

Passive Acoustic Monitoring for Marine Mammals in the Jacksonville Range Complex 2010

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Minke Whale, Photo by Amanda J. Debich

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Individual technical reports of the HARP deployments are available at:
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Executive Summary

Passive acoustic monitoring was conducted at a site in the US Navy's Jacksonville Range Complex during 9 March – 26 August 2010. The site is located 50 nm east of the Florida coastline on the continental shelf. Acoustic data collected at this site provide information on the presence of marine mammals and naval sonar. High-frequency Acoustic Recording Packages (HARPs) recorded sounds between 10 Hz and 100 kHz with recording duty cycles of 5 minutes every 10 minutes. The data were divided into two frequency bands: (1) low frequencies, between 1 – 1000 Hz, and (2) mid frequencies, between 500 – 5000 Hz. These data were not analyzed for high frequency marine mammal sounds, such as the echolocation clicks of delphinids. Data were analyzed by scans of long-term spectral averages and spectrograms.

High ambient noise levels, caused by instrument strumming and fluid flow at the sensor, were prevalent during this deployment and decreased detection ability for low-frequency sounds. Only one species of baleen whale—the humpback whale—was detected. Humpback non-song calls were detected during two days in March 2010. No blue whale, fin whale, Bryde's whale, minke whale, North Atlantic right whale, or sei whale calls were detected in this deployment.

Anthropogenic sound in the form of Mid-Frequency Active Sonar (MFA) was detected throughout this deployment. It was most common in late March 2010.

Project Background

The US Navy's Jacksonville Range Complex (JAX) is located within the South Atlantic Bight that extends from Cape Hatteras, North Carolina to the Florida Straits. The sea floor is relatively smooth and features a broad continental shelf, with an inner zone of less than 200m water depth, and an outer zone extending to water depths of 2000m. A diverse array of marine mammals are found in this region, including mysticete whales, dolphins, toothed whales, and manatees.

In April 2009, an acoustic monitoring effort was initiated within the boundaries of JAX with support from the Atlantic Fleet under contract to Duke University. This report documents the analysis for presence of baleen whale and sonar events during one deployment of High-frequency Acoustic Recording Package (HARP) within JAX, from 9 March to 26 August 2010. The site analyzed was JAX-B HARP site, deployed 50 nm east of the Florida coastline (Figure 1).

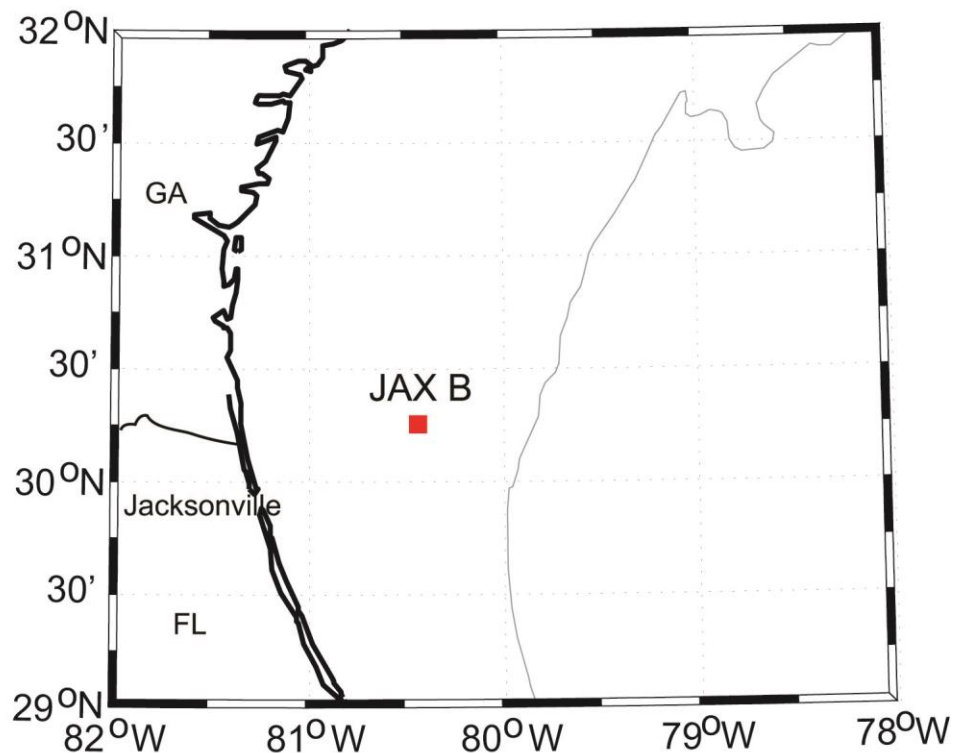


Figure 1: Location of HARP at site B in JAX. The grey line is 500 m depth contour.

Methods

High Frequency Acoustic Recording Packages

High-frequency Acoustic Recording Packages (HARPs) were used to record marine mammal species, anthropogenic noise, and ambient noise. HARPs record underwater sounds from 10 Hz to 100 kHz. The HARP sensor and mooring package are described in (Wiggins & Hildebrand, 2007). For the JAX deployments, the HARP electronics package was located near the seafloor with the hydrophone suspended 10 m above. Each HARP is calibrated in the laboratory to provide a quantitative analysis of the received sound field. Representative data loggers and hydrophones are calibrated at the Navy's TRANSDEC facility to verify the laboratory calibrations.

Data Collected to Date

Acoustic data have been collected at two sites in the Jacksonville Range Complex JAX since 2009. The deployment analyzed in this report is from Site B (30° 15.55 W, 80° 25.54).

Table 1: JAX-B HARP deployments. Period of deployment analyzed in this report is shown in bold.

Deployment Designation	Site B Deployment Period
JAX 01	4/2/2009 – 9/5/2009
JAX 04	3/9/2010 – 8/26/2010
JAX 05	8/27/2010 – 2/1/2011
JAX 06	2/2/2011 – 7/14/2011

Data Analysis

To assess the quality of the acoustic data, frequency spectra were calculated for all the data using a time average of 5 seconds and variable frequency bins (1, 10, and 100 Hz). These data, called Long-Term Spectral Averages (LTSA) were examined both for characteristics of ambient noise and also as a means to discover marine mammal and anthropogenic sounds.

The presence of acoustic signals from baleen whales was analyzed along with the presence of naval sonar. All data were analyzed by visually scanning LTSA in appropriate frequency bands or by running automatic detectors. When a sound of interest was identified in the LTSA, the waveform or spectrogram at the time of interest was examined to further classify particular sounds to species or source. Acoustic classification was carried out either by comparison to species-specific spectral characteristics or by analysis of the time and frequency character of individual sounds.

To document the data analysis process, we describe the major classes of baleen whale calls and naval sonar in JAX, and the procedures used to test for their presence in the HARP data. For effective analysis, the data were divided into two frequency bands and each band was analyzed for the sounds of an appropriate subset of species or sources. The two frequency bands are as follows: (1) low frequencies, between 1 – 1000 Hz, (2) mid frequencies, between 500 – 5000 Hz. Blue whale, fin whale, Bryde's whale, minke whale, North Atlantic right whale, and sei whale sounds, and an unknown sound found during earlier JAX data analysis named "5pulse" were classified as low frequency; humpback whale, and mid-frequency active sonar sounds were classified as mid-frequency. We describe the calls and analysis procedures separately for each frequency band.

Low Frequency Marine Mammals

For the low frequency data analysis, the 200 kHz sampled raw-data were decimated by a factor of 100 for an effective bandwidth of 1 kHz. Long-term spectral averages (LTSA) of these data were created using a time average of 5 seconds and frequency bins of 1 Hz. The presence of each call type was determined in hourly bins.

Whale calls for which low frequency effort was expended include: blue whale North Atlantic A and arch calls, fin whale 20 and 40 Hz pulses, Bryde's whale Be7 and Be9 calls, minke pulse trains, North Atlantic right whale upcalls, sei low frequency downsweeps. In addition, presence of "5pulse" call type of unknown origin was also monitored. The same LTSA and spectrogram parameters were used to detect all call types. For spectrogram scrolling, the LTSA frequency was set to display between 1-200 Hz. To observe individual calls, spectrogram parameters were typically set to 60 seconds by 200-250 Hz. The FFT was generally set to 2000 data points (yielding 1 Hz frequency resolution), with a 98% overlap of data in the input time series.

