



Centre for Marine Science and Technology



Assessment of marine megafauna found at the edge of the continental shelf off Bremer Bay using passive acoustic observations

Prepared for
The National Environmental Science Programme

Prepared by: Alexander Gavrilov and Christine Erbe

PROJECT: CMST-1300

REPORT: 2017 – 3

March 2017

Contents

Contents	2
1. Introduction.....	3
2. Methodology	3
3. Results.....	5
Mysticetes (baleen whales)	5
Odontocetes (toothed whales).....	7
4. Summary and Conclusion	34
Acknowledgements.....	34
References.....	34

1. Introduction

Long-term passive acoustic observations were made at the edge of the continental shelf south of Bremer Bay, Western Australia, from February 2015 to February 2016, in order to assess seasonal patterns in the presence of various baleen and toothed whales in the area around the Bremer Canyon. This short report summarises results of observation.

2. Methodology

Two autonomous underwater sound recorders were deployed on the seafloor south of Bremer Bay (Figure 1) in February 2015. One of these two recorders was a low-frequency (LF) sound recorder designed and built at the Centre for Marine Science and Technology (CMST, (<http://cmst.curtin.edu.au/products/usr.cfm>)). It stayed in the water recording sea noise from the 10th of February 2015 to the 6th of February 2016. The recorder made 300-s recordings repeated with 900-s intervals (600-s sleep time). The housing of the recorder was equipped with cross-bars, as shown in Figure 2, to stabilize its position on the seafloor.

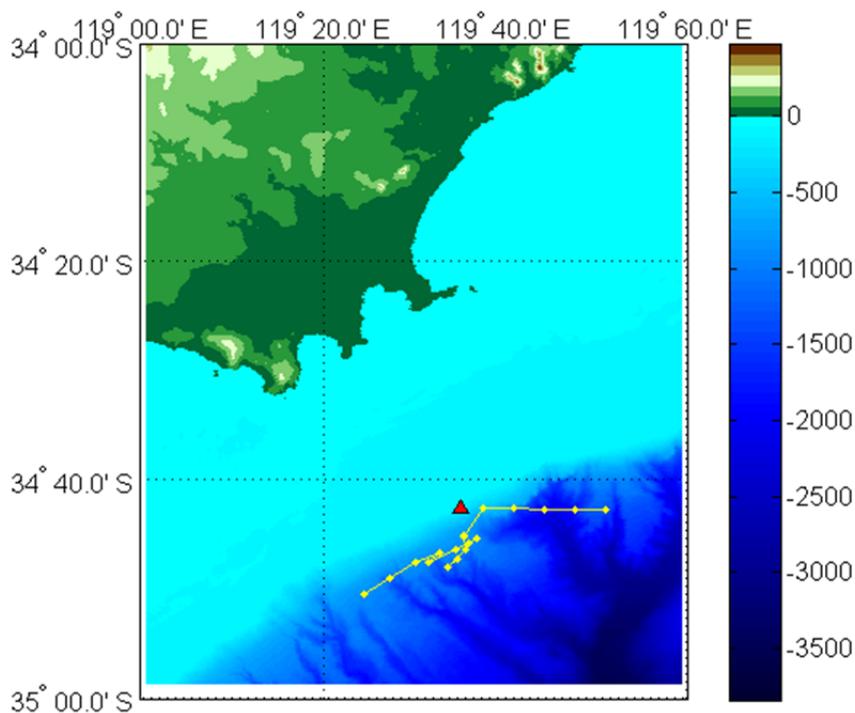


Figure 1: Locations of the sea noise recorders (red triangle) and towed acoustic array (yellow line) deployed in the monitored area.

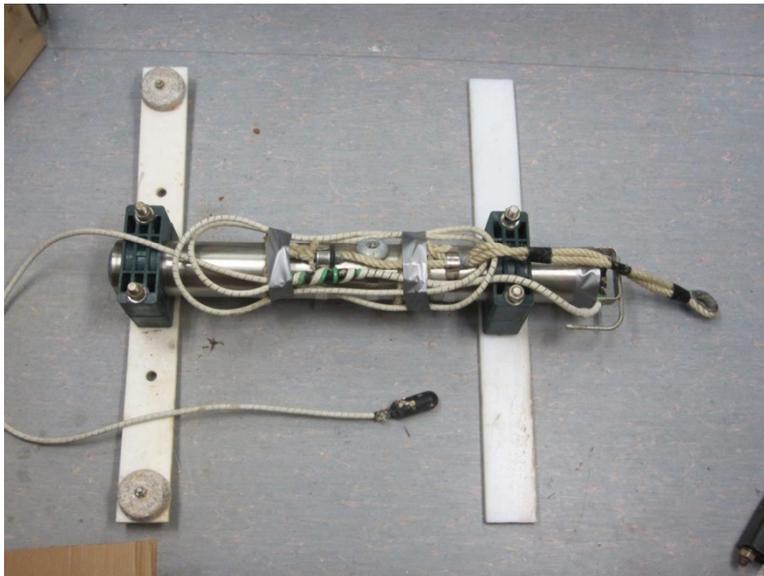


Figure 2: Photo of the CMST underwater sound recorder mounted on two crossbars.

The gain of an impedance matching pre-amplifier in the sound recorder was set at 40 dB. The underwater noise signal was digitized at a sampling rate of 6,000 samples per second using a 16-bit analogue-to-digital converter. An anti-aliasing filter with a cut-off frequency of 2.8 kHz was applied to the analogue signal before conversion. The recorder was calibrated before deployment by using a white noise signal of known spectral level as an input signal of the recording system with the hydrophone connected in-series to the noise generator. The recorded signals and their spectra were corrected for the end-to-end frequency response of the recording system, including the hydrophone sensitivity (Figure 3), so that the sound pressure and power spectrum density were measured in absolute units, μPa and $\mu\text{Pa}^2/\text{Hz}$ respectively.

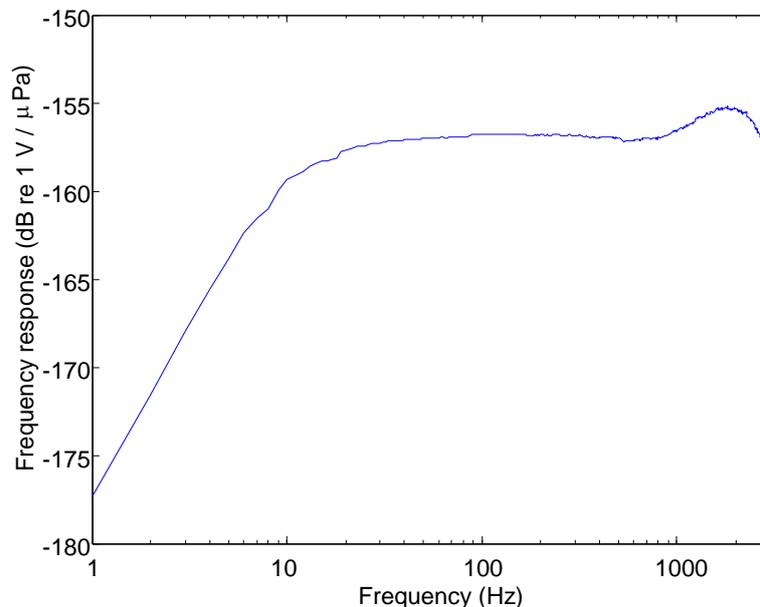


Figure 3: Frequency response of the sound recording system of the CMST LF recorder.

The second underwater sound recorder was a high-frequency (HF) SM2+ model from Wildlife Acoustics. It was recording sea noise at approximately the same location as the LF recorder from the 10th of February to the 11th of March 2015. This recording period was much shorter than that of the LF recorder because of a significantly higher sampling rate of 192,000 samples per second,

which shortened considerably the total duty time at a limited memory capacity of the recorder. The recorder was programmed to make recordings of approximately 960 s length repeated with 30 min intervals. The SM2+ model does not have a calibration circuit, so that the sound pressure was derived from the digitised waveform of sea noise based on the sensitivity specifications provided by the manufacturer.

A towed acoustic array was deployed from *R/V Whale Song* during its voyage in the Southern Ocean in January-February 2016. Recordings from the towed array were made in the region of the Bremer Canyon (see Figure 1) from about 7:00 to 22:00 WST on the 7th of February. The sampling rate of recording was 48,000 samples per second.

Processing and analysis of noise recordings to identify sources of underwater noise in the monitored area, including vocal marine fauna, were performed using a Matlab (The MathWorks Inc.) software tool for the Characterisation of Recorded Underwater Sound (CHORUS) developed by the Centre for Marine Science and Technology at Curtin University (Gavrilov & Parsons, 2014). Acoustic data from the towed array were also processed using CHORUS.

3. Results

Figures 4 to 27 show long-time averaged spectrograms of underwater noise recorded by the LF and HF sound recorders over 10-day periods from February 2015 to February 2016. These spectrograms reveal long-term changes in spectral levels of sea noise and allow the searching for the major components in ambient noise in a time-efficient way. Waveforms and high-resolution spectrograms of sounds from various species of marine fauna found in this datasets are also shown on smaller panels in these Figures.

Figures 29 and 30 show waveforms and spectrograms of the sounds from toothed whales found in the towed array recordings.

Fish choruses were heard at night-time every month of the year, with at least three distinct choruses (from three different fish species) visible in the spectrograms.

Mysticetes (baleen whales)

Sounds from four identified species of baleen whales were detected in sea noise recordings made by the LF recorder: Antarctic blue (*Balaenoptera musculus intermedia*), pygmy blue (*Balaenoptera musculus brevicauda*), fin (*Balaenoptera physalus*) and humpback (*Megaptera novaeangliae*) whales. The fifth whale species producing the so called “spot call” at about 26 Hz was also observed in sound recordings. This whale is certainly from the great baleen whale family. Given the area of observation as well as the other locations where similar sounds were observed (Gavrilov et al., 2015), it is likely that spot calls are produced by southern right whales (*Eubalaena australis*), although this hasn't been verified yet by concurrent visual and acoustic observations. Hereinafter this whale will be referred to as a spot-call whale for unambiguity.

Antarctic blue whale

Multiple calls from many remote Antarctic blue whales (ABW) in the Southern Ocean form a whale chorus, which is continuous noise within a relatively narrow band from about 17 Hz to 26-27 Hz with spectral levels exceeding the background sea noise (Gavrilov et al., 2012). This chorus can be distinguished in sea noise spectrograms from early March to early October (Figures 6 - 21). Based on the spectral levels of the observed chorus one can conclude that the whales contributing to it were located predominantly more than a hundred kilometres away, most like south of the recorder location.

Only two instances of ABWs approaching the observation site took place in late July, namely 25 July and 31 July, when individual calls from ABWs could be recognised in sea noise (Figures 16 and 17). Based on the received signal level of 115-120 dB re 1 μ Pa (31 July), expected source level

of ABW calls of about 190 dB re 1 μ Pa at 1 m (Širović et al., 2007) and estimated sound transmission loss, the singing whale was within approximately 10 km from the sound recorder.

Pygmy blue whale

Series of calls (songs) from pygmy blue whales (PBW) (McCauley et al., 2000) were only rarely observed from late April to late May (Figures 9 and 10). This is somewhat unexpected as PBWs are usually observed by acoustic means in the adjacent area south of Cape Leeuwin in November-December during their southern migration leg and from February to June during their northern migration leg.

Fin whale

Fin whales visited the monitored area from late May to late June (Figures 11-13). Based on the received signal level of 120-129 dB re 1 μ Pa (6 June) and expected source level of fin whale calls of about 190 dB re 1 μ Pa at 1 m (Širović et al., 2007), the vocalising fin whales were within a few kilometres from the sound recorder.

Spot-call whale

The high frequency resolution spectrogram calculated for the entire measurement period and shown in Figure 28 reveals two whale choruses distinguished by narrowband noise of higher intensity. The upper noise band at about 26 Hz is the ABW chorus formed by the first unit of their Z-shaped calls. The lower one at about 24.5 Hz is formed by remote spot calls. The spot call chorus differs from the ABW chorus not only in frequency but also in the duration period – it starts and ends later by approximately two months. The whales making this call often approached the monitored area from mid July (Figure 15) to mid November (Figure 23). The received sound level of calls reached 120-130 dB re 1 μ Pa on some days (e.g. 1 August). Although the source level of spot calls has not been published in the literature yet, preliminary estimates by the author showed that it should be within 180 ± 3 dB re 1 μ Pa at 1 m. This implies that the whales making this sound were located on those days within a kilometre or so from the sound recorder.

Spot calls are often accompanied by short impulsive signals with the frequency modulated from about 100 Hz to 50 Hz within a few tenths of a second (Figure 17). These sounds repeated with irregular intervals are thought to be produced by the same whale. Similar sounds from blue whales are commonly referred to as a D-type call (Oleson et al., 2007).

Humpback whale

Series of sounds produced at frequencies from about 200 Hz to nearly 1 kHz from late June (Figure 14) to early August (Figure 17) and structured as long lasting songs were observed in sound recordings. These sounds belong most likely to humpback whales, although they were rather unusual for this whale species as they did not contain low-frequency sounds typical for humpback whale songs in Australia (Garland et al., 2013).

Other great whale species

An unattributed type of sound was observed on the 29th of May (Figure 11). It is a short impulsive frequency-modulated signal with the sound frequency downswept from about 200 Hz to 40-50 Hz within a fraction of a second. The spectrogram of this sound looks similar to that of the D-type calls accompanying the spot calls. However, no spot calls were detected during the same time period. Moreover, the first series of apparent spot calls was observed more than a month later. So, it is rather unlikely that these sounds were from the spot-call whale. The source of this sound is most likely a great baleen whale; however, it cannot be identified based on available literature and data on whale sounds.

Odontocetes (toothed whales)

Only a few instances of whistles and echolocation sounds produced by toothed whales were found in the recordings made by the HF recorder and towed array. The main reason of fewer detections was the short duration of recording (only one month for the HF recorder and one day for the towed array). The source of some of those sounds was not identifiable due to the very limited recording length (Figure 4) or the limited bandwidth of the LF recorder (Figure 8). The whistles recorded by the towed array at about 17:00 on the 7th of February were most likely from killer whales (Figure 29) based on similar calls reported by Wellard et al. (2015). The trains of echolocation impulses recorded at about 19:40 on the same day (Figure 30) belong most likely to a sperm whale, given the waveform and frequency band (lower than those of smaller odontocetes) of these sounds (Madsen et al., 2002).

