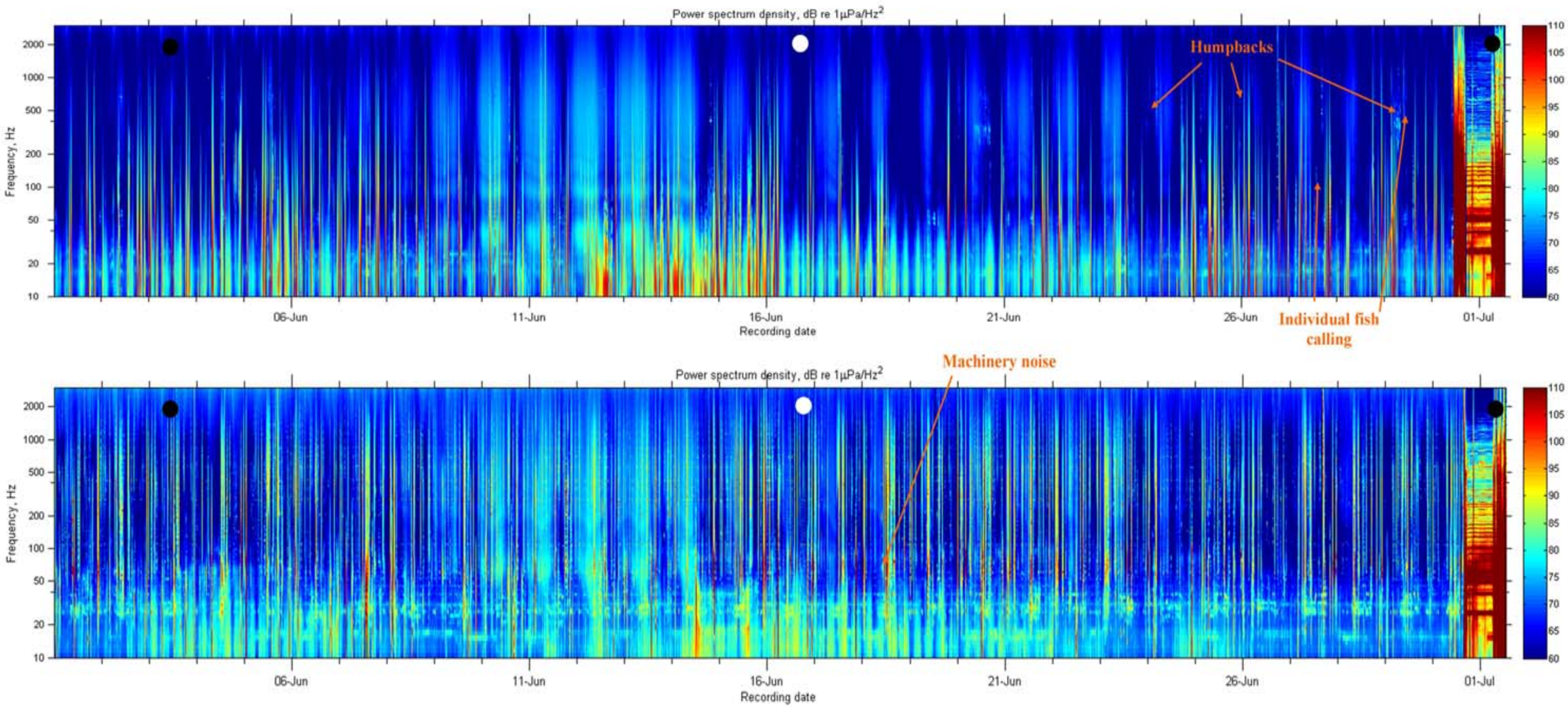

Figure 5: Stacked sea noise spectra in 31 day batches from 01-June-2011 for (top) the offshore site and (bottom) the inshore site. The white and black circles represent full and new moon periods respectively.