Blue Whales

Several different calls were used to test for the presence of blue whales. Detection effort included North Atlantic call type A and the arch call (Mellinger & Clark, 2003). The A call is a constant 18-19 Hz tone lasting approximately 8 seconds, with if often followed by a 18-15 Hz downsweep lasting approximately 11 seconds (Figure 2). The other call, the arch call, starts around 60 Hz, can ascend up to

70 Hz, then descends to approximately 35 Hz over a period of about 6 seconds (Figure 3). Manual scanning of the LTSA was the primary means to search for blue whale calls, however, no blue whale calls of any type were detected in the JAX data.

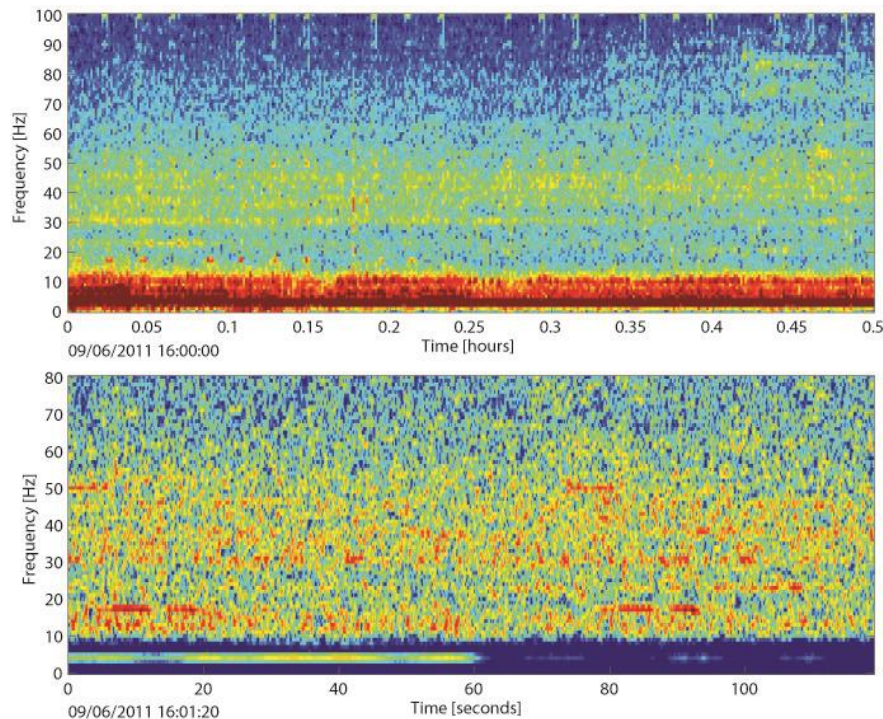


Figure 2: North Atlantic blue whale calls in the LTSA (top) and spectrogram (bottom) recorded at the Cherry Point OPAREA (USWTR) approximately 100 miles east of the North Carolina coastline: 33° 46.7 N, 75° 55.6 W, depth 580 m.

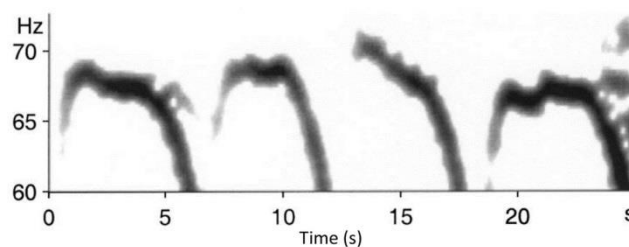


Figure 3: Blue whale arch calls (Mellinger & Clark, Blue whale (*Balaenoptera musculus*) sounds from the North Atlantic, 2003)

Fin Whales

Fin whales produce a variety of calls. Most have frequency lower than 100 Hz, they are short in duration, and frequency-modulated. The best-known fin whale call is the 20 Hz pulse, downswept from 30 – 15 Hz (Figure 4). These pulses occur at regular intervals as song (Thompson, et al. 1992). Fin

whales also produce 40 Hz pulse, which sweeps down in frequency from 75 to 40 Hz (Watkins, 1981; Širović, et al. 2013)(Figure 5). No fin whale calls of either type were detected during this deployment.

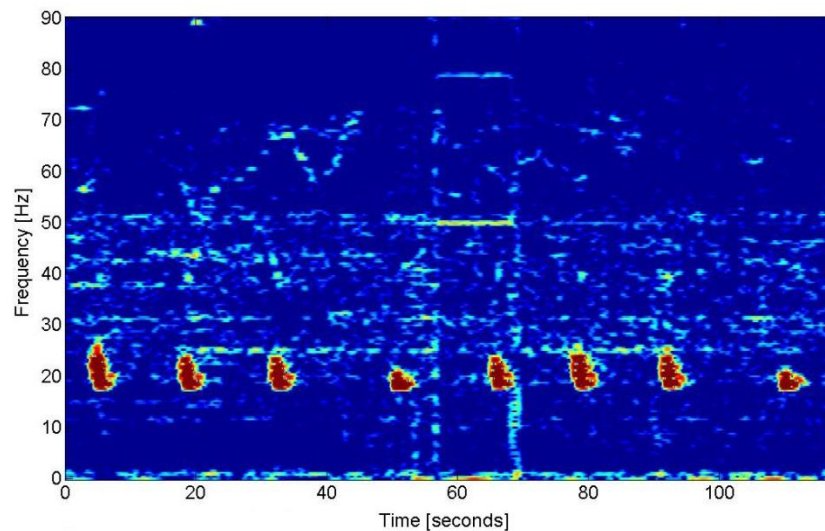


Figure 4: Fin whale 20Hz pulse recorded at JAX site A on January 24, 2011.

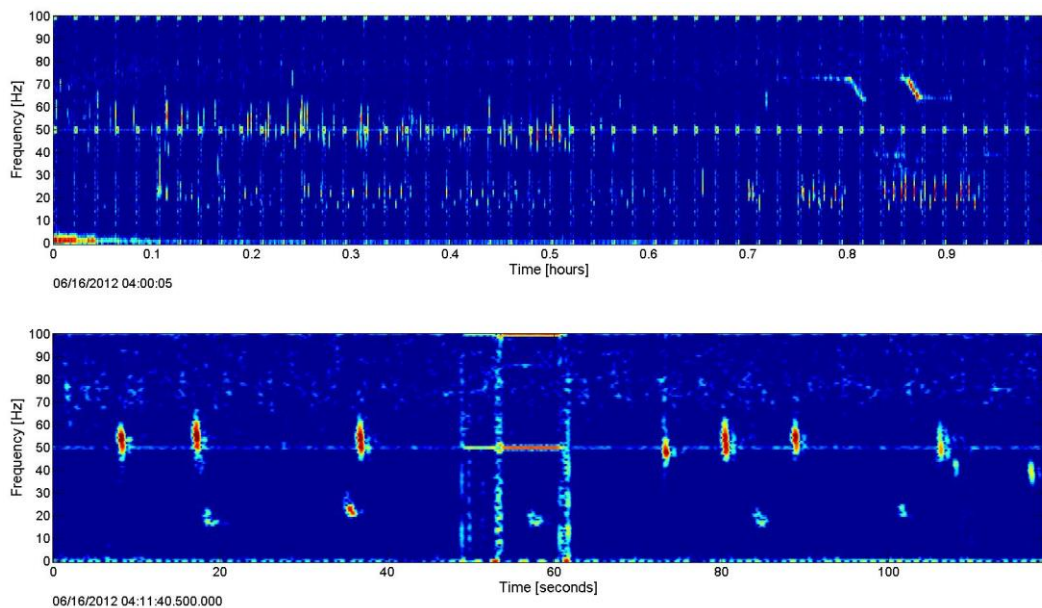


Figure 5: 40Hz fin calls in the LTSA (top) and spectrogram (bottom) from southern California HARP data, June 2012

Bryde's Whales

Bryde's whales inhabit tropical and subtropical waters worldwide (Omura, 1959; Wade & Gerrodette, 1993), and the JAX HARP site is considered near to their northerly range limit. The Be7 call is one of several call types in the Bryde's whale repertoire, first described in the Southern Caribbean (Oleson, et

al. 2003). The average Be7 call has a fundamental frequency of 44 Hz and ranges in duration between 0.8 and 2.5 seconds with an average intercall interval of 2.8 minutes (Figure 6). The Be9 call type, described for the Gulf of Mexico (Širović, et al. 2013), is a downswept pulse ranging from 143 to 85 Hz, with each pulse approximately 0.7 seconds long (Figure 7). No Bryde's whale calls were detected in this analysis.