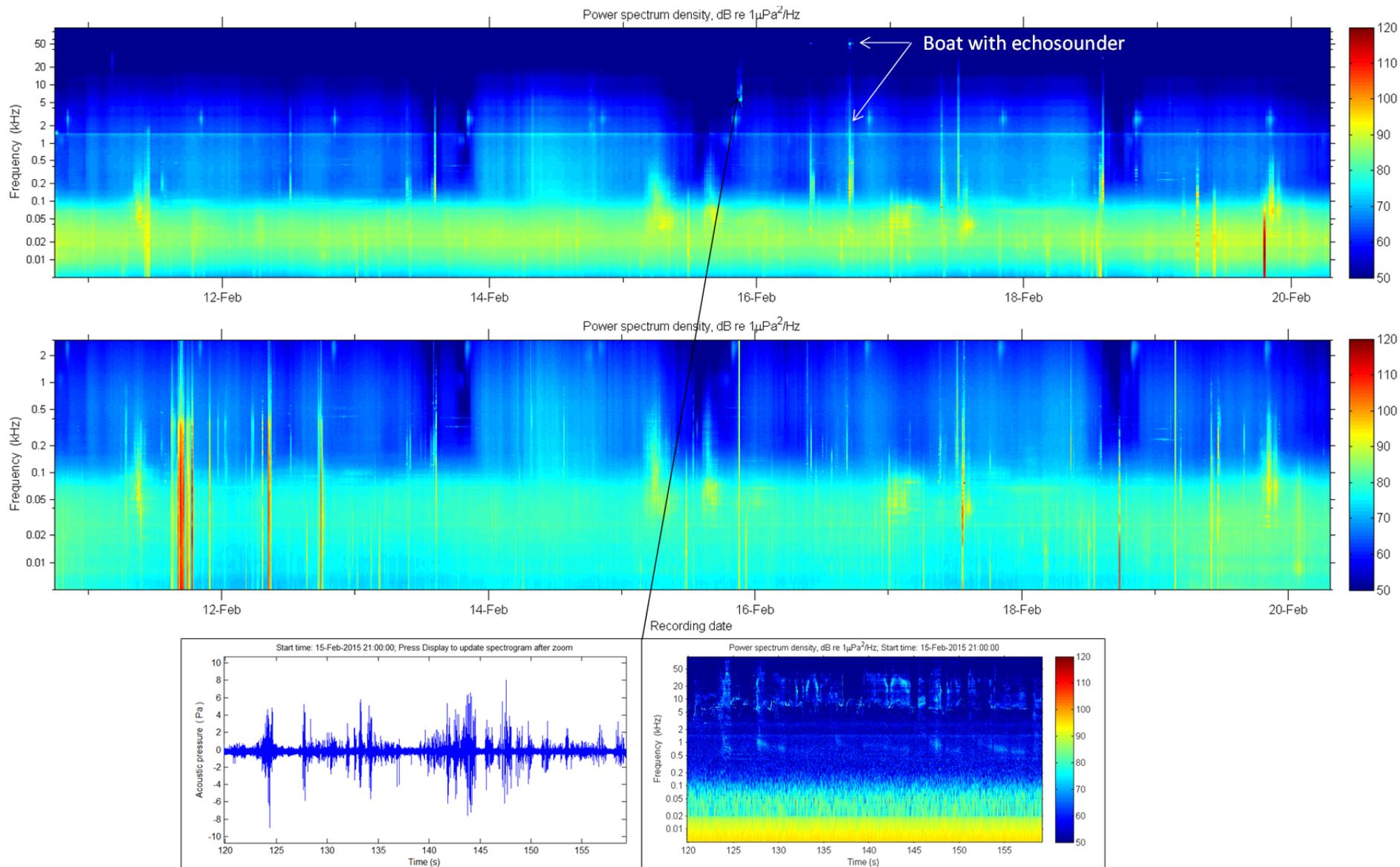


Figure 4: Long-time average spectrograms of sea noise recorded on the HF (top panel) and LF (middle panel) noise recorders during the first 10-day period of measurements. The bottom panels show the waveform and spectrogram of whistles from an unidentified odontocete (toothed whale) species.

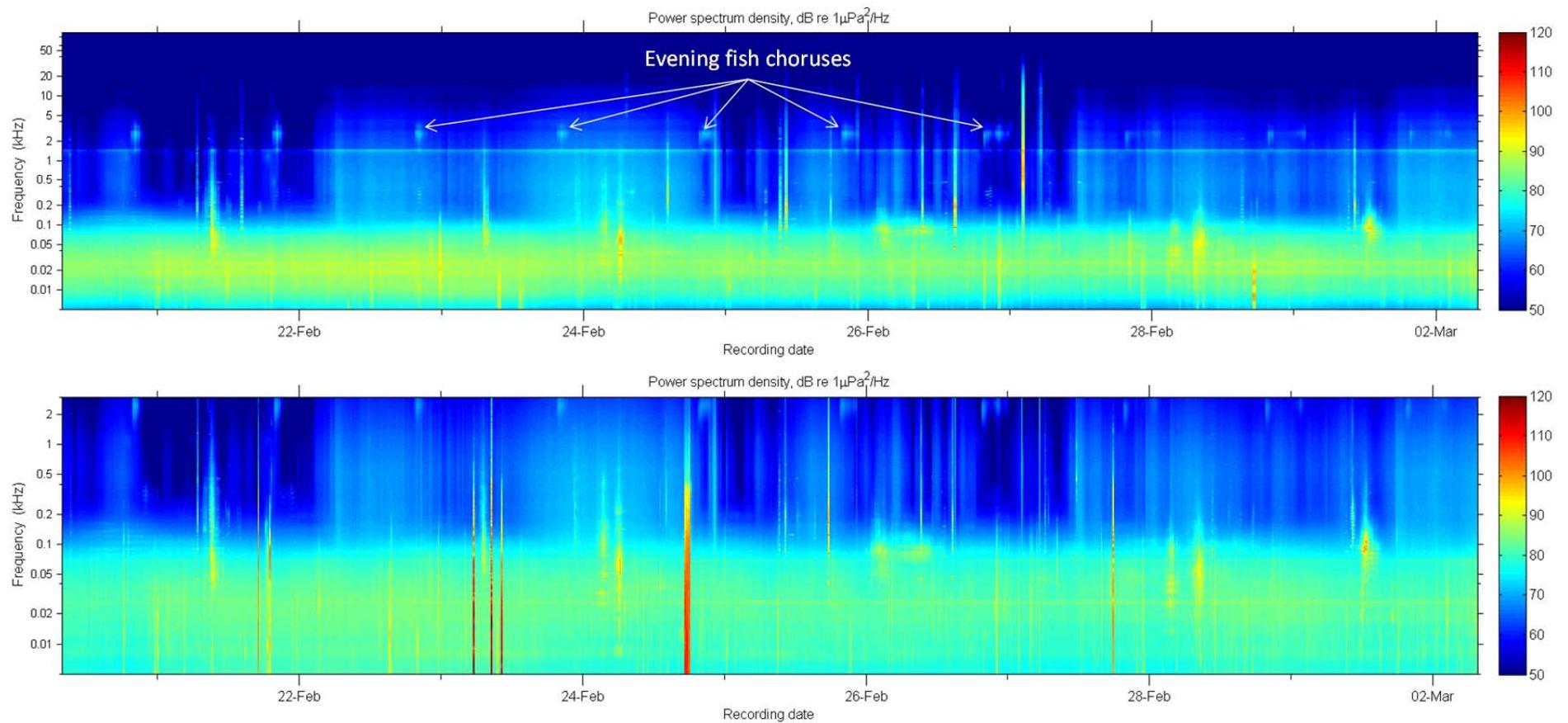


Figure 5: Long-time average spectrograms of sea noise recorded on the HF (top panel) and LF (middle panel) noise recorders during the second 10-day period of measurements.

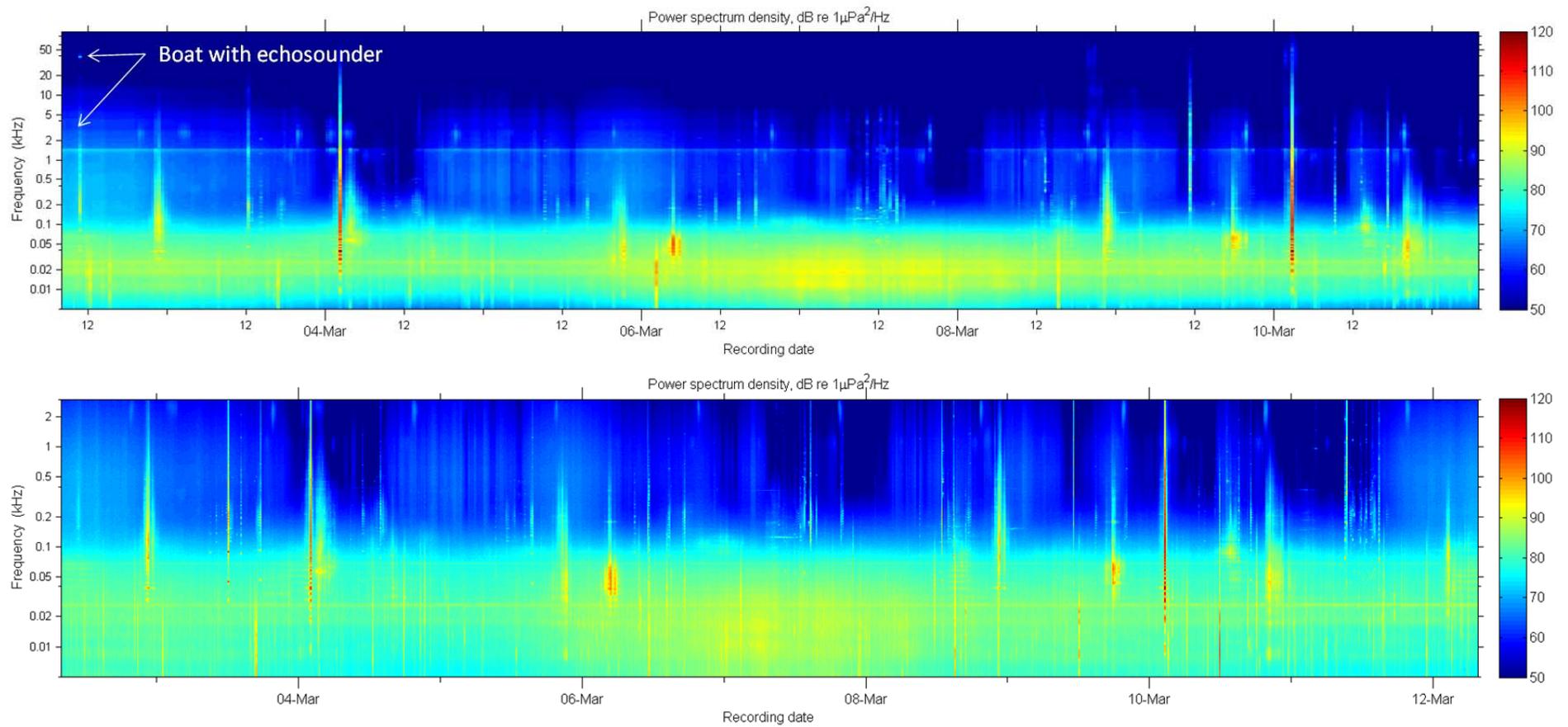


Figure 6: Long-time average spectrograms of sea noise recorded on the HF (top panel) and LF (middle panel) noise recorders during the third 10-day period of measurements.

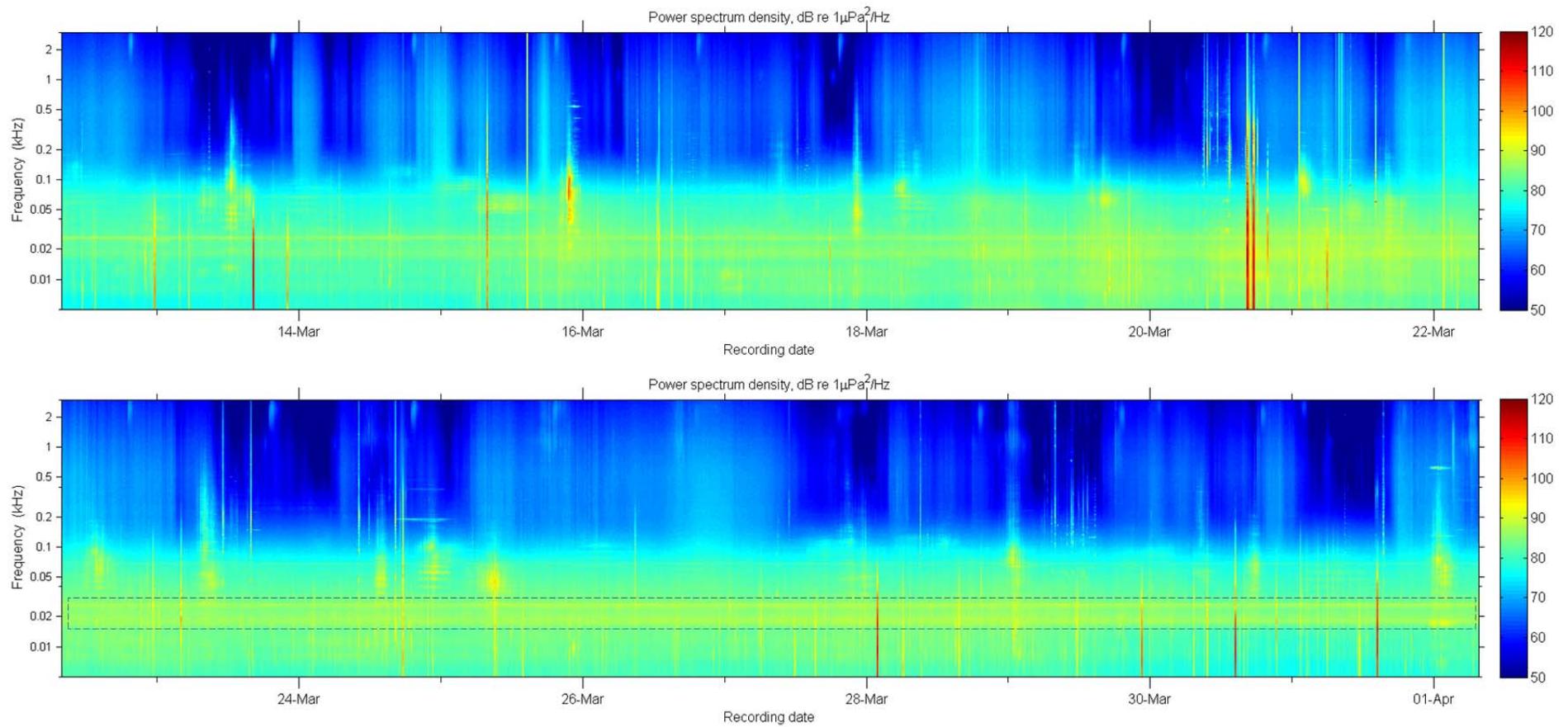


Figure 7: Long-time average spectrograms of sea noise recorded on the LF noise recorders during the fourth (top) and fifth (bottom) 10-day periods of measurements. The dashed rectangle indicates broadband noise from about 17 Hz to 26 Hz formed by multiple calls (whale chorus) from remote Antarctic blue whales.