3.2 Humpback whales

Humpback whale calls were recorded at the offshore site during the last week of the deployment between the 24th and 29th June (Figure 5). Humpback whales are often reported in this area during winter and spring months. They sing most prolifically on their migration to breeding grounds, while on breeding grounds (in low latitude regions), and during the migration back to feeding grounds (generally in high latitude polar regions). The songs are more or less stereotypical for the whale sub-population migrating yearly along the WA coast. They usually have a similar structure, although there may be sections of the song which vary considerably amongst individuals. Relatively little singing appears to occur in feeding grounds. Often a singer remains in one location while singing, and in these situations singers often adopt a head-down posture at 15-30 m below the surface (Frankel, 2009). There is some suggestion that singing may increase significantly at night (Au *et al.*, 2001 and indeed the whale vocalisations in these recordings occurred predominantly during hours of darkness (Figure 5). An example 12 seconds of humpback calls from the 27th June can be seen in Figure 6. The call energy is present between 150 and 1000 Hz with the major components within approximately 250-800 Hz.

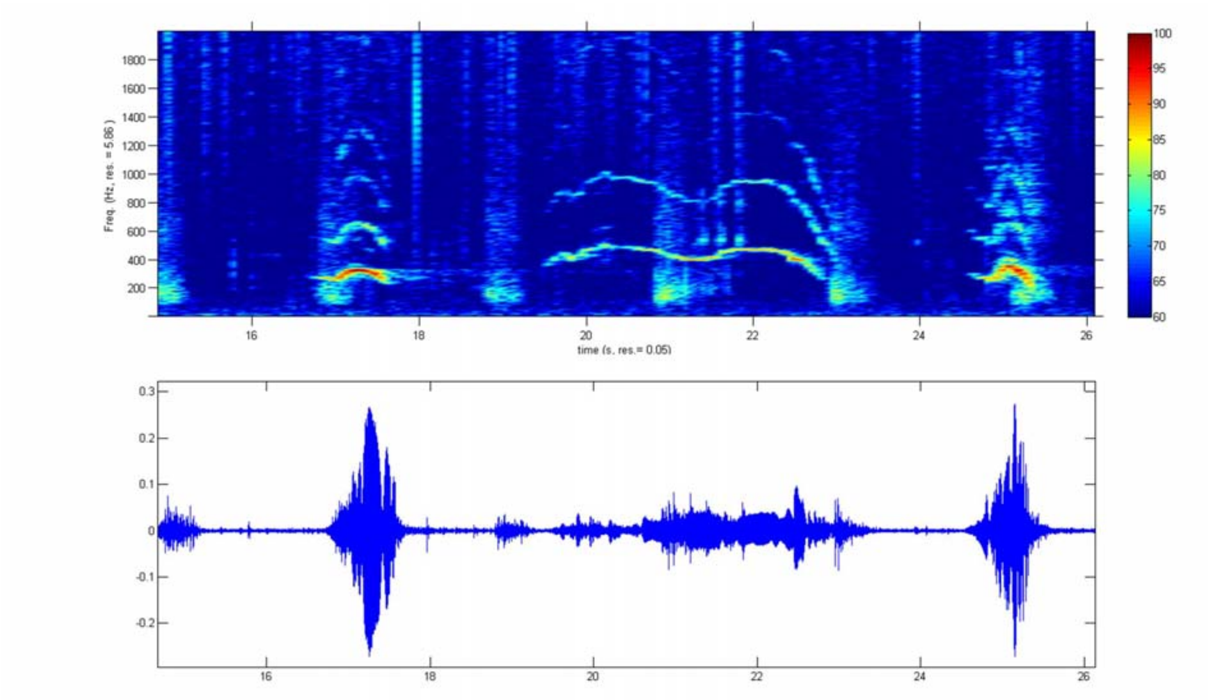

Figure 6: Example 12 seconds of humpback whale calls with weaker calls (more distant animals) in the background recorded at 23:30 on the 26-Jun-2011.