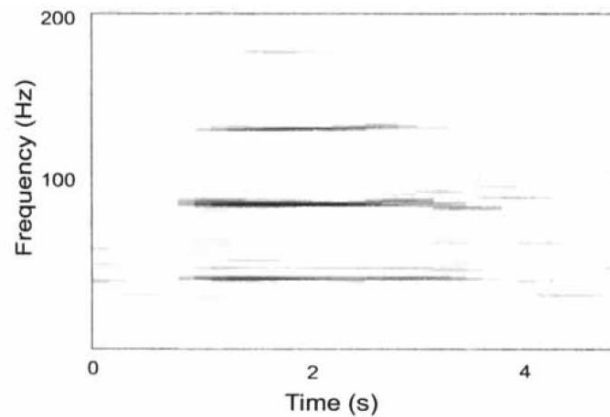


Figure 6: Spectrogram of Bryde's whale Be7 call from the Southern Caribbean (Oleson, et al. 2003)

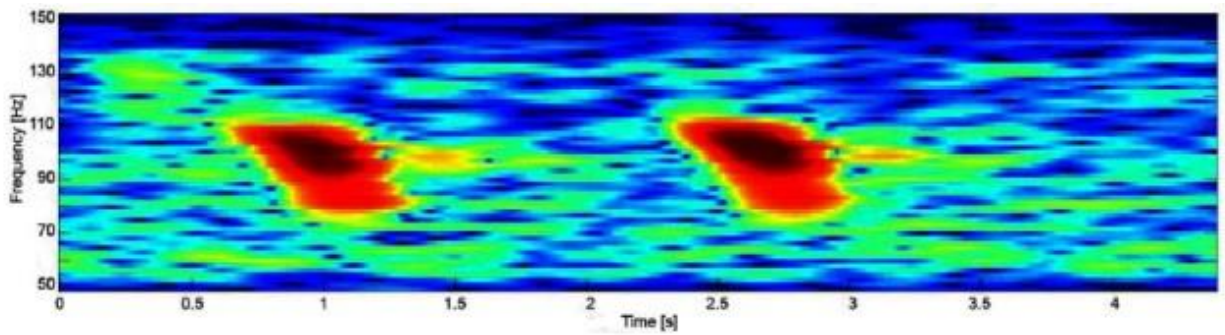


Figure 7: Bryde's whale Be9 call from the Gulf of Mexico (Širović, et al. 2013)

Minke Whales

Minke whales in the North Atlantic produce long pulse trains. Mellinger et al. (2000) described minke whale pulse sequences near Puerto Rico as speed-up and slow-down pulse trains, with increasing and decreasing pulse rate respectively. Recently, those call types were detected in the North Atlantic and they were expanded to also include pulse trains with non-varying pulse rate (Risch, et al. 2013)(Figure 8). No minke pulse trains were detected during this analysis.

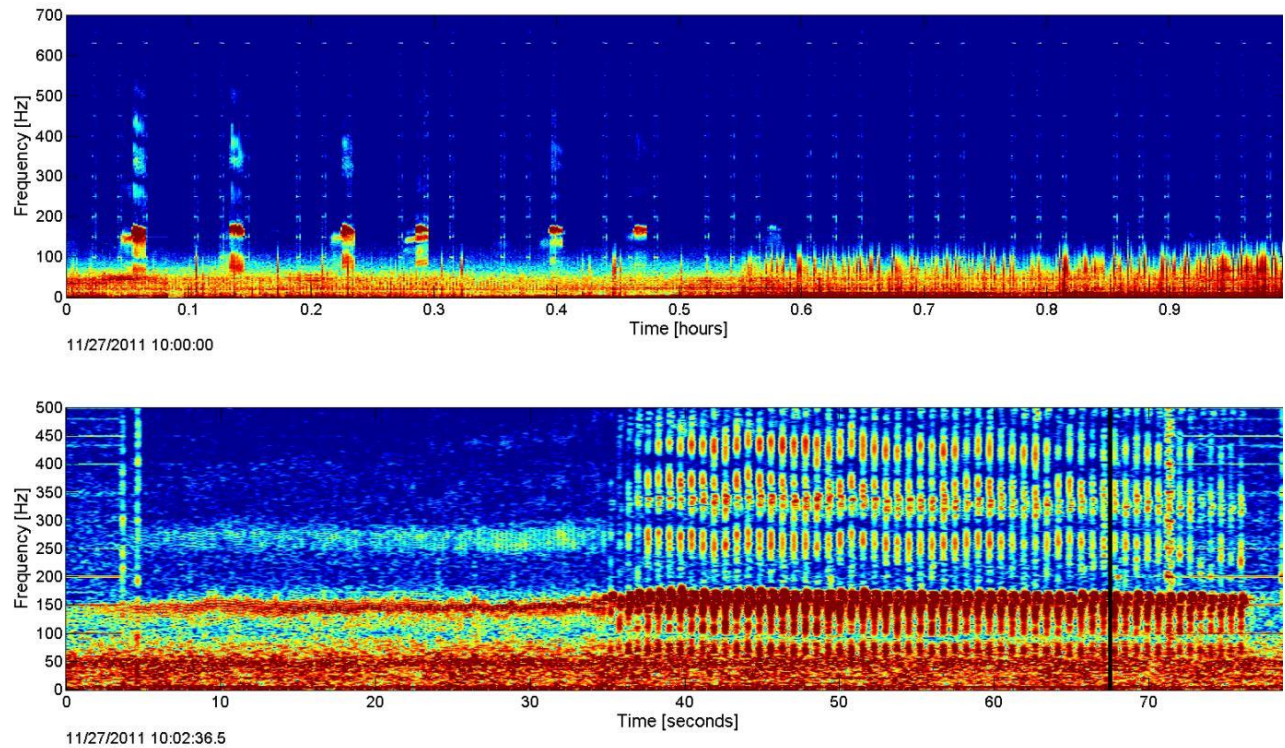


Figure 8: Minke whale pulse train in the LTSA (top) and spectrogram (bottom) from USWTR, November 2011

North Atlantic Right Whales

The North Atlantic right whale is a critically endangered whale found in the Western North Atlantic. Several call types that have been described for the North Atlantic right whale include the scream, gunshot, blow, upcall, warble, and downcall (Parks & Tyack, 2005). For low-frequency analysis, we examined the data for upcalls, which are approximately 1 second in duration and range between 80 Hz and 200 Hz, sometimes with harmonics (Figure 9). No North Atlantic right whale upcalls were detected.

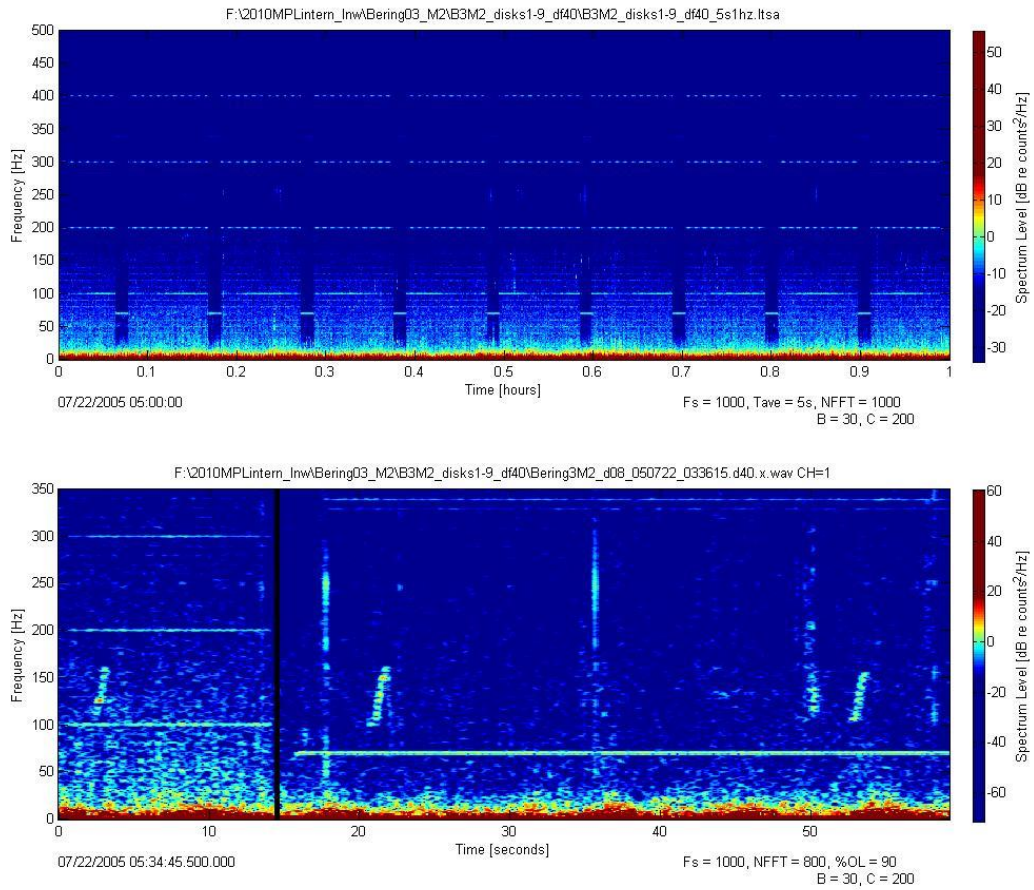


Figure 9: Right whale upcall from Bering sea HARP data, July 2005

Sei Whales

Sei whales are found primarily in temperate waters and undergo annual migrations between lower latitude winter breeding grounds and higher latitude summer feeding grounds (Mizroch, et al. 1984; Perry, et al. 1999). Multiple sounds have been attributed to sei whales, but we report on a low frequency downsweep call similar to those reported as sei whale calls (Baumgartner & Fratantoni, 2008; Baumgartner, et al. 2008). These calls typically sweep from a starting frequency around 100 Hz to an ending frequency around 40 Hz (Figure 10 and Figure 11).