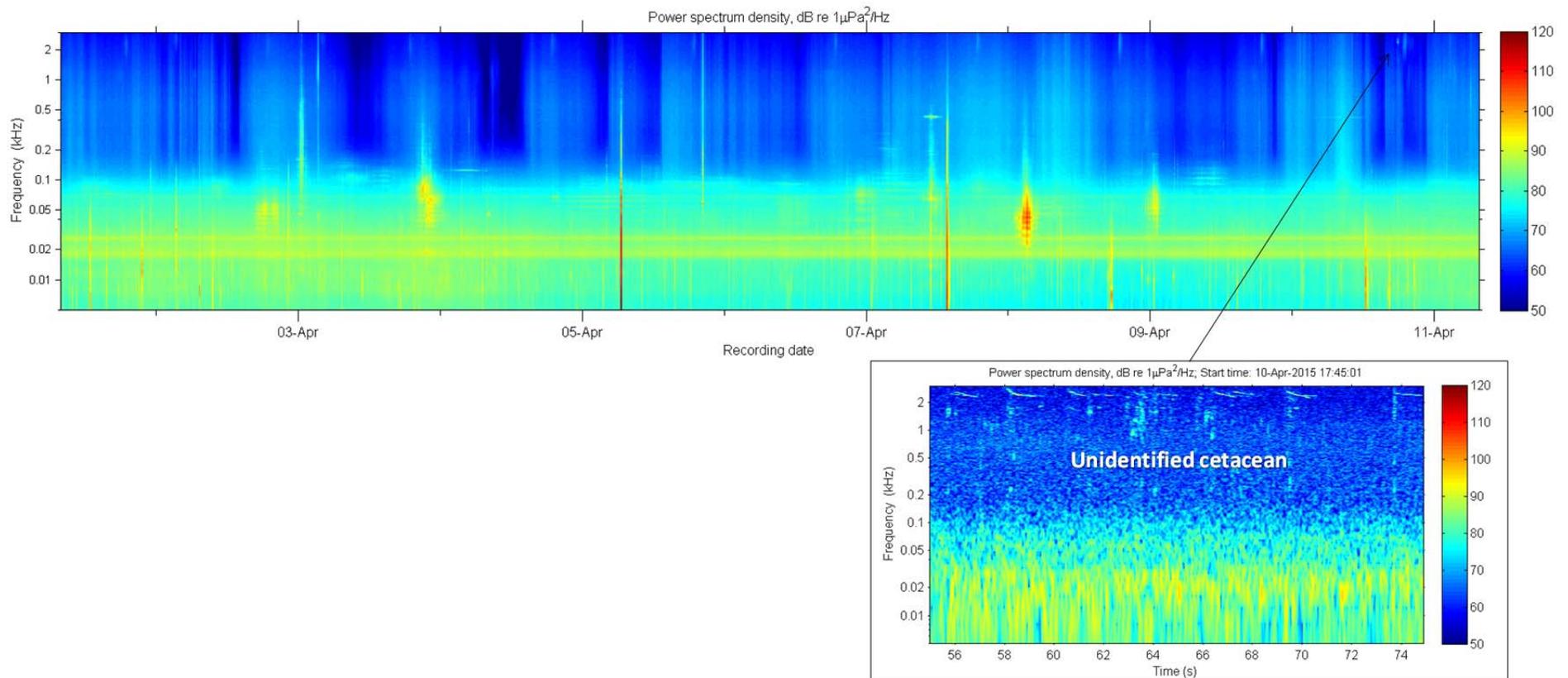


Figure 8: Long-time average spectrogram of sea noise recorded on the LF noise recorders during the sixth (top) 10-day periods of measurements. The bottom panel shows the spectrogram of high-frequency whistles from an unidentified cetacean.

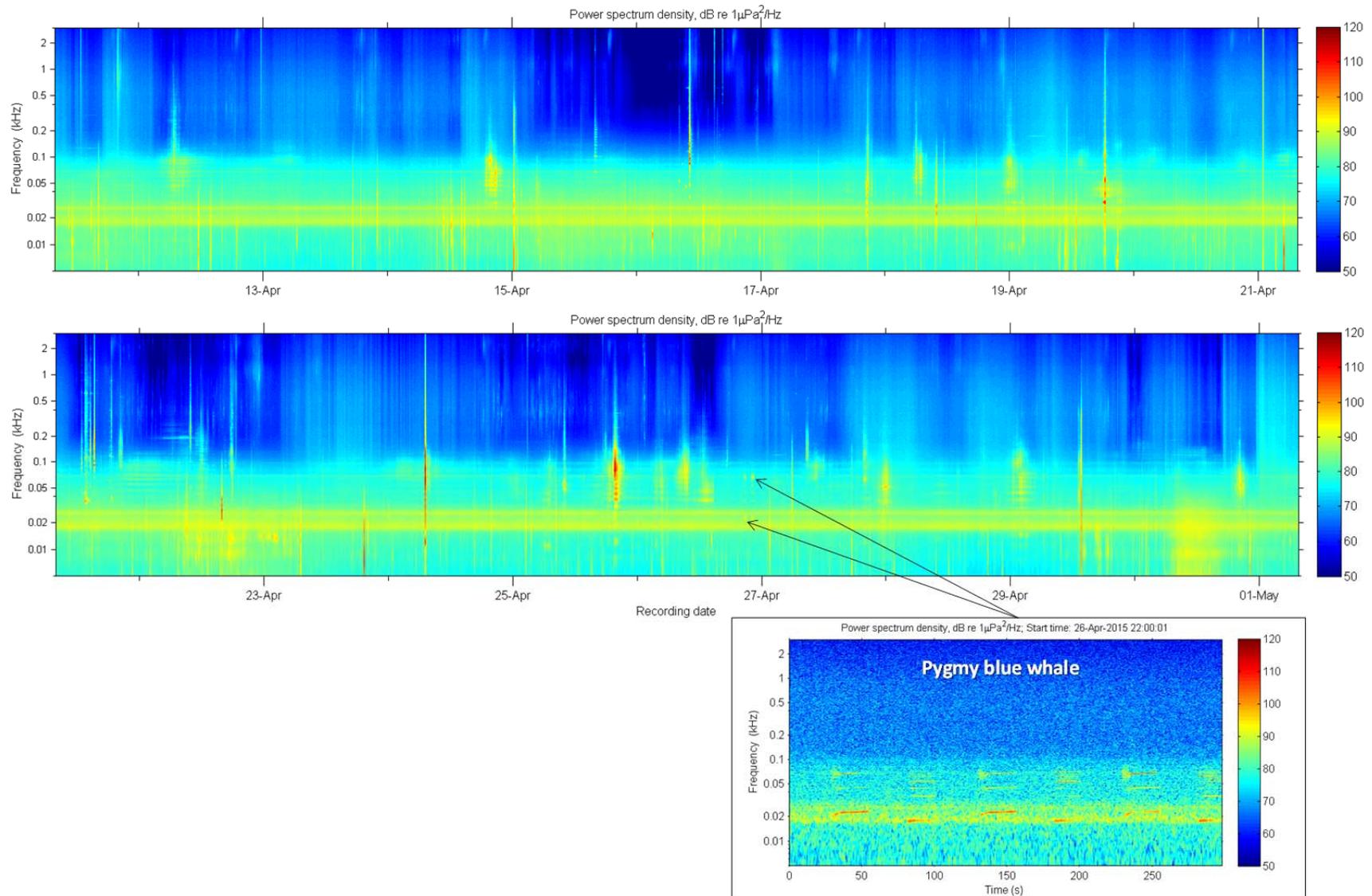


Figure 9: Long-time average spectrograms of sea noise recorded on the LF noise recorders during the seventh (top) and eighth (bottom) 10-day periods of measurements. The bottom panel shows the spectrogram of pygmy blue whale sounds.

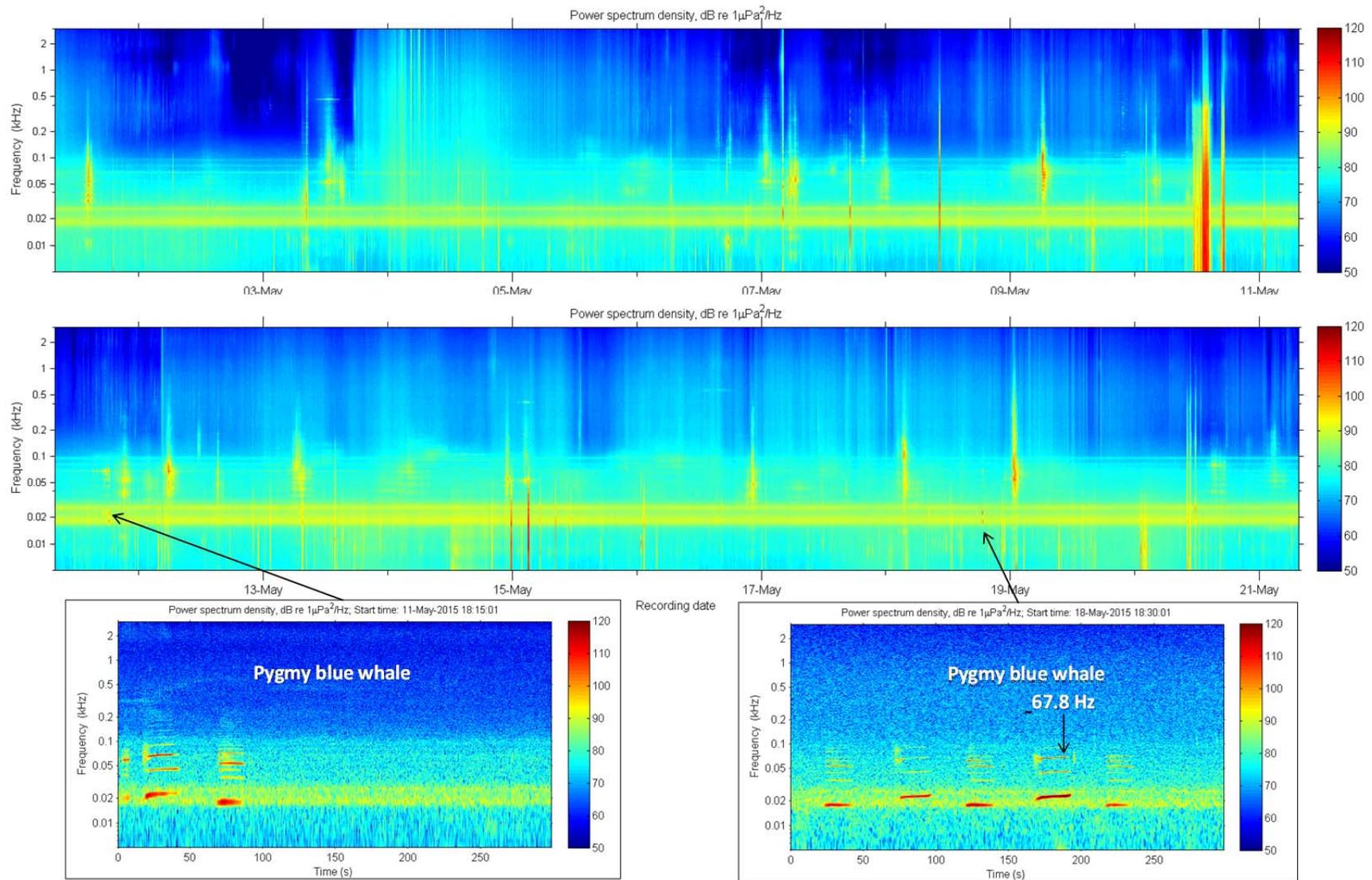


Figure 10: Long-time average spectrograms of sea noise recorded on the LF noise recorders during the ninth (top) and tenth (bottom) 10-day periods of measurements. The bottom panels show the spectrograms of pygmy blue whale sounds.

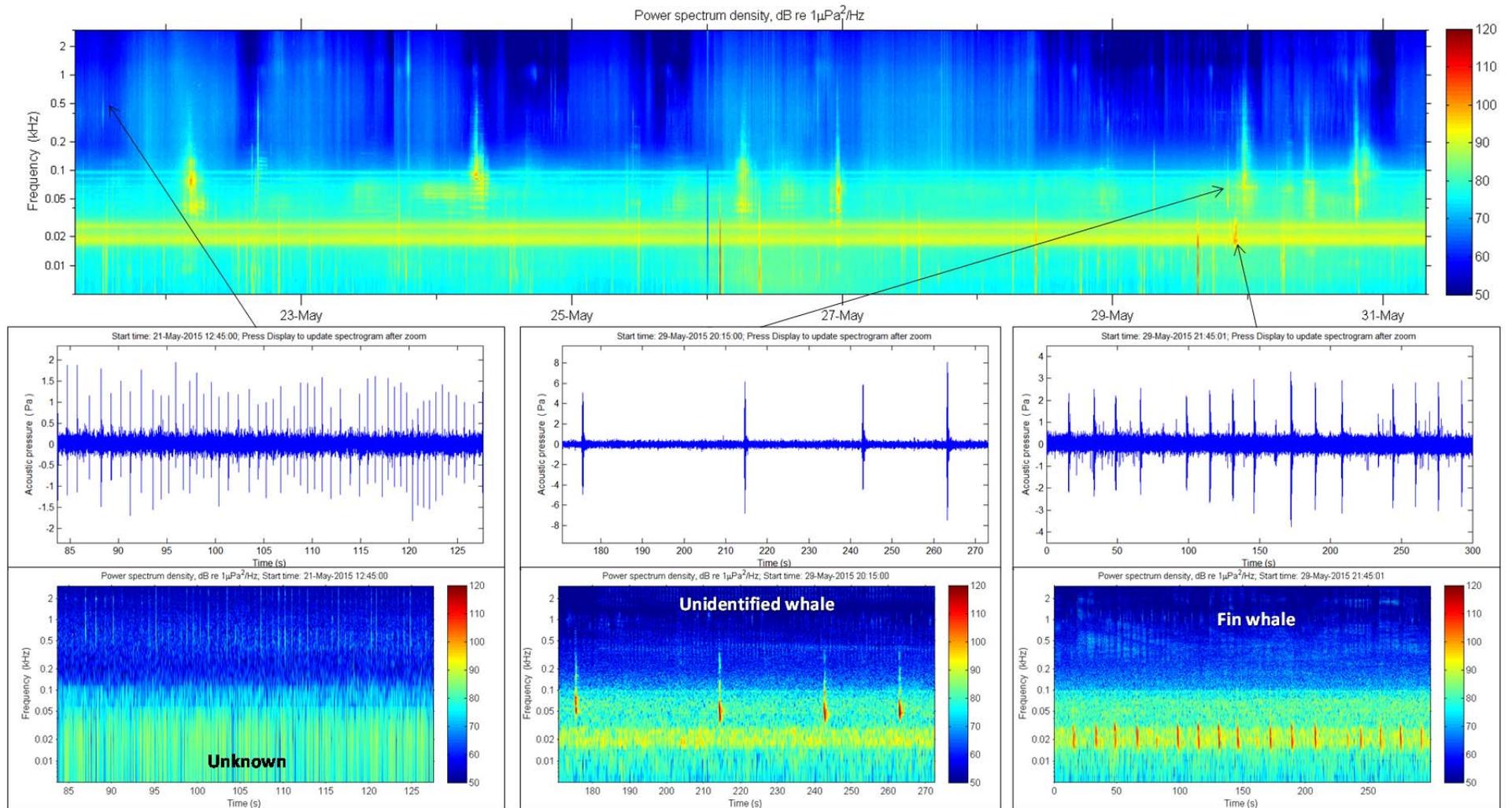


Figure 11: Long-time average spectrogram of sea noise recorded on the LF noise recorders during the eleventh 10-day periods of measurements (top). The middle and bottom panels show the waveform and spectrogram of echolocation clicks from an uncertain toothed (probably sperm) whale (left column), frequency modulated calls from an unidentified baleen whale (middle column) and calls from a fin whale (right column).