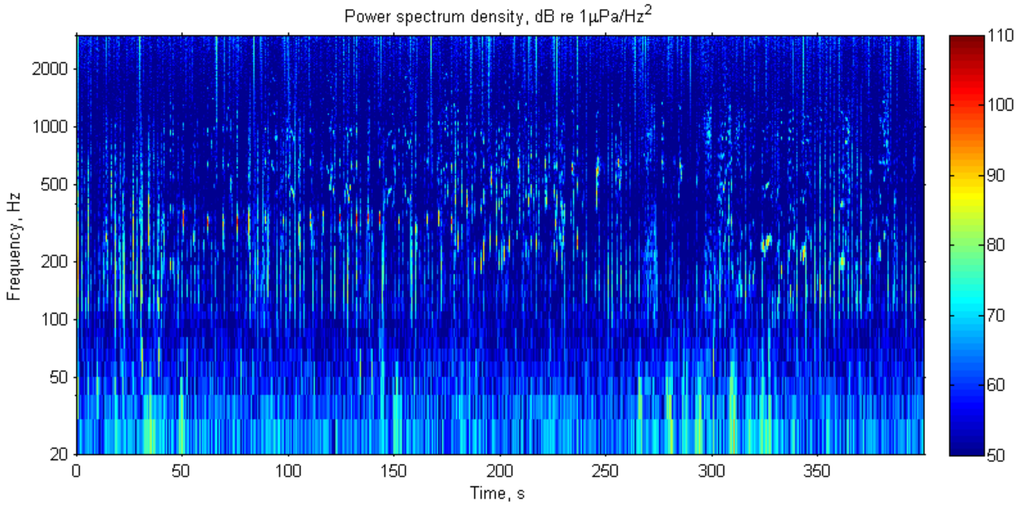

Figure 7: Spectrogram showing a passage of humpback whale calls over a 7 minute period. Humpback call energy occurs predominantly between 150 and 1000 Hz. The peaks of energy below 50 Hz are probably turbulent flow over the hydrophone related to tidal flow.

3.3 Fish calling and choruses

The two sites were rich in fish call types and choruses. While fish may call individually with only one or few fish heard at any point in time they commonly call as a group in schools, producing choruses which may raise ambient noise levels by tens of dB for extended periods over wide frequency bands (usually in the range 10-2500 Hz). Typically fish choruses are produced at night with one species calling for several hours and often many species calling consecutively across a night with the chorus type different for each sepcies. However, several species call during the day. There were many fish chorus types detected at the two sites, plus persistent bouts of calling by individual fish. Two examples of such choruses are shown in Figure 8 and 9, as marked on Figure 3 on the 7-April and 8-April respectively. The chorus in Figure 8 appeared for a few hours in the afternoon of several days in April. These calls were centred around 200 Hz, covering a 50-400 Hz bandwidth. The chorus in Figure 9 was observed on records from both loggers between 4-April and 17-April, occurring predominantly through hours of darkness, but also to a lesser extent during daylight. Spectral peaks from these calls were centred around 375 Hz with a harmonic at approximately 750 Hz. An example of two evening fish choruses possibly produced by nocturnal planktivorous fishes is shown on Figure 10 by the energy above 1000 Hz, during hours of darkness each day.

There were numerous fish species involved in fish calling and choruses, some common between the two sites and some different. Examples of four fish call types from the northern site are shown on Figure 11 to Figure 13.