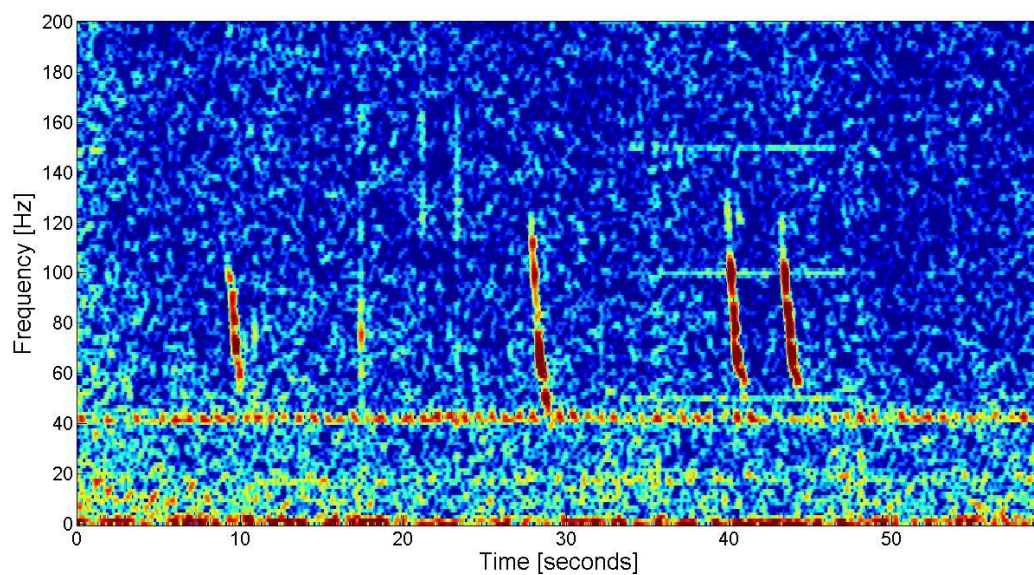


Figure 10: Downsweep calls reported to be from sei whales recorded at JAX site A on December 26, 2010

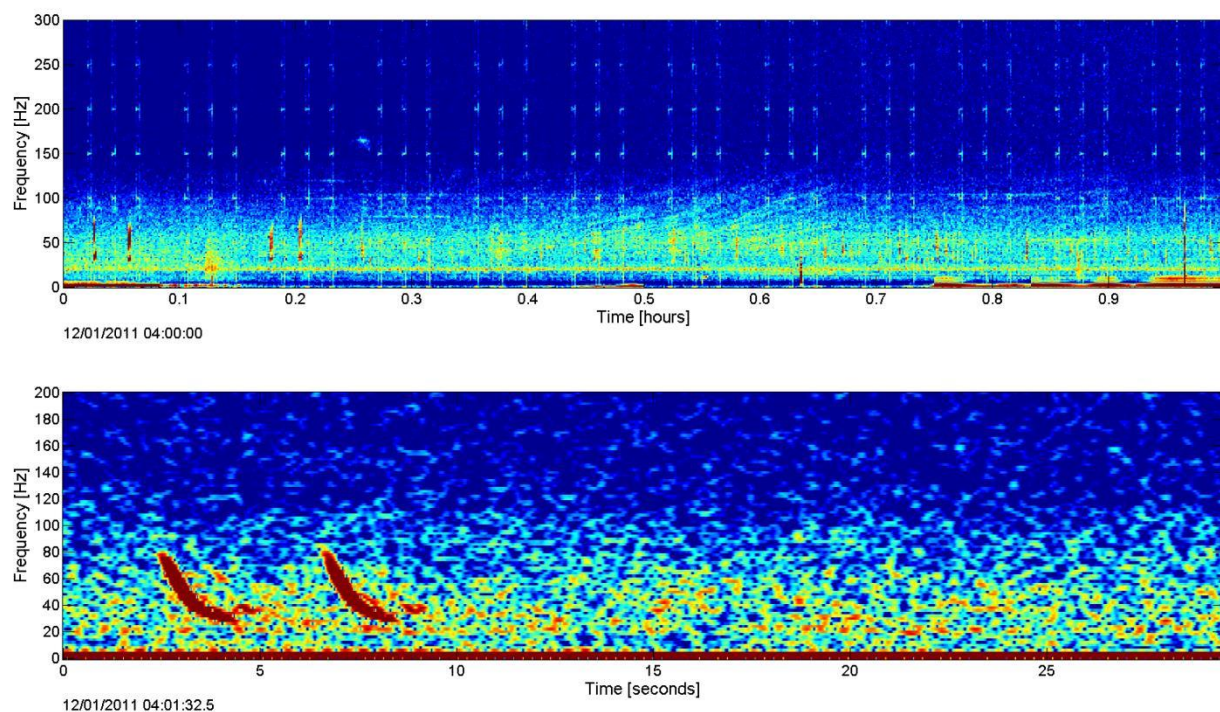


Figure 11: Downsweep calls reported to be from sei whales in the LTSA (top) and spectrogram (bottom) from USWTR, December 2011

5pulse

The sound named 5pulse was common during analysis of JAX deployments 05A and 06B with most observed sounds occurring in late August 2010 and early April 2011 (at each site respectively). The 5pulse sound consists of one to five pulses over approximately two seconds. It has a starting frequency around 150Hz with a very slight upsweep. However, 5pulses can vary in fundamental frequency from 120 – 200Hz (Figure 12). Because of its features, it is possible this sound could be heretofore unclassified call of a baleen whale. No 5pulse sounds were detected during this deployment.