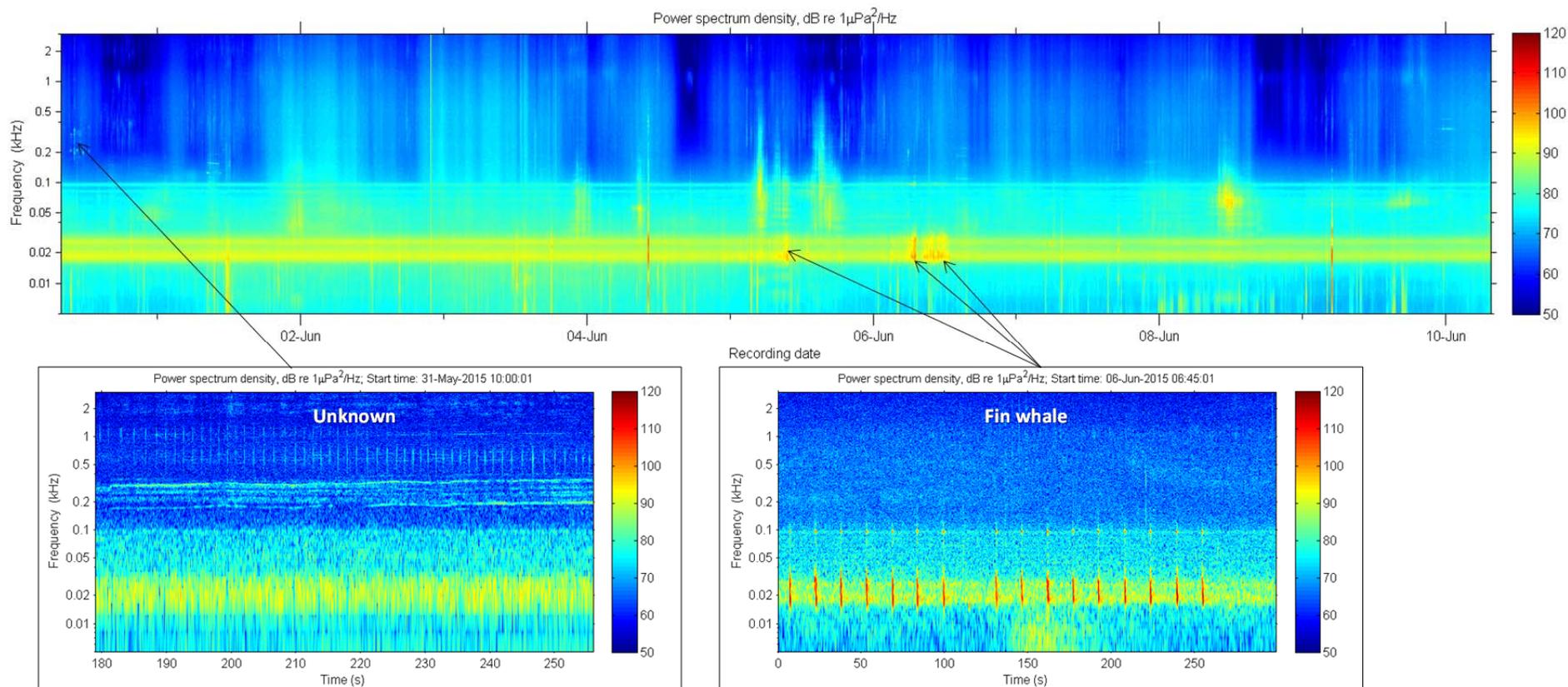


Figure 12: Long-time average spectrogram of sea noise recorded on the LF noise recorders during the twelfth 10-day period of measurements (top). The bottom panels show the spectrograms of impulsive sounds of unknown, most likely anthropogenic origin (left) and calls from a fin whale (right).

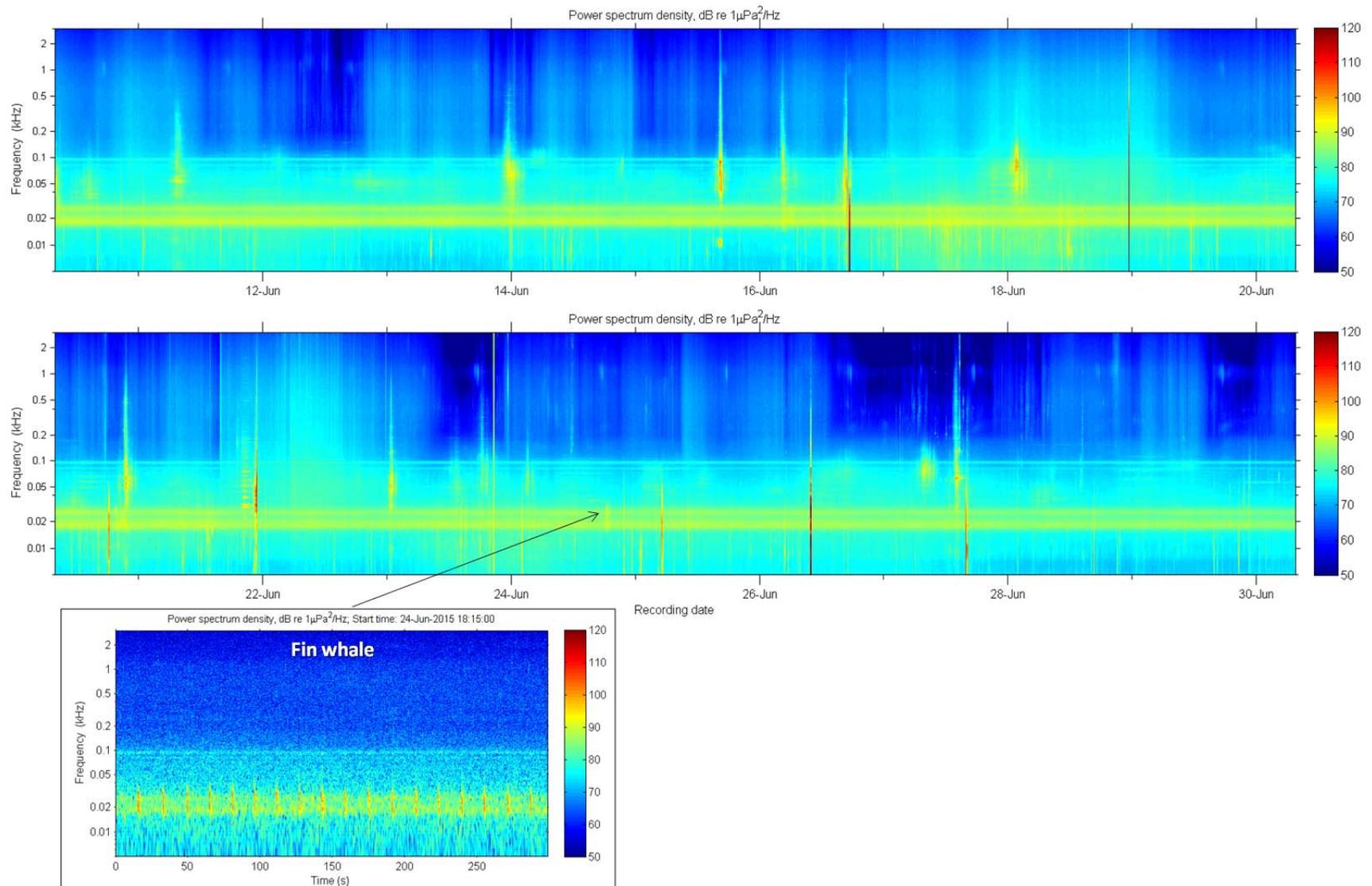


Figure 13: Long-time average spectrograms of sea noise recorded on the LF noise recorders during the thirteenth (top) and fourteenth (middle) 10-day periods of measurements.

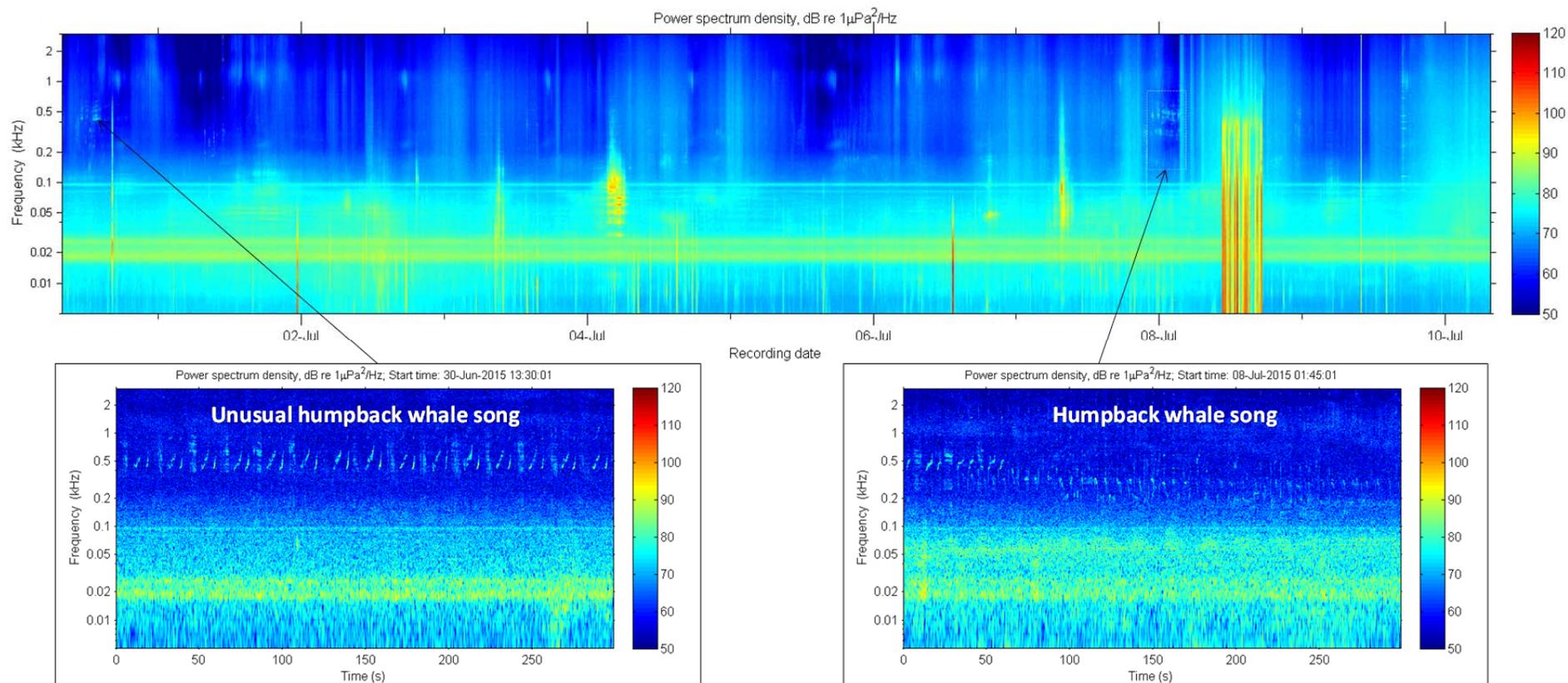


Figure 14: Long-time average spectrogram of sea noise recorded on the LF noise recorders during the fifteenth 10-day period of measurements (top). The bottom panels show the spectrograms of atypical humpback whale song.