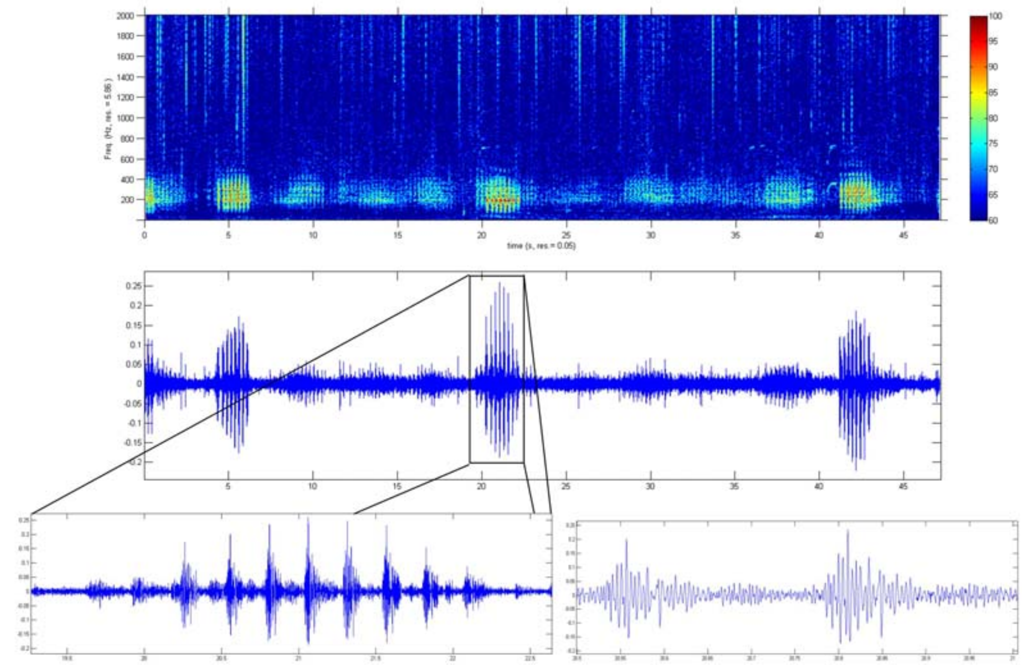

Figure 8: The presence of fish choruses as given by the energy between 50 and 400 Hz, with spectral peaks at around 200 Hz (top plot). Magnified waveforms offer an insight into the structure of the calls.