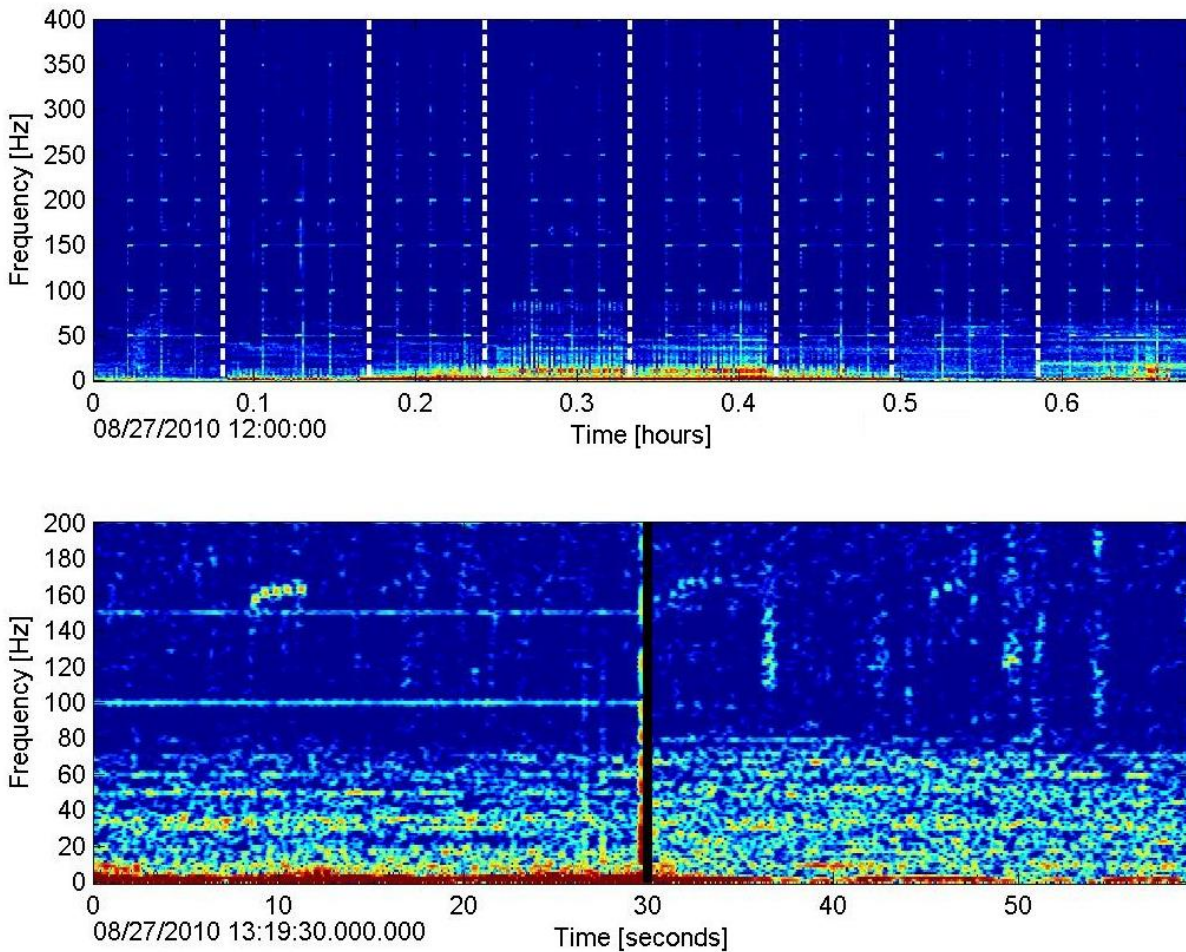


Figure 12: 5pulse in LTSA (above) and spectrogram (below) from JAX05A, August 2010

Mid-Frequency Marine Mammals

For mid-frequency data analysis, the raw 200 kHz HARP data were decimated by a factor of 20 for an effective bandwidth of 5 kHz. Humpback whales were the only marine mammal monitored in mid-frequency data.

Humpback Whales

Humpback whale song is categorized by the repetition of units, phrases and themes (Payne & McVay, 1971). Non-song vocalizations such as social sounds and feeding sounds consist of individual units that can last from 0.15 to 2.5 seconds (Dunlop, et al. 2007; Stimpert, et al. 2011) (Figure 13). Most humpback whale vocalizations have acoustic energy between 100 – 3000 Hz. For this report, we examined the data for humpback calls (both song and non-song) using the generalized power-law algorithm (Helbe, et al. 2012), followed by verification of the accuracy of detected signals by a trained analyst (Figure 14).

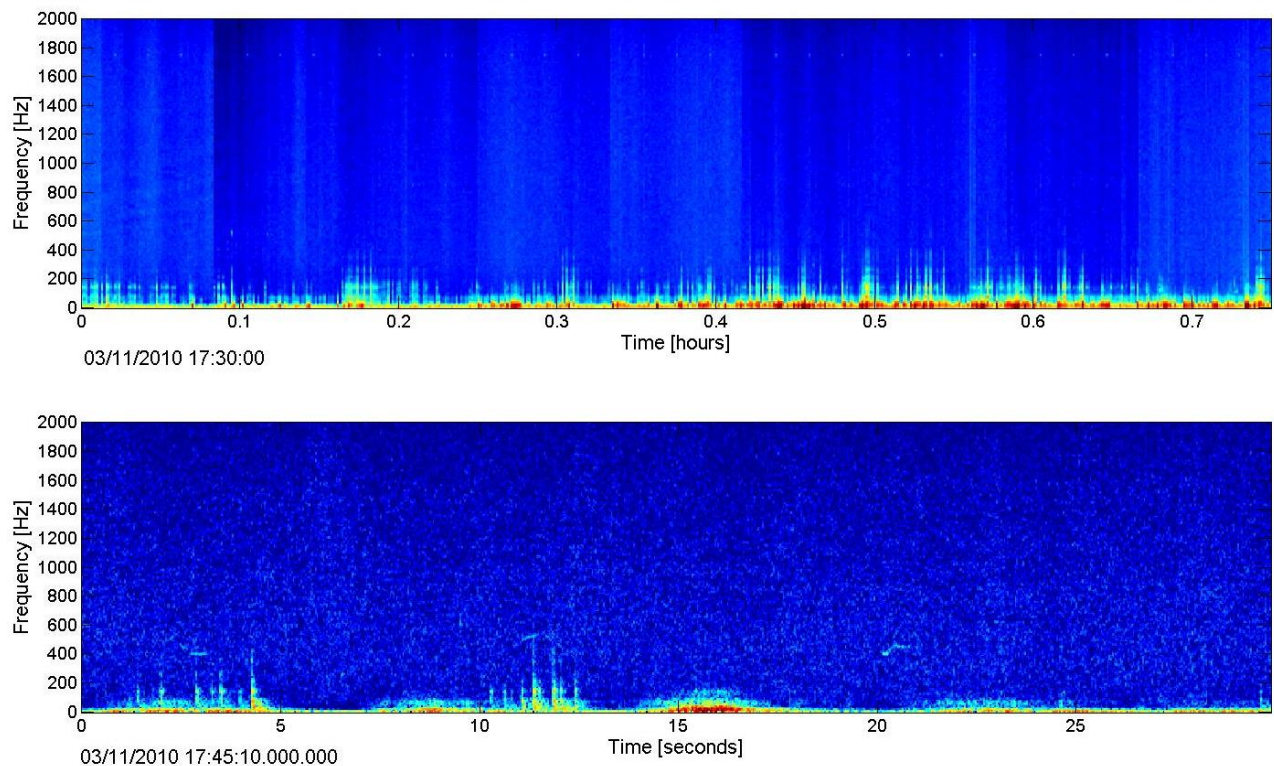


Figure 13: Humpback calls in the LTSA (above) and spectrogram (below) from JAX04B, March 2010

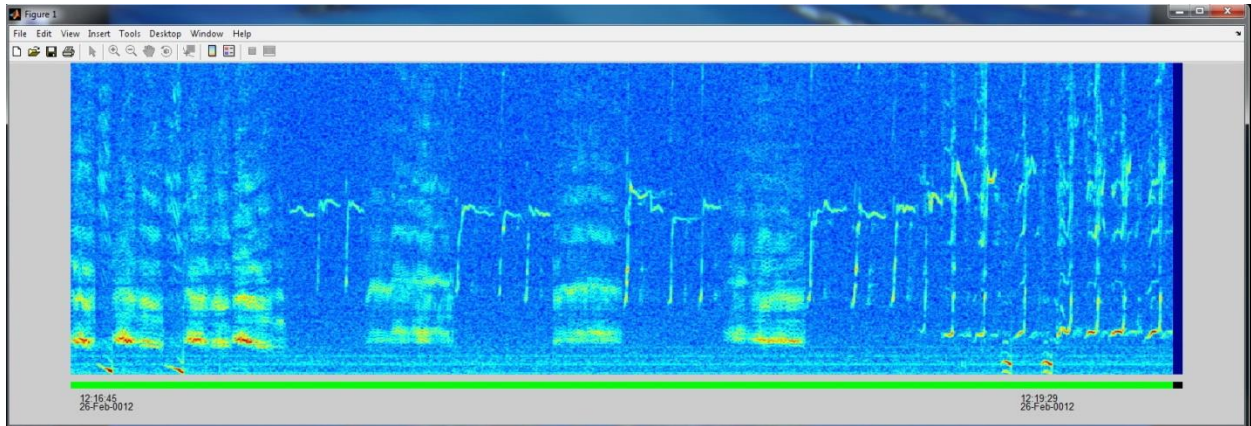


Figure 14: Example of humpback whale song from southern California in analyst verification stage of detector

Anthropogenic Sounds

Mid-Frequency Active Sonar

A common type of sonar used in JAX is mid-frequency active (MFA) sonar. Sounds from MFA sonar vary in frequency and duration and can be used in a combination of sweeps and tones; however, many of these are between 2 and 5 kHz and are generically known as '3.5 kHz' sonar. We describe the process for identifying MFA sonar and how pings from these events were analyzed, including counts and distributions of sonar levels.

The first step in analyzing MFA sonar was conducted by an analyst scanning for periods of sonar activity. Start and end times of MFA sonar events from LTSAs were noted to provide target periods for automatic detections. Individual MFA sonar pings typically span 1 – 3 s, but are intense enough to show up as 'pulses' in LTSA plots (Figure 15). LTSA display parameters used by the analyst were 1 or 2 hour window length, and 2 – 5 kHz bandwidth.