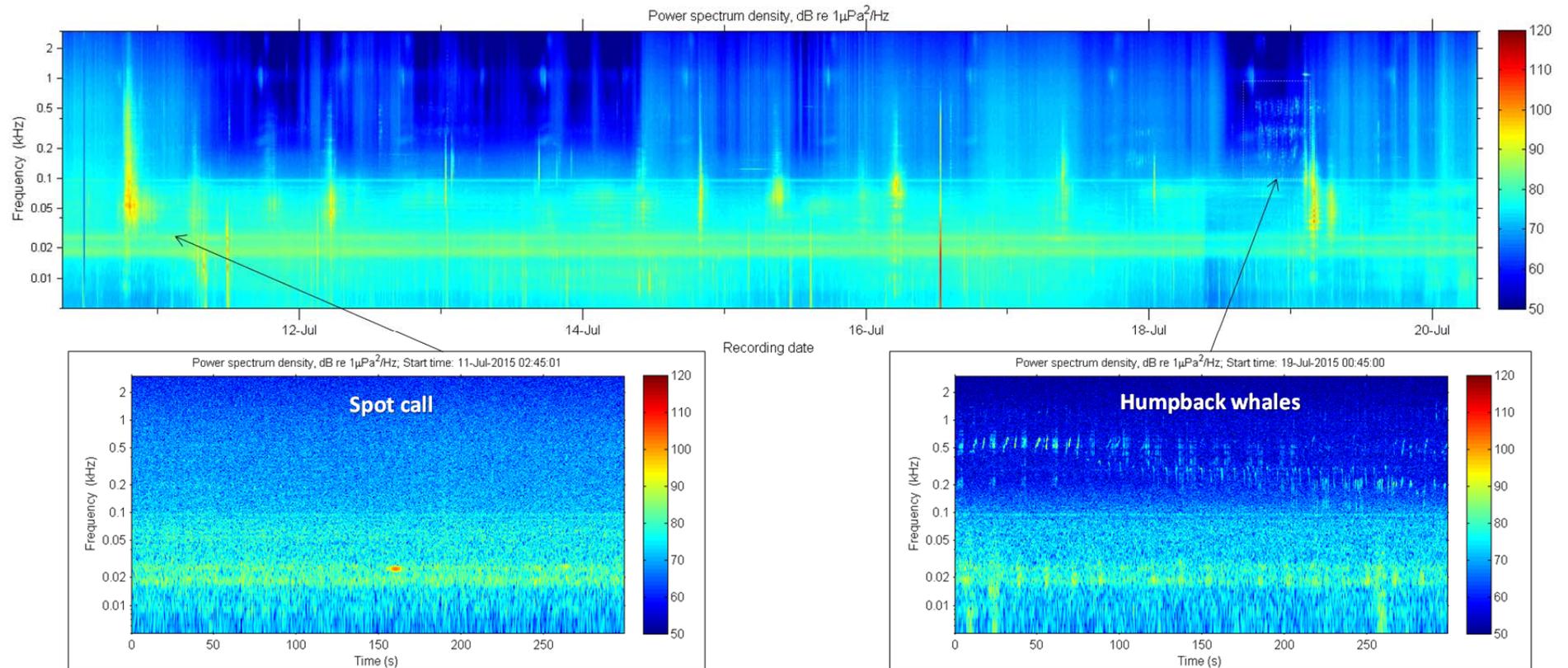


Figure 15: Long-time average spectrogram of sea noise recorded on the LF noise recorders during the sixteenth 10-day period of measurements (top). The bottom panels show the spectrograms of spot call from an unidentified great whale (left) and humpback whale song (right).

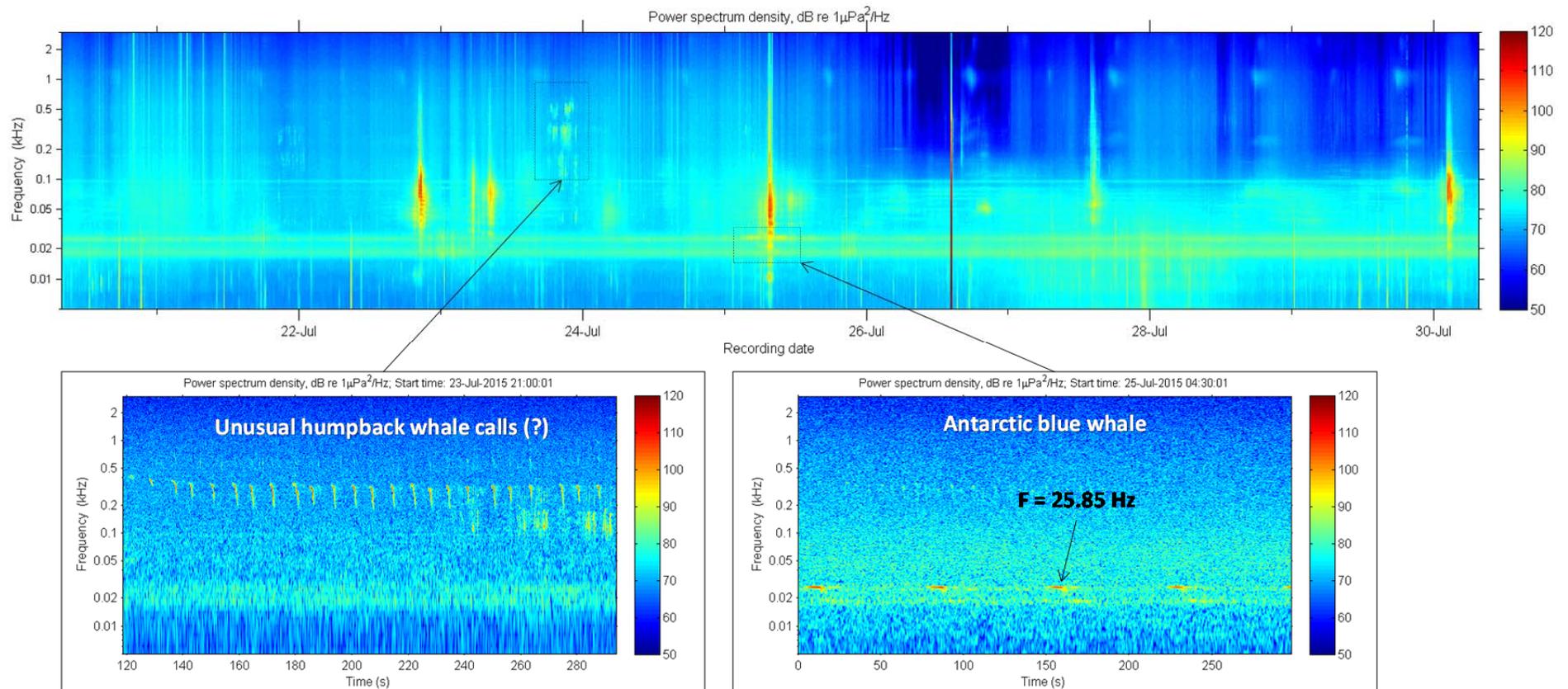


Figure 16: Long-time average spectrogram of sea noise recorded on the LF noise recorders during the seventeenth 10-day period of measurements (top). The bottom panels show the spectrograms of atypical sounds probably from a humpback whale (left) and so-called Z-shaped calls from an Antarctic blue whale (right).

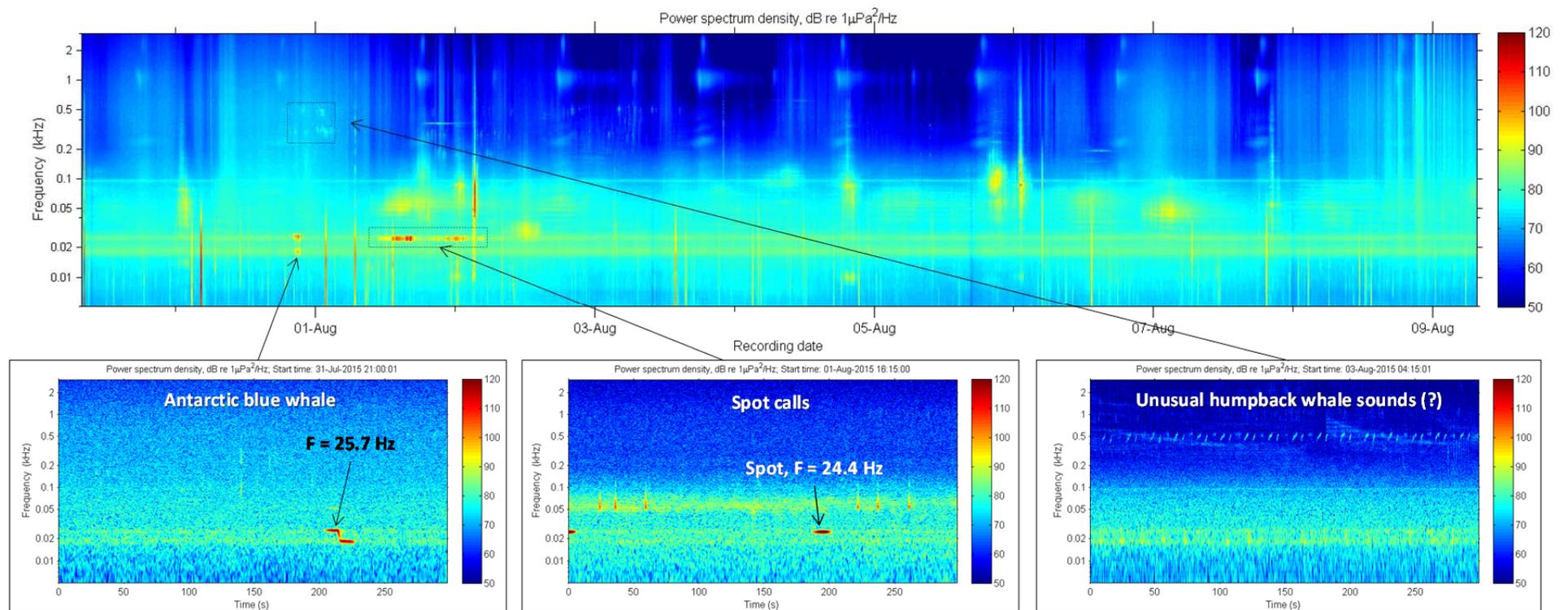


Figure 17: Long-time average spectrogram of sea noise recorded on the LF noise recorders during the eighteenth 10-day period of measurements (top). The bottom panels show the spectrograms of: ABW Z-shaped call of high intensity (left), spot call with accompanying D-type impulsive sounds (middle) and unusual sounds probably from a humpback whale (right).

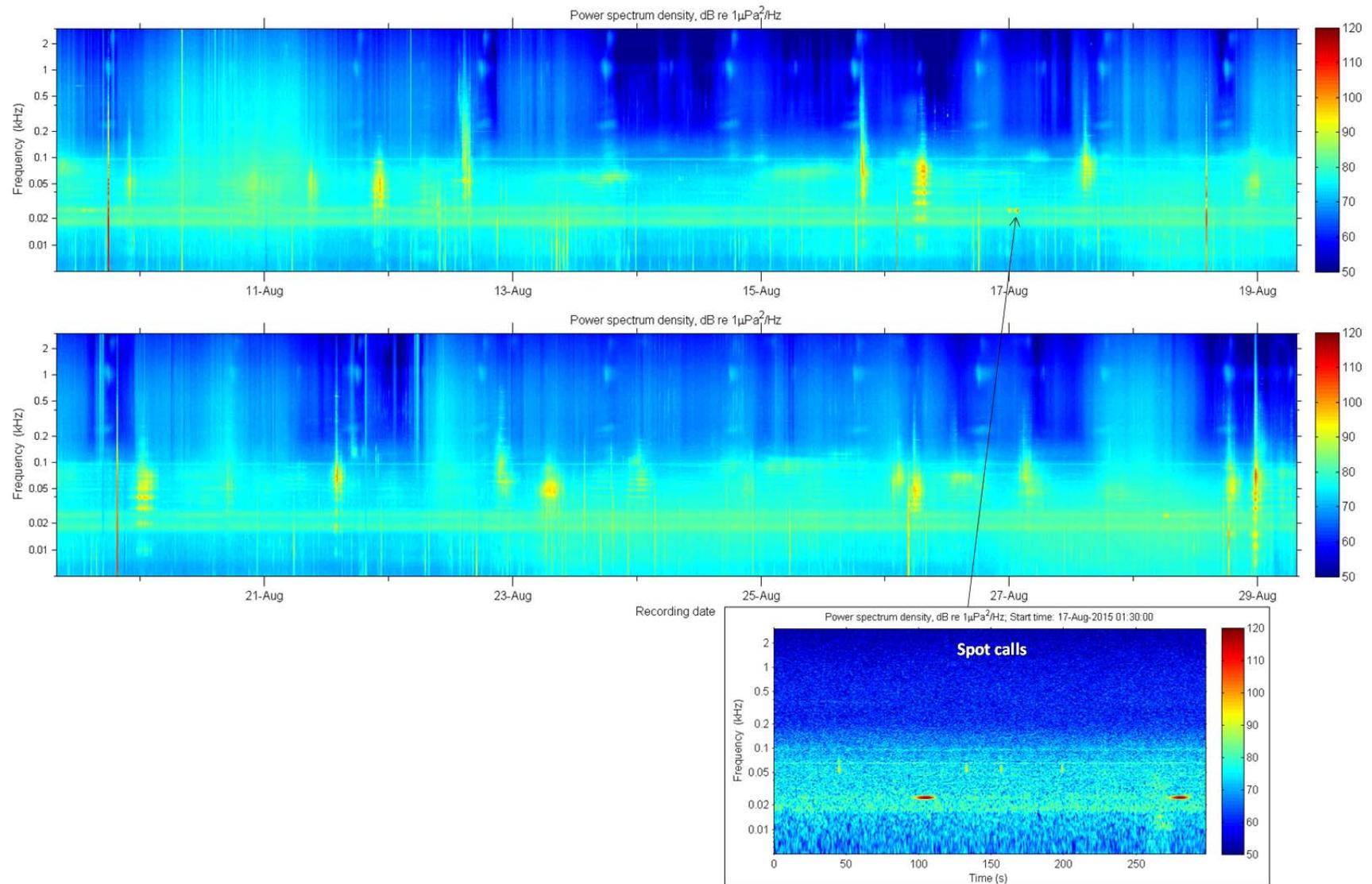


Figure 18: Long-time average spectrograms of sea noise recorded on the LF noise recorders during the nineteenth (top) and twentieth (middle) 10-day periods of measurements.