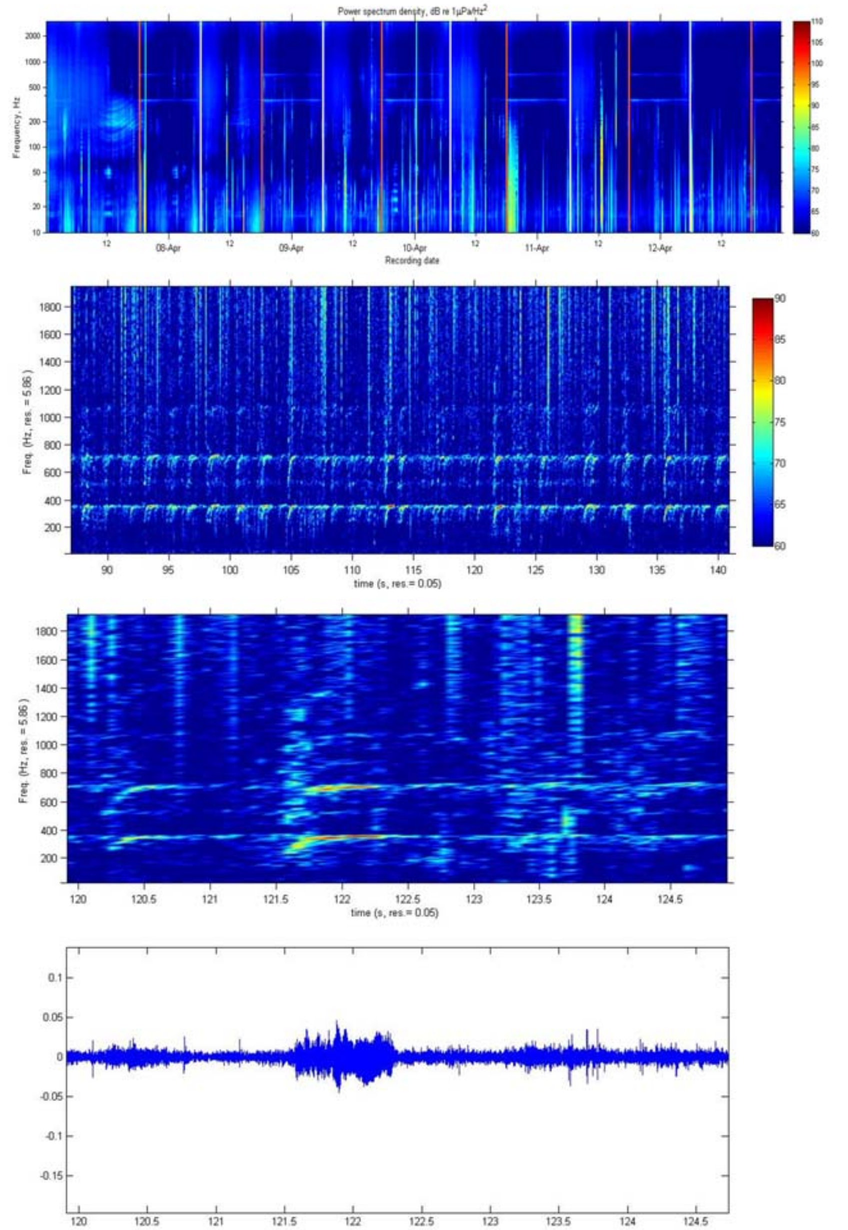

Figure 9: The presence of fish choruses as shown by the energy between 200 and 800 Hz each evening (top plot). The times of local sunrise and sunset are shown by the white and red dotted lines, respectively. Individual call spectrograms and waveforms are shown in the lower plots.

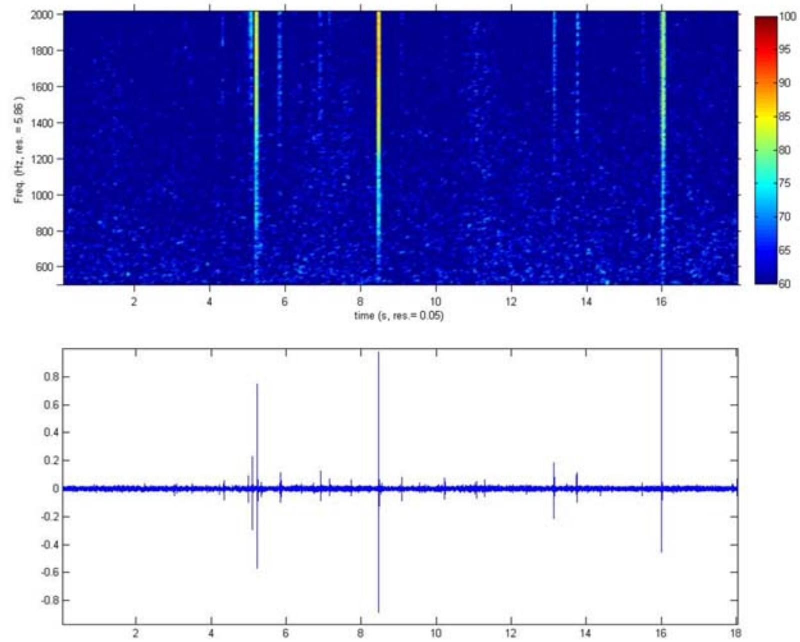

Figure 10: Fish signal produced during evening chorus attributed to nocturnal planktivorous fishes (i.e. as shown by increased energy close to 2000 Hz on Figure 3 and 9).