A custom developed software routine was used to detect sonar pings and calculate peak-to-peak (PP) received sound pressure levels. For this detector, a sonar ping is defined as the presence of sonar within a 5 s window and may contain multiple individual pings. The detector calculates the average spectral level across the frequency band from 2.4 to 4.5 kHz for each 5 s window. This provides a long-term time series of the average received levels in that frequency band. Minimum values were noted for each 15 time bins, and used as a measure of background noise level over the sonar event period. Spectral bins that contained system noise (disk writing) were eliminated. Each of the remaining average spectral bins was compared to the background minimum levels. If levels were more than 3 dB above the background, then a detection time was noted. These detection times were used to index to the original time series to calculate PP levels. Received PP levels were calculated by differencing the maximum and minimum amplitude of the time series in the 5 s window. The raw time series amplitudes are in units of analog-to-digital converter (ADC) counts. These units were corrected to μPa by using the HARP calibrated transfer function for this frequency band. The HARP response is not flat over the 2.4 – 4.5 kHz band, and the

value at 3.3 kHz was used to approximate the entire band. The transfer function value used for site 4B was 82.7 dB re $\mu\text{Pa}^2/\text{counts}^2$.

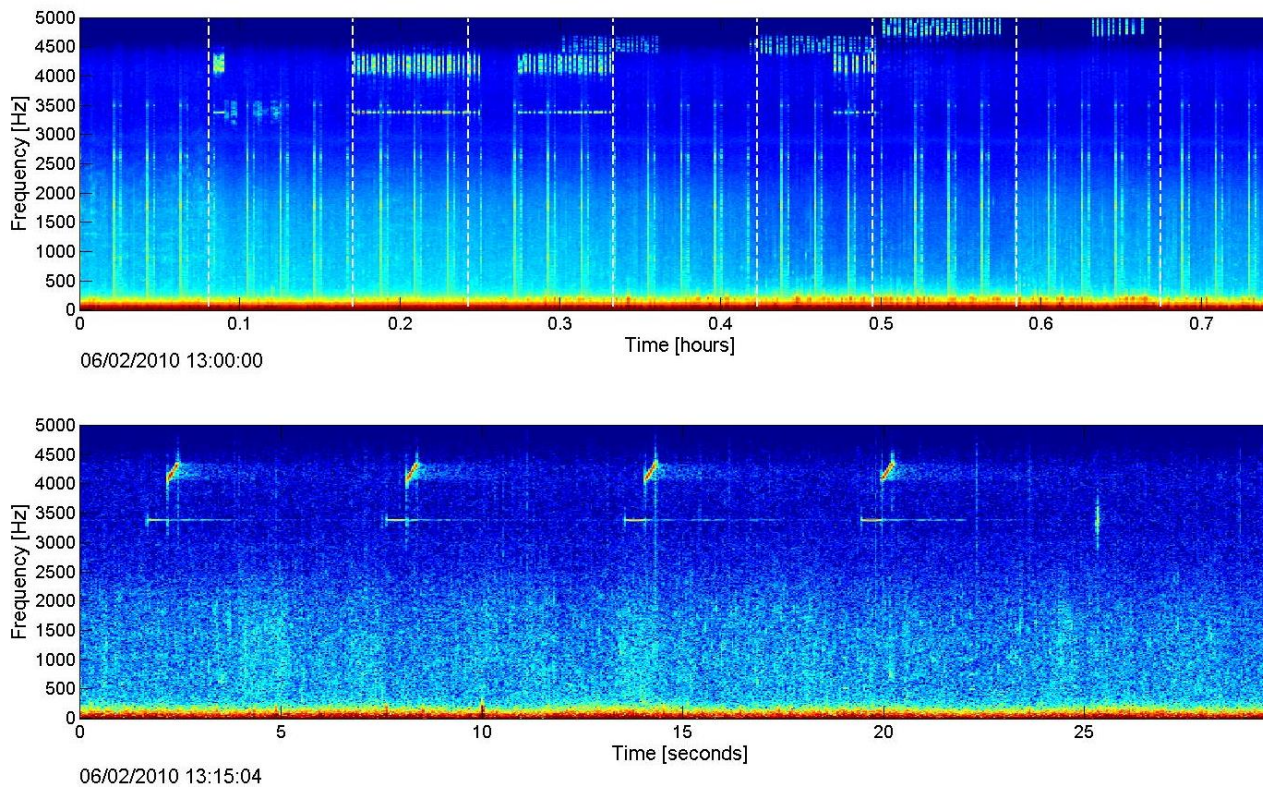


Figure 15: MFA example seen in the LTSA (above) and spectrogram (below)

Results

Ambient Noise

Underwater ambient noise at JAX site B has spectral shapes with higher levels at low frequencies (Figure 16), owing to many factors including the presence of ship noise (Hildebrand, 2009) and the noise due to mooring strum and fluid motion near the hydrophone sensor. At this site, the HARP is deployed at the shallow depth of 38 m. Shallow sites are expected to have higher amounts of ambient noise than deeper sites because there is less attenuation of natural and anthropogenic sounds as will occur in deeper water (Hildebrand, 2009). At low frequencies, there is up to 25 dB variability in average monthly sound pressure levels (Figure 16), indicative of large levels of fluctuation in noise at this site.

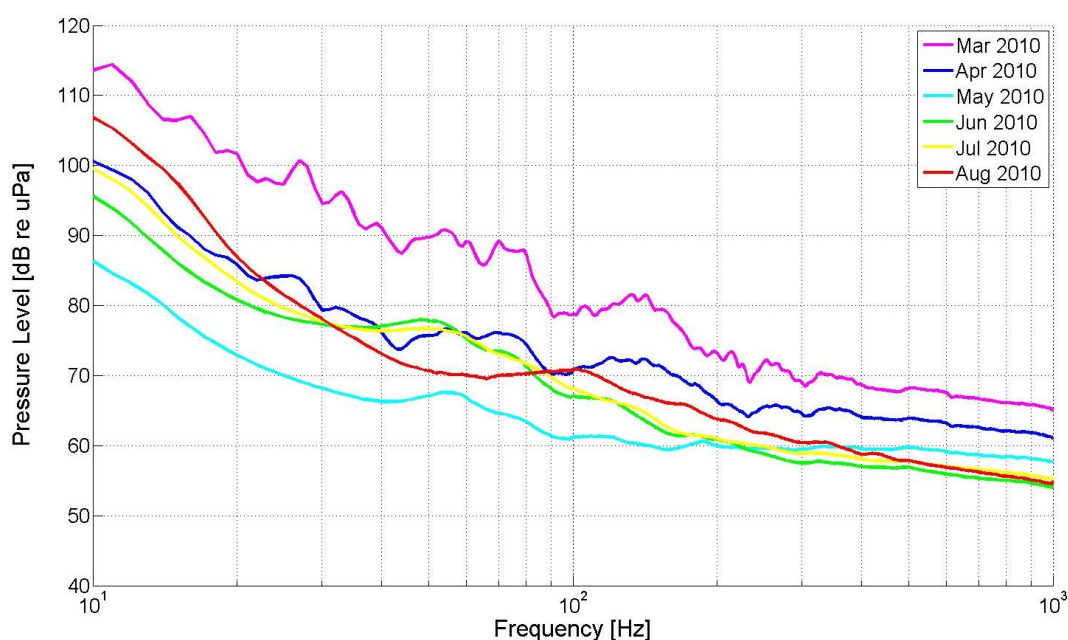


Figure 16: Monthly averages of ambient at site B for the period March – August 2010. Legend gives color-coding by date.

The month of March had the highest ambient noise levels in this deployment (Figure 16). March also had a very high occurrence of strumming. Strumming was prevalent throughout the entire deployment from March to August 2010, but the intensity of the strumming was variable. In March 2010, the strumming was intense enough to mask the low frequency (<150 Hz) for the majority of time. Figure 17 shows a typical example of strumming during the month of March. In contrast, May 2010 showed the lowest levels of ambient noise (Figure 16) and the lowest occurrence of strumming (Figure 18). In both March and May, the relative difference between the strumming and non-strumming sections was around 30 dB (Figure 17 and Figure 18).