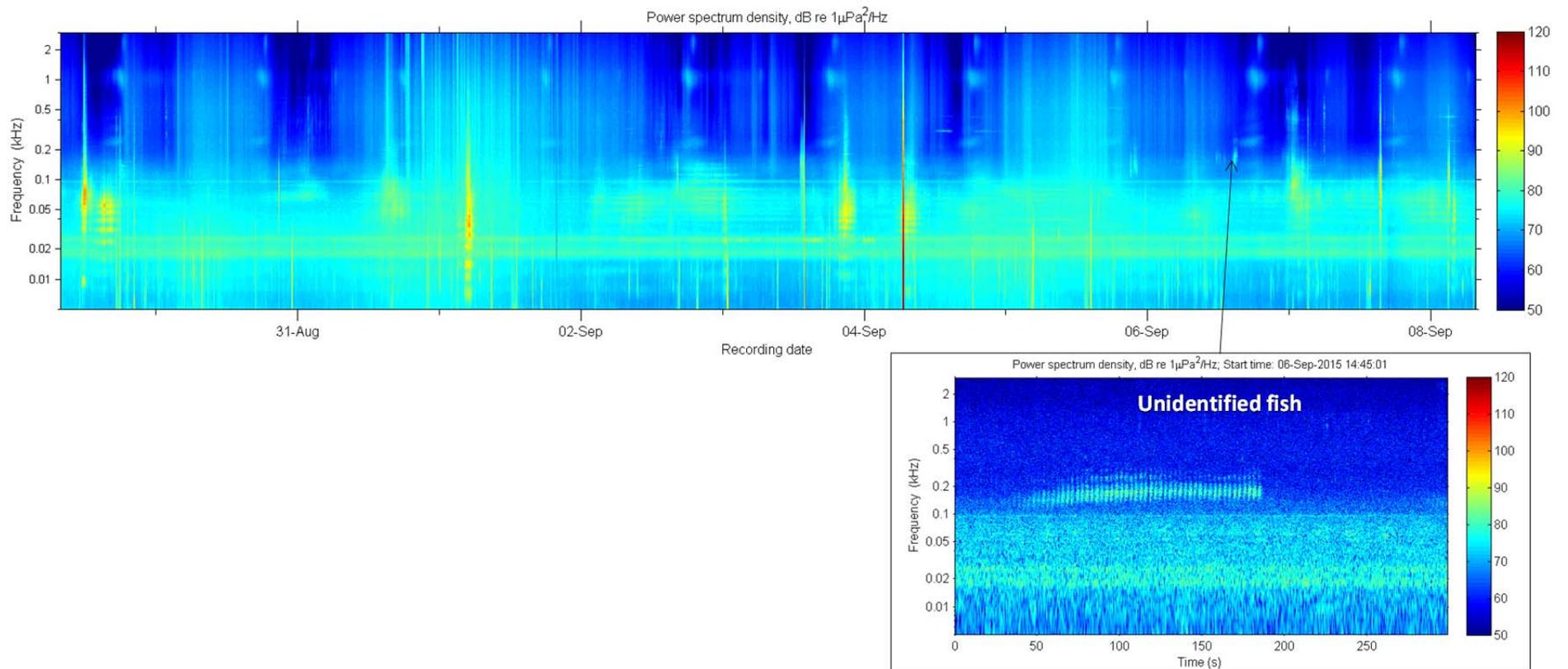


Figure 19: Long-time average spectrogram of sea noise recorded on the LF noise recorders during the twenty-first 10-day period of measurements (top). The bottom panel shows the spectrograms of sound from unidentified fish.

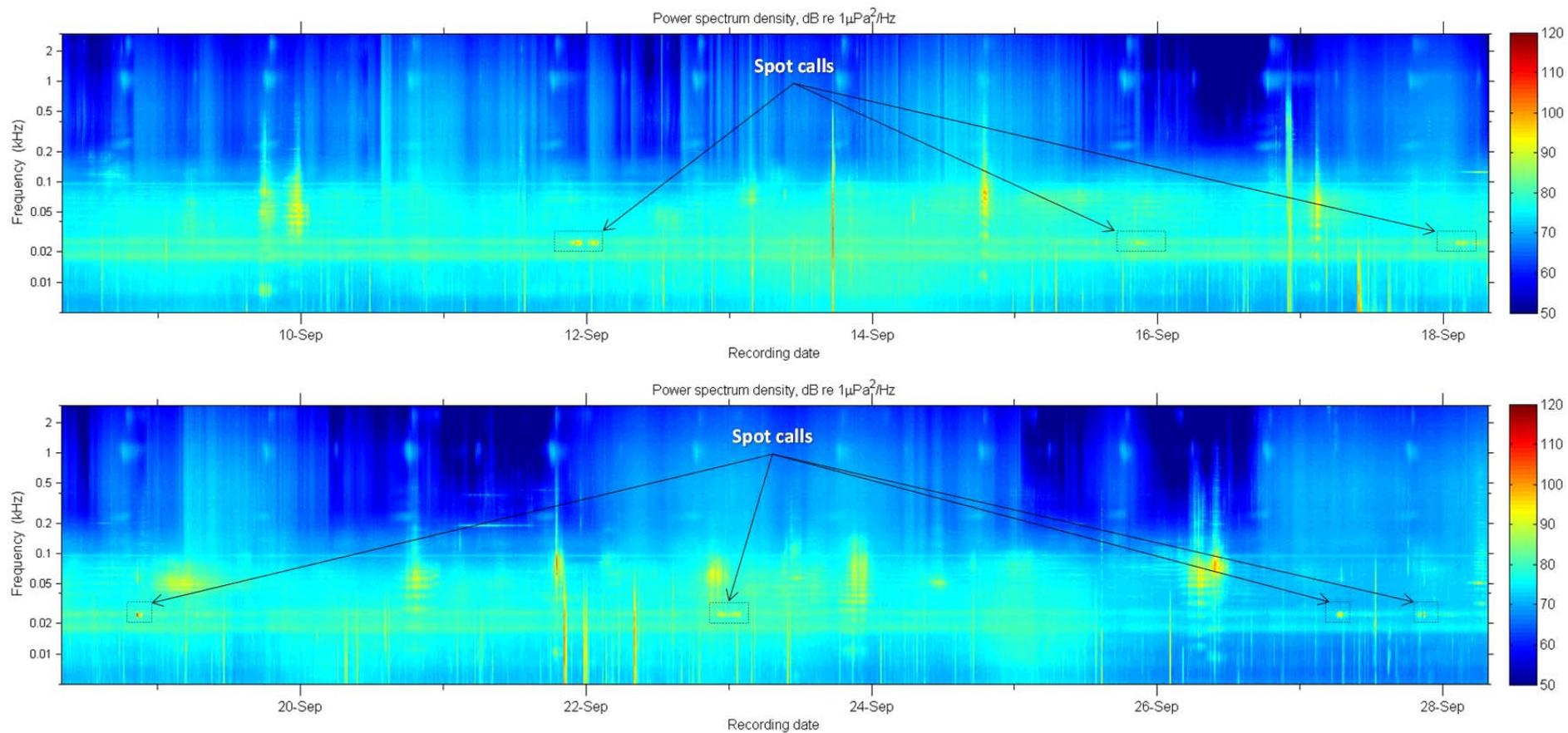


Figure 20: Long-time average spectrograms of sea noise recorded on the LF noise recorders during the twenty-second (top) and twenty-third (bottom) 10-day periods of measurements.

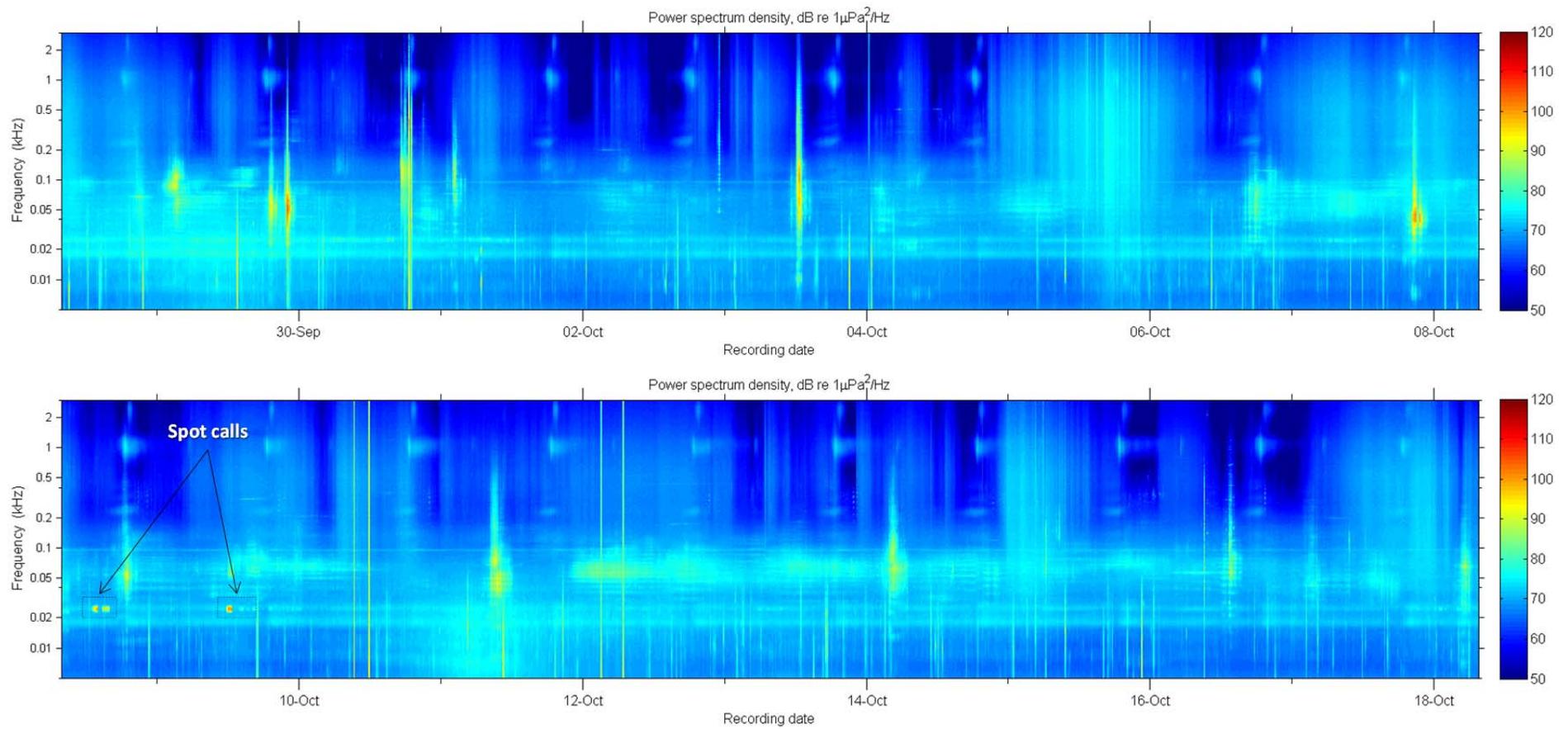


Figure 21: Long-time average spectrograms of sea noise recorded on the LF noise recorders during the twenty-fourth (top) and twenty-fifth (bottom) 10-day periods of measurements.

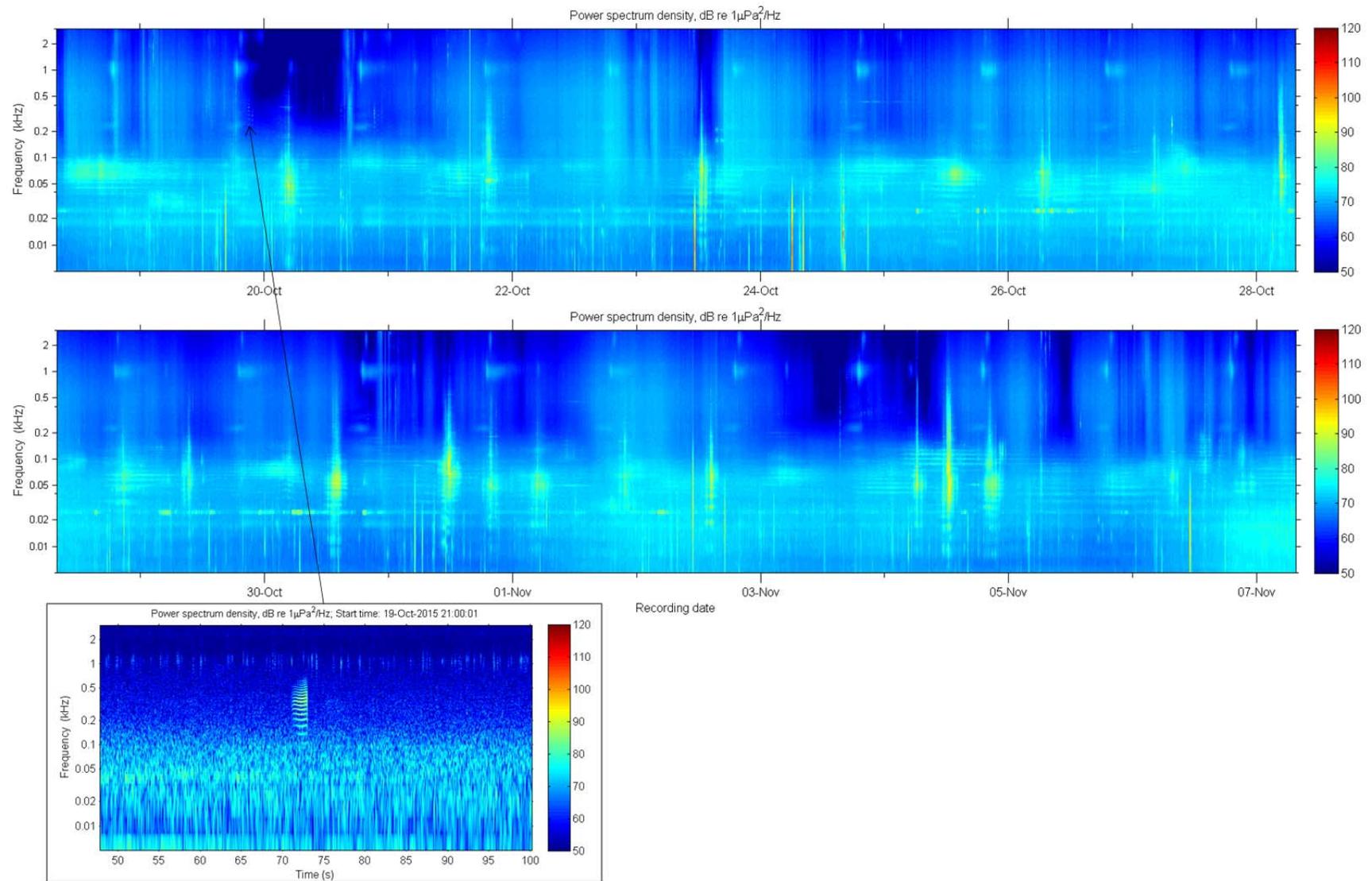


Figure 22: Long-time average spectrograms of sea noise recorded on the LF noise recorders during the twenty-sixth (top) and twenty-seventh (middle) 10-day periods of measurements. The bottom panel shows the spectrogram of sound most likely from unidentified fish.