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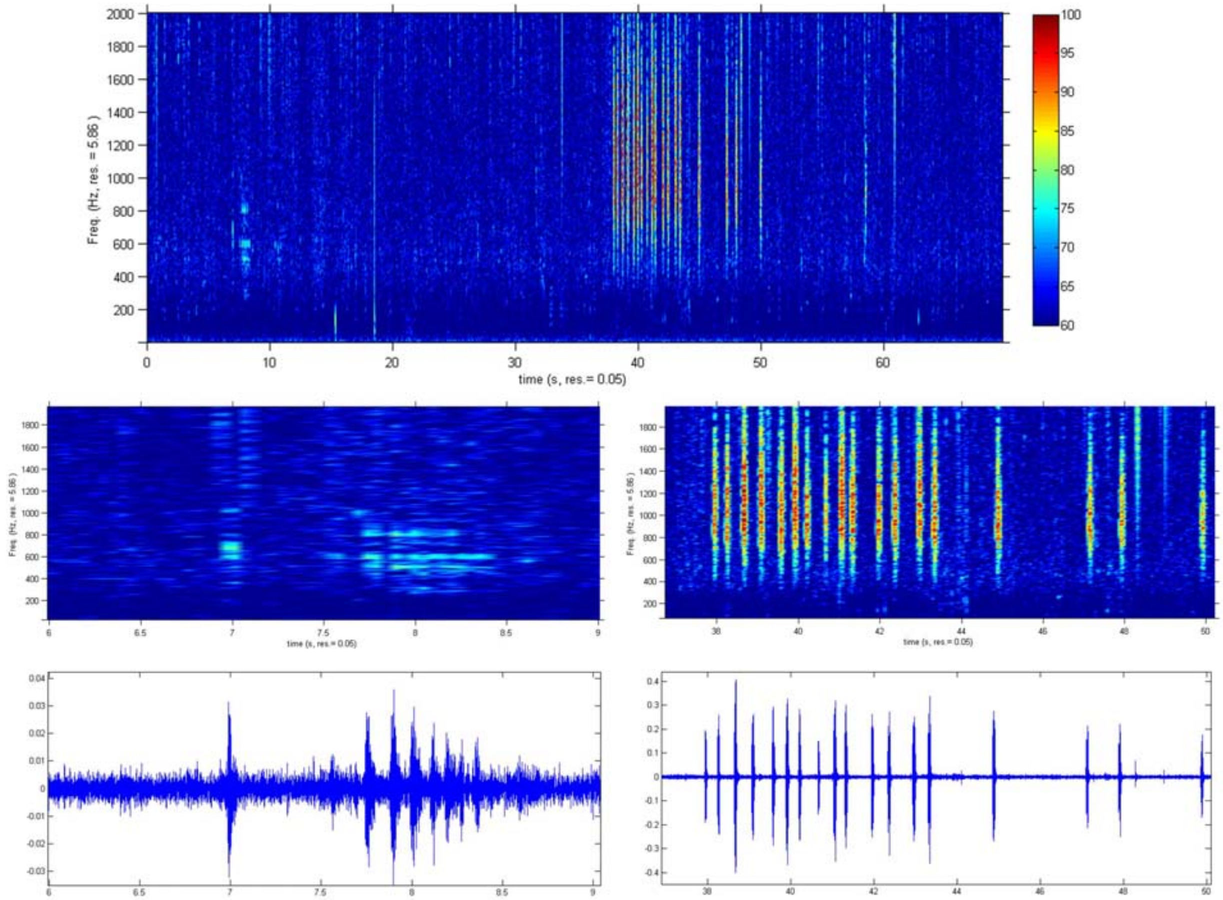

Figure 11: Two types of calls thought to be different, unknown fish, recorded at the offshore site on the 27-Jun.