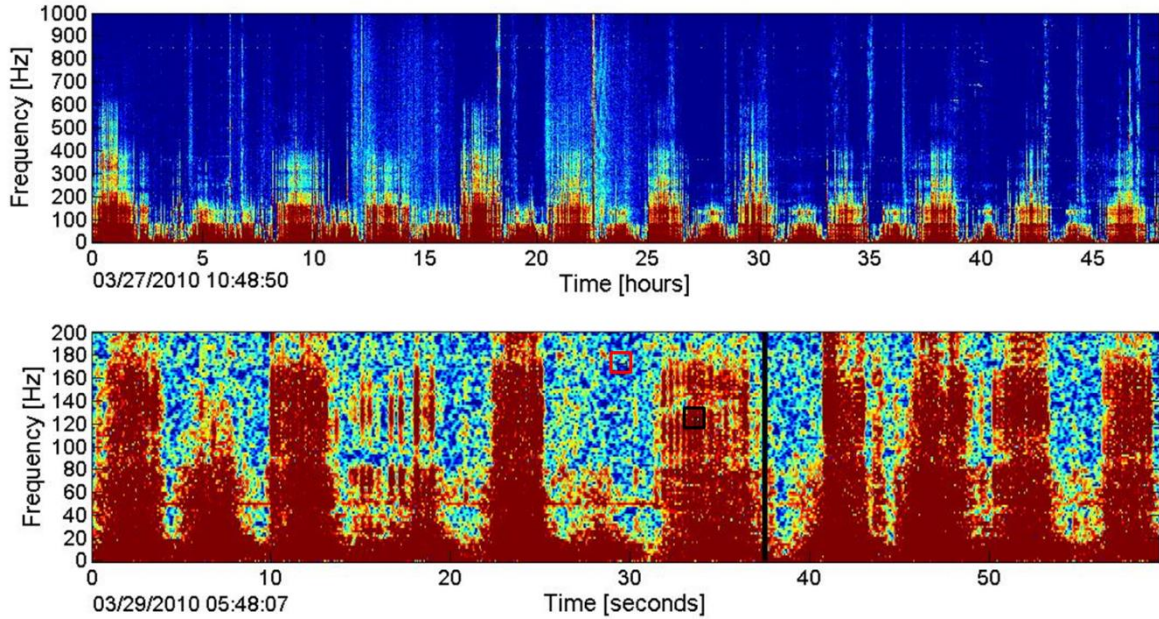


Figure 17: Typical strumming occurrences in March. Shown in an LTSA (above), 0-1000Hz, 48h window, and a (below), 0-200Hz, 60s window, in the typical viewing parameters used by low frequency analysts. The relative change in levels between area with no strumming (red rectangle) and high strumming (black rectangle) is about 30 dB.

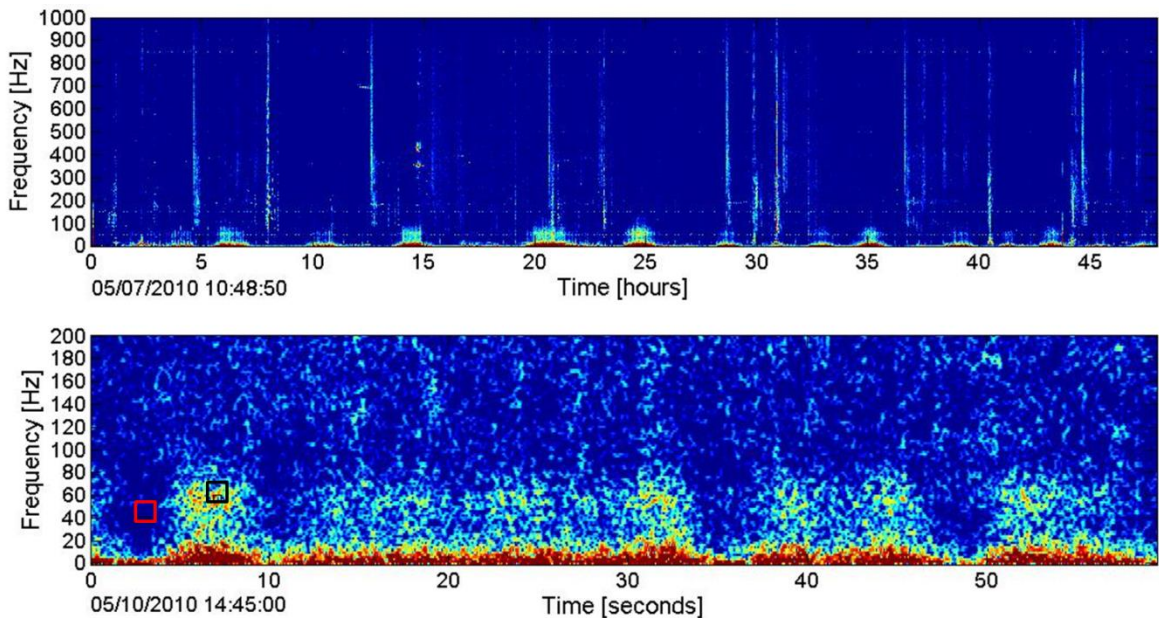


Figure 18: Typical strumming occurrences in May. Shown in an LTSA (above), 0-1000Hz, 48h window, and a (below), 0-200Hz, 60s window, in the typical viewing parameters used by low frequency analysts. The The relative change in levels between area with no strumming (red rectangle) and high strumming (black rectangle) is about 30 dB.

Mysticetes

Only humpback whale calls were detected in this deployment. There were no calls detected from blue whales, fin whales, Bryde's whales, minke whales, North Atlantic right whales, or sei whales. There were no 5pulse sounds detected either.

Humpback Whales

Humpback whale non-song vocalizations were detected during two days, March 11th and 12th (Figure 19). There were a total of eight instances of non-song. There were no instances of humpback song. Daily presence of humpback whale non-song did not have any temporal patterns (Figure 20).

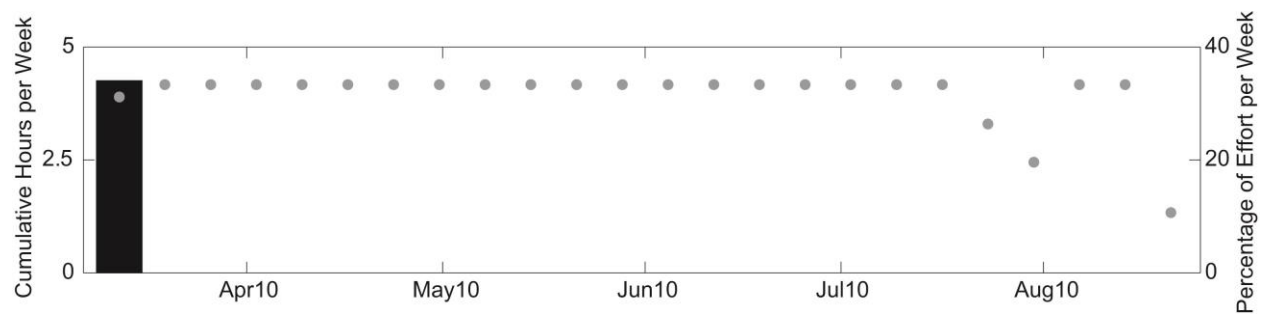


Figure 19: Weekly humpback whale non-song presence in 2010. The light gray dots represent weekly recording effort

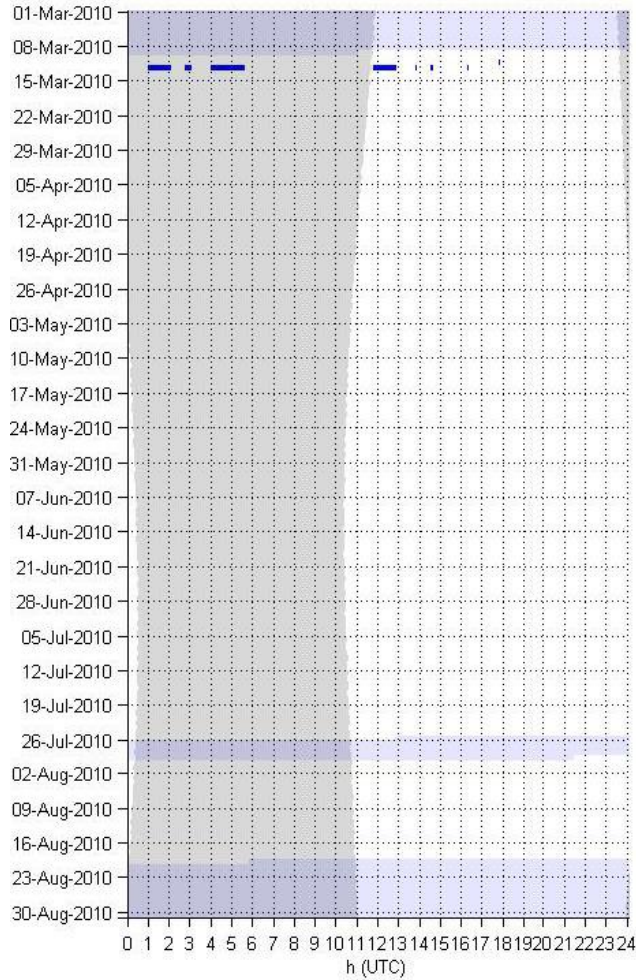


Figure 20: Seasonal/diel plot of humpback whale non-song presence. Dark gray shading represents hours of darkness and blue are periods with no effort.