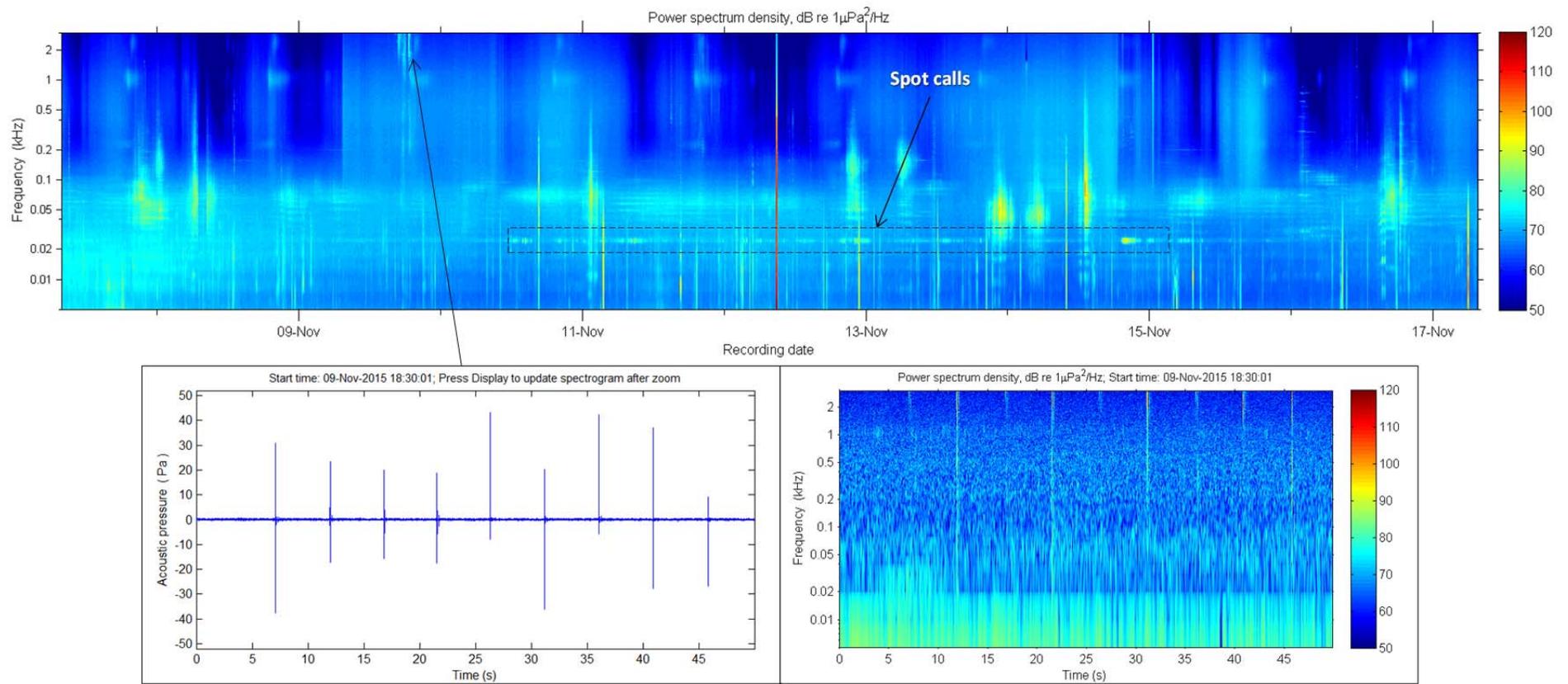


Figure 23: Long-time average spectrogram of sea noise recorded on the LF noise recorders during the twenty-eighth 10-day period of measurements (top). The bottom panel shows the waveform and spectrogram of regular impulsive signals, most likely of anthropogenic origin given their frequency band and regular repetition intervals.

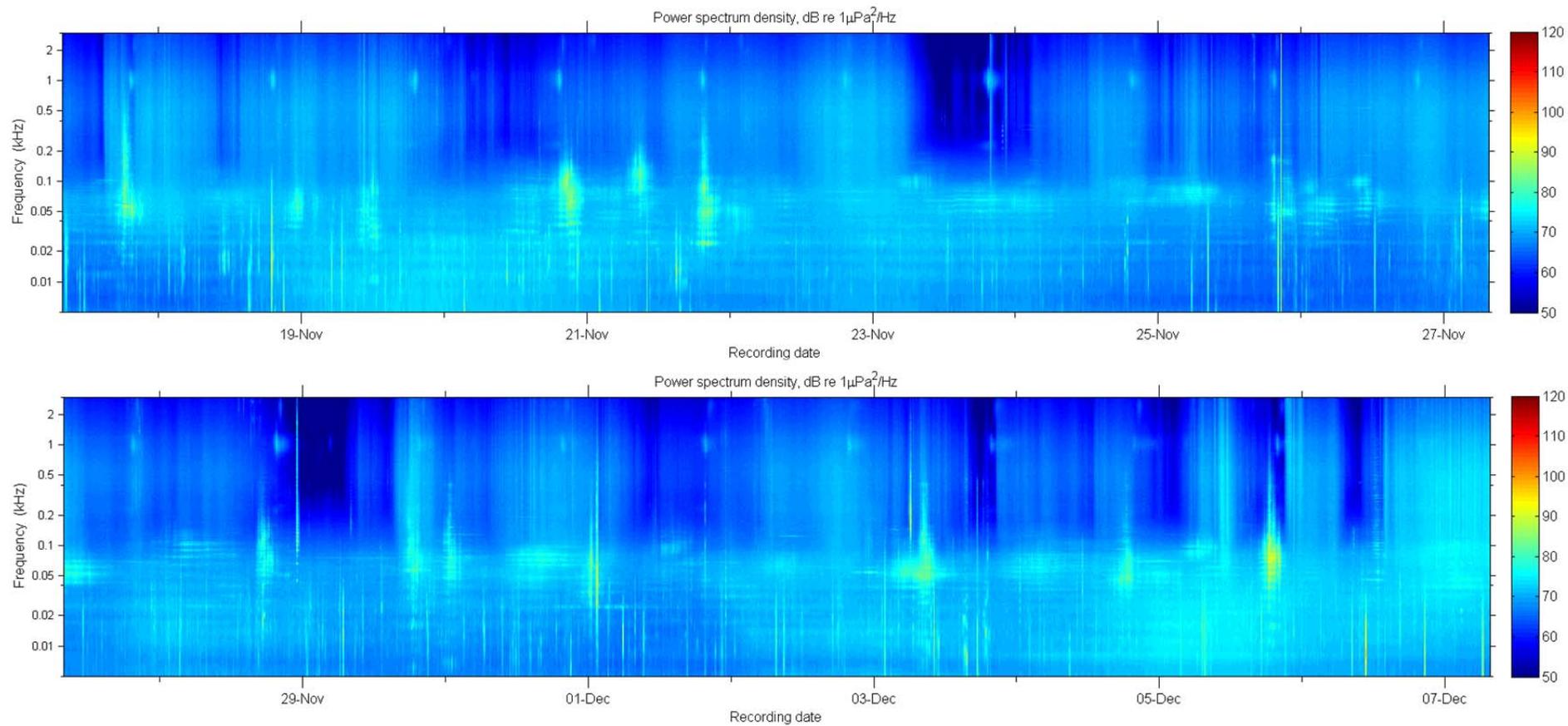


Figure 24: Long-time average spectrograms of sea noise recorded on the LF noise recorders during the twenty-ninth (top) and thirtieth (bottom) 10-day periods of measurements.

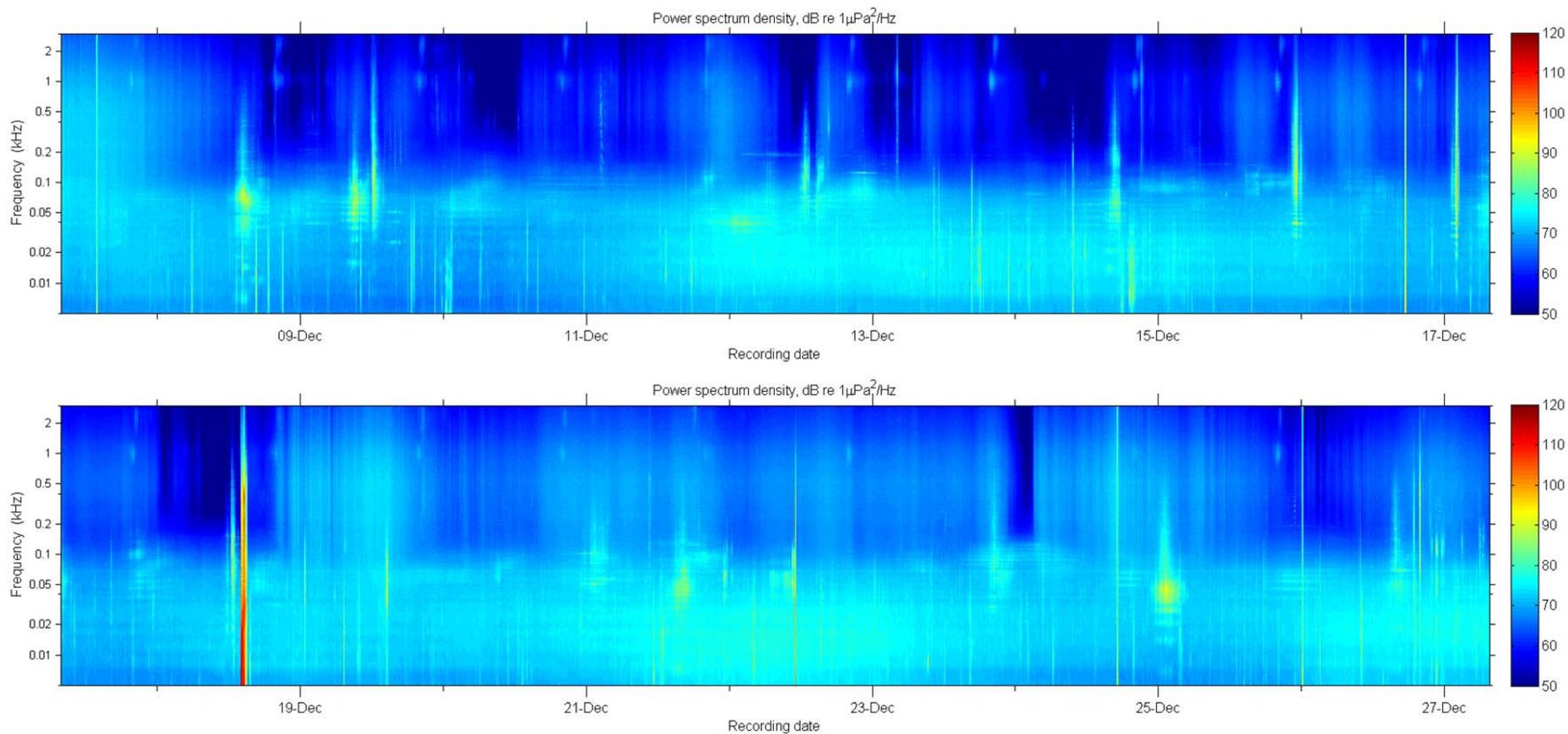


Figure 25: Long-time average spectrograms of sea noise recorded on the LF noise recorders during the thirty-first (top) and thirty-second (bottom) 10-day periods of measurements.

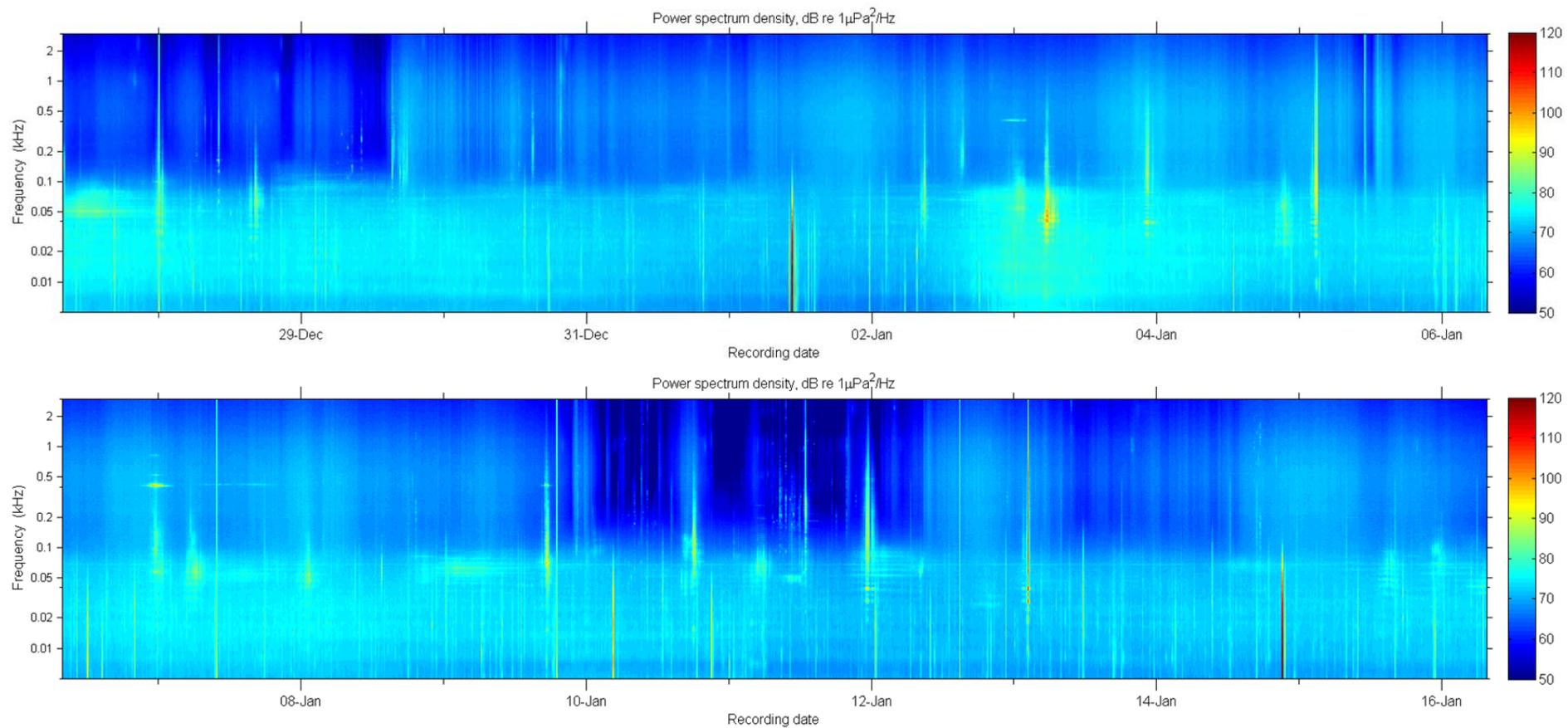


Figure 26: Long-time average spectrograms of sea noise recorded on the LF noise recorders during the thirty-third (top) and thirty-fourth (bottom) 10-day periods of measurements.