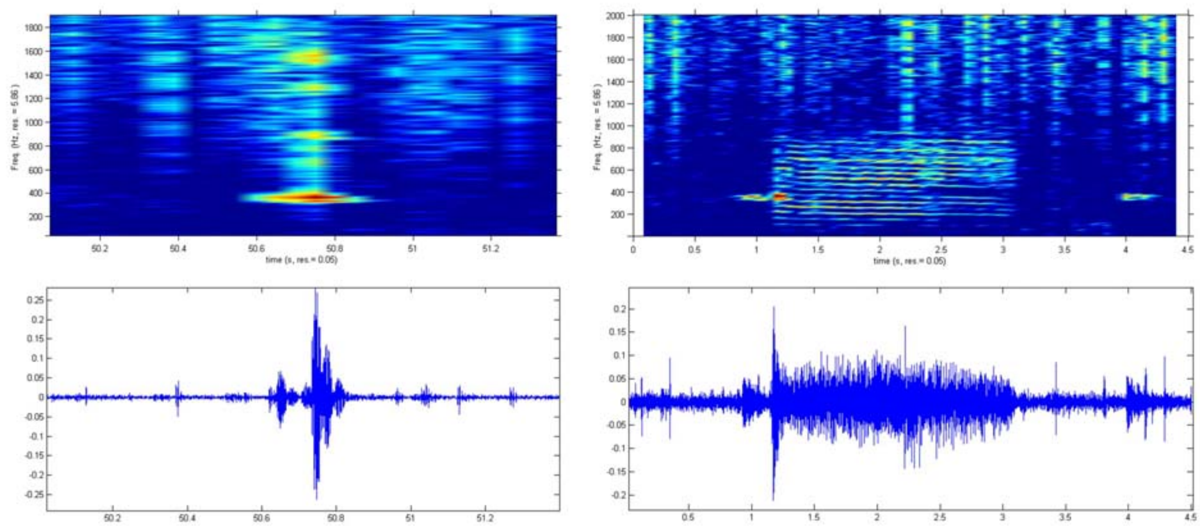

Figure 12: Two example calls thought to be produced by fish, recorded at the inshore site on the 30-Mar.

3.4 Wind driven noise and notch frequencies

Examples of the variation in ambient noise likely due to wind driven waves can be seen in Figure 3 to 5 and Figure 13 by the energy between 20-2000 Hz which fluctuates daily. The wind noise produces reasonably broad band energy but the received frequency spectra are dependent on local sound propagation conditions which in turn vary with tide height, producing the variations seen between 100 and 500 Hz in Figure 13. The limestone seabed preferentially blocks some frequencies, producing the notches in the spectra and the change in tidal height shifts these notches up and down in frequency.

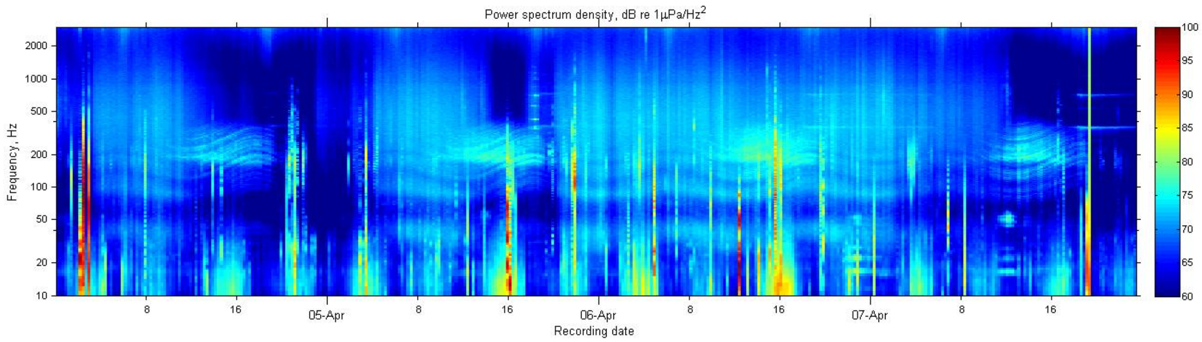

Figure 13: Examples of tidal effects on ambient noise levels at different frequencies recorded at the offshore site between 04-Apr-2011 to 07-Apr-2011.

4. References

Frankel, A. 2009. Sound Production. In: Encyclopedia of Marine Mammals. Eds: Perrin, W. Wursig, B. and Thewissen, J.G.M. Academic Press. London, UK. Pp: 1056-1070.

Au, W.W., D. James and K. Andrews. 2001. High-frequency harmonics and source level of humpback whale songs. J. Acoust. Soc. Am. 110(5):2770.