Anthropogenic Sounds

Mid-frequency active sonar was detected during this deployment.

Mid-Frequency Active Sonar

Mid-frequency active sonar (MFA) was detected on a few days each in March, June, July, and August (Figure 21). There were a total of twelve instances of MFA detection with most of them occurring in late March (Figure 22).

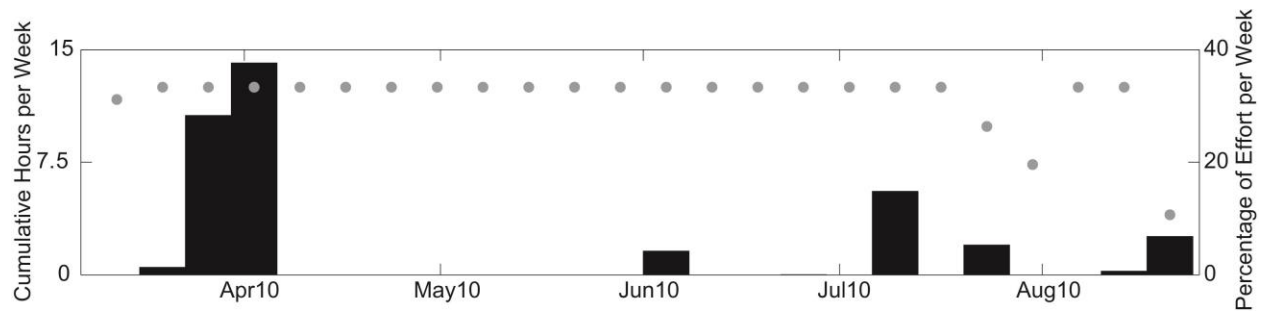


Figure 21: Weekly MFA presence in 2010. The light gray dots represent weekly recording effort

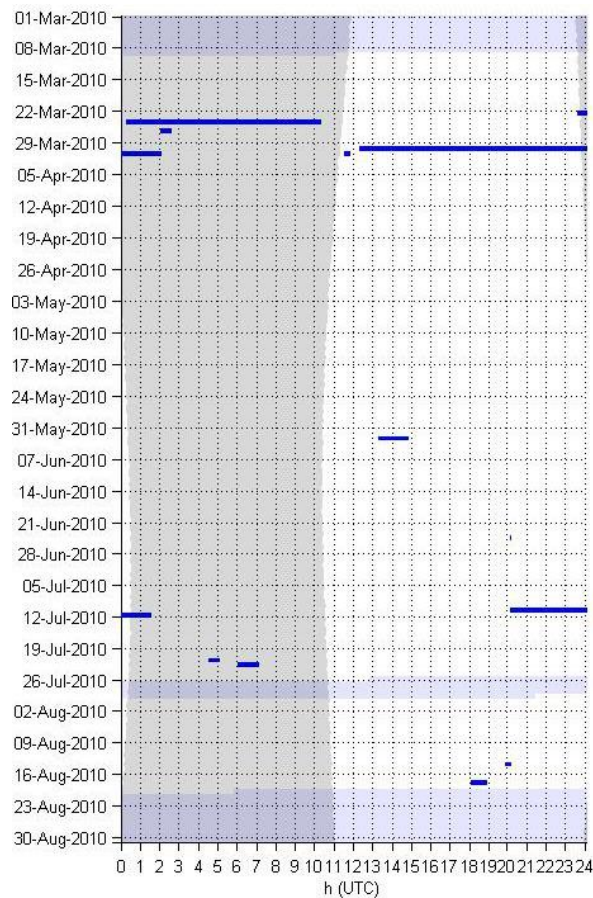


Figure 22: Seasonal/diel plot for MFA presence in hourly bins. Dark gray shading represents hours of darkness and blue are periods with no effort.

An automatic ping counter was run on the data from this deployment. A total of 1378 MFA sonar pings were detected. These pings ranged from 100 to 173 dB pp re 1 μ Pa; the maximum value is the clipping level of the HARP and the minimum value is a threshold limit based on the analysis methods used. Distribution of ping levels shows a double peak, one peak at 120 dB pp re 1 μ Pa and a secondary peak at 126 dB pp re 1 μ Pa (Figure 23). Cumulative distribution of ping levels shows that half of the pings detected are above 124 dB pp re 1 μ Pa (Figure 24).

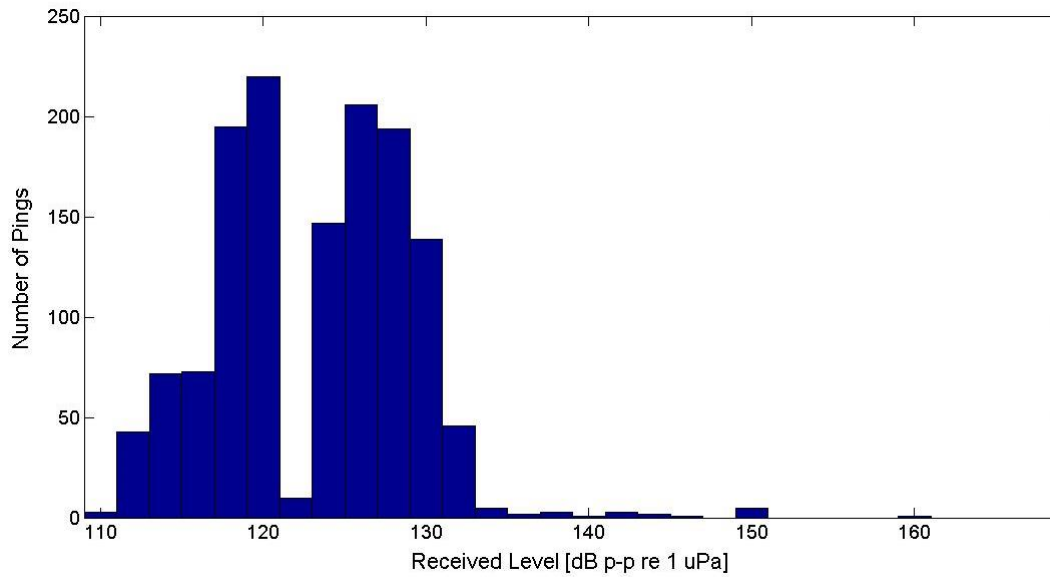


Figure 23: Distribution of MFA sonar pings by received level in 2 dB bins.

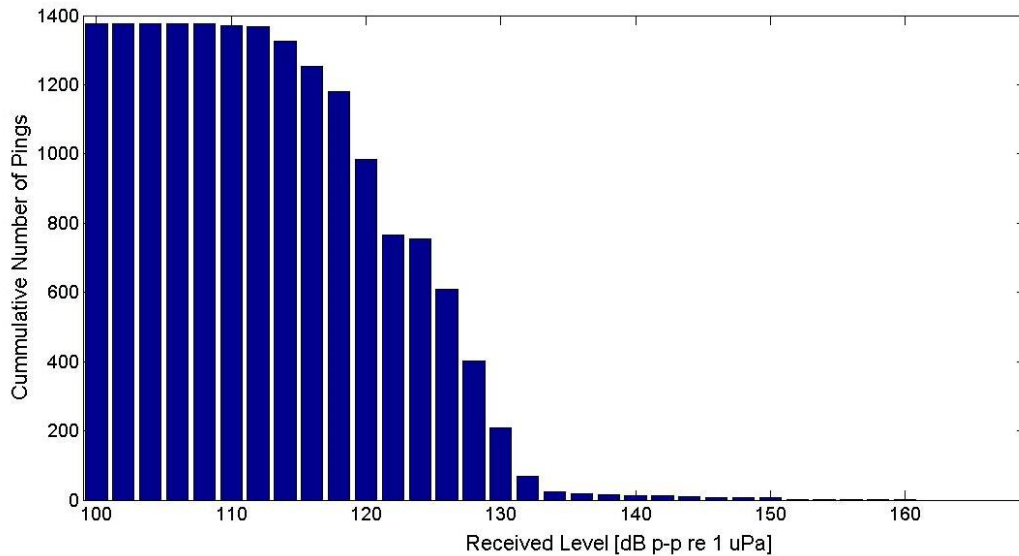


Figure 24: Cumulative distribution for the number of MFA sonar pings detected at a given received level or higher in 2 dB bins