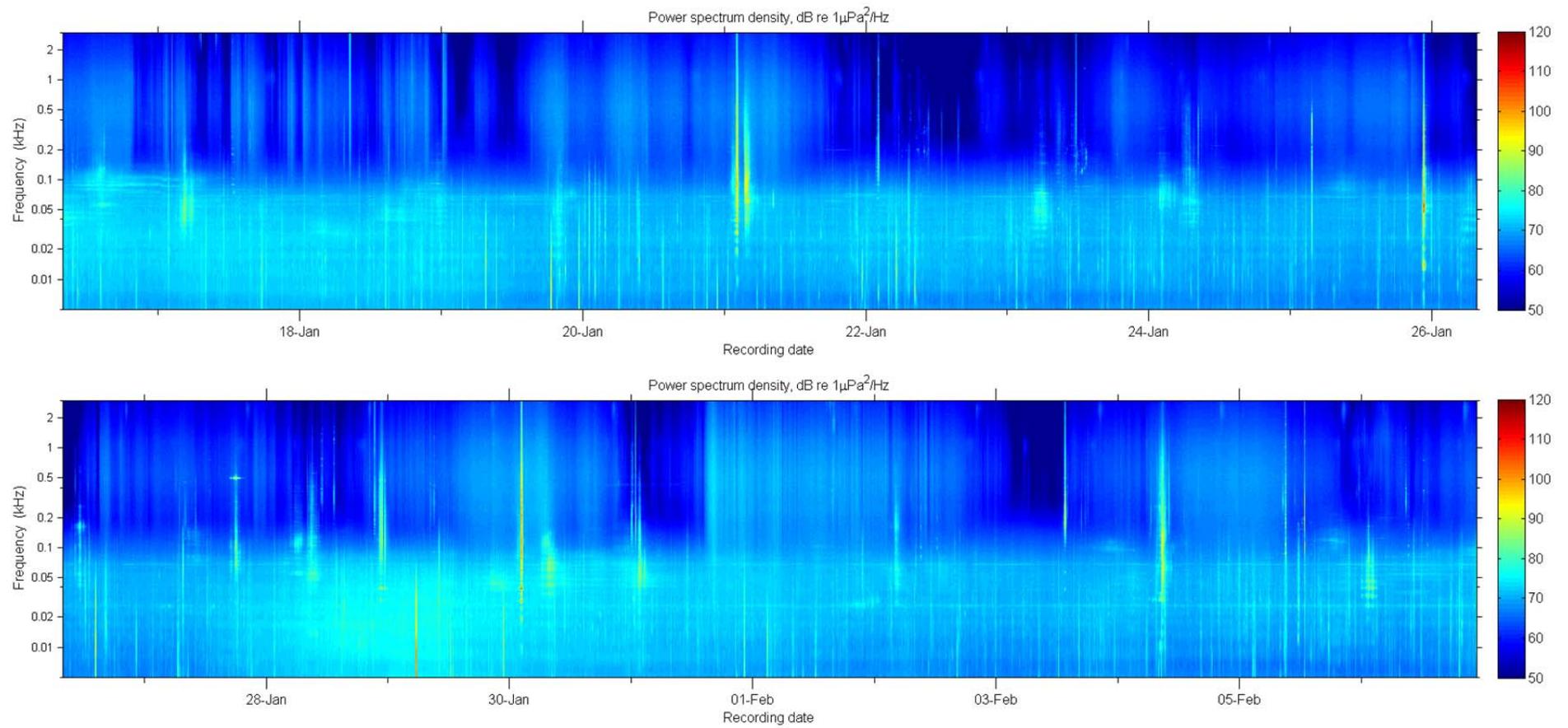


Figure 27: Long-time average spectrograms of sea noise recorded on the LF noise recorders during the thirty-fifth 10-day (top) and the last 12-day (bottom) periods of measurements.

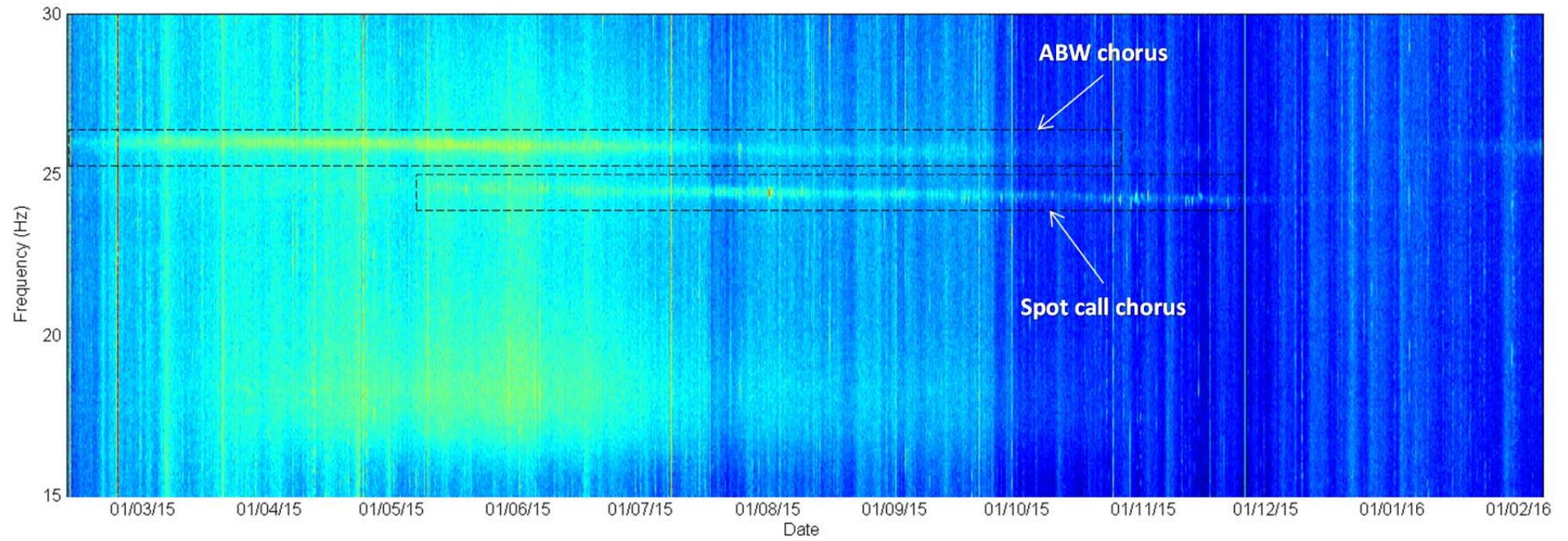


Figure 28: Long-time averaged spectrogram of high frequency resolution of sea noise over the entire recording time revealing choruses from ABW and spot calls.

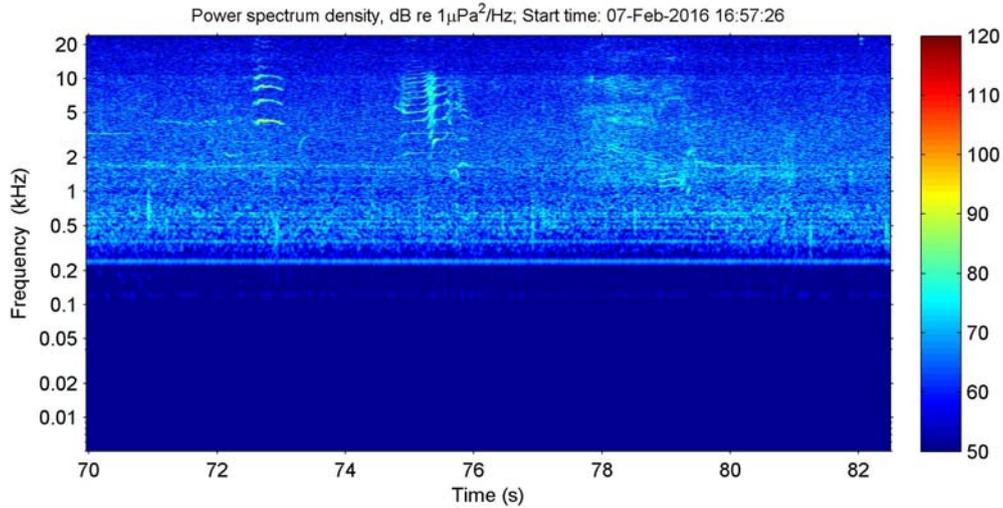


Figure 29: Spectrogram of whistles most likely from killer whales recorded on the towed array. The signal was high-pass filtered at 300 Hz to suppress intense low-frequency noise from the vessel.

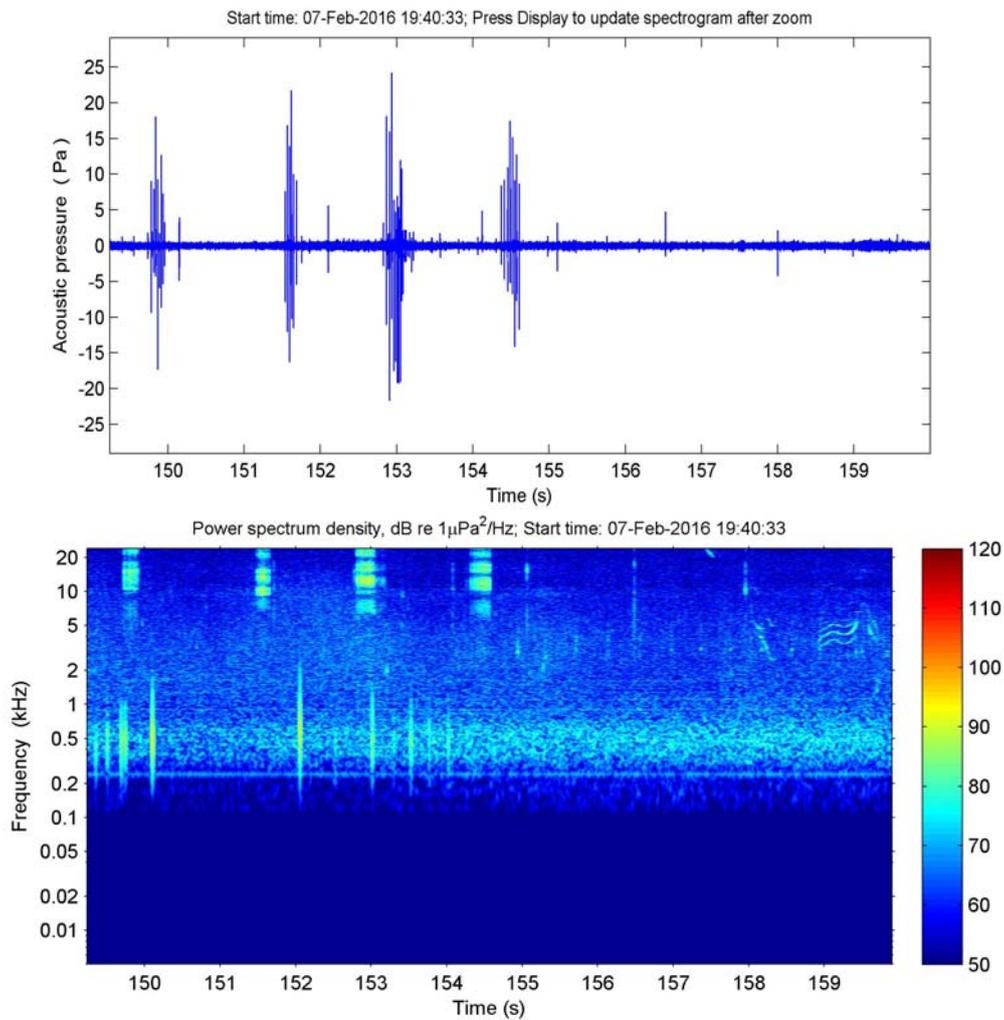


Figure 30: Waveform (top) and spectrogram (bottom) of echolocation click trains most likely from a sperm whale recorded on the towed array. The signal is high-pass filtered at 300 Hz to suppress intense low-frequency noise.

4. Summary and Conclusion

The presence of whales in the acoustically monitored area off Bremer Bay is summarised in Table 1. Most of the great whale species found in the sound recordings visited this area from late autumn to late spring. They left this area or stayed away during summer and early autumn. The seasonality of toothed whale presence in the monitored area cannot be determined as high-frequency acoustic recordings were only made from February to March. To better quantify the acoustic presence of odontocetes, all-year recording at a sampling frequency of at least 40 kHz would be beneficial. Nightly fish choruses were heard every month of the year from at least three different fish species.

Table 1: Seasonal presence of great whales in the observed area

Species	Start of season	End of season
Antarctic blue whale	Late July (?)*	Late July (?)*
Pygmy blue whale	Late April	Late May
Fin whale	Late May	Late June
Spot-call whale (probably southern right whale)	Mid July	Mid November
Humpback whale	Late June	Early August

*Few calls recorded within a few days in late July.

Acknowledgements

The two noise loggers were deployed with funding from the SeaWorld Busch Gardens Conservation Fund.

References

- Garland, E., Noad, M., Goldizen, A., Lilley, M., Rekdahl, M., Garrigue, C., Constantine, R., Hauser, N. D., Poole, M., and Robbins, J. (2013). Quantifying humpback whale song sequences to understand the dynamics of song exchange at the ocean basin scale. *J. Acoust. Soc. Am.*, 133(1), 560-569.
- Gavrilov, A.N., McCauley, R.D. and Gedamke, J. (2012). "Steady inter and intra-annual decrease in the vocalization frequency of Antarctic blue whales", *J. Acoust. Soc. Am.* **131**(6), pp. 4476-4480.
- Gavrilov, A.N. and Parsons, M. J. (2014). "A Matlab tool for the characterisation of recorded underwater sound (CHORUS)", *Acoustics Australia*. 42 (3) pp. 190-196.
- Gavrilov, A.N., McCauley, R.D., Charlton, C. and Ward, R. (2015). "Spot call and its potential source", UACE2015 - 3rd Underwater Acoustics Conference and Exhibition, Crete, Greece.
- Madsen, P. T., Wahlberg, M., and Mohl, B. (2002). Male sperm whale (*Physeter macrocephalus*) acoustics in a high-latitude habitat: implications for echolocation and communication. *Behavioral Ecology and Sociobiology*, 53(1), 31-41, doi: 10.1007/s00265-002-0548-1.
- McCauley, R. D., Jenner, C., Bannister, J. L., Cato, D. H., and Duncan, A. J. (2000, 15-17 Nov.). *Blue whale calling in the Rottneest trench, Western Australia, and low frequency sea noise*. Paper presented at the Annual Conference of the Australian Acoustical Society, Joondalup, Western Australia.

- Oleson, E. M., Calambokidis, J., Burgess, W. C., McDonald, M. A., LeDuc, C. A., and Hildebrand, J. A. (2007). "Behavioral context of call production by eastern North Pacific blue whales," *Mar. Ecol. Prog. Ser.* 330, 269–284.
- Širović, A., Hildebrand, J. A., and Wiggins, S. M. (2007). "Blue and fin whale call source levels and propagation range in the Southern Ocean." *J. Acoust. Soc. Am.* 122, 1208–1215.
- Wellard, R., Erbe, C., Fouda, L., and Blewitt, M. (2015). Vocalisations of killer whales (*Orcinus orca*) in the Bremer Canyon, Western Australia. *PLoS ONE*, 10(9), e0136535, doi: 10.1371/journal.pone.0136535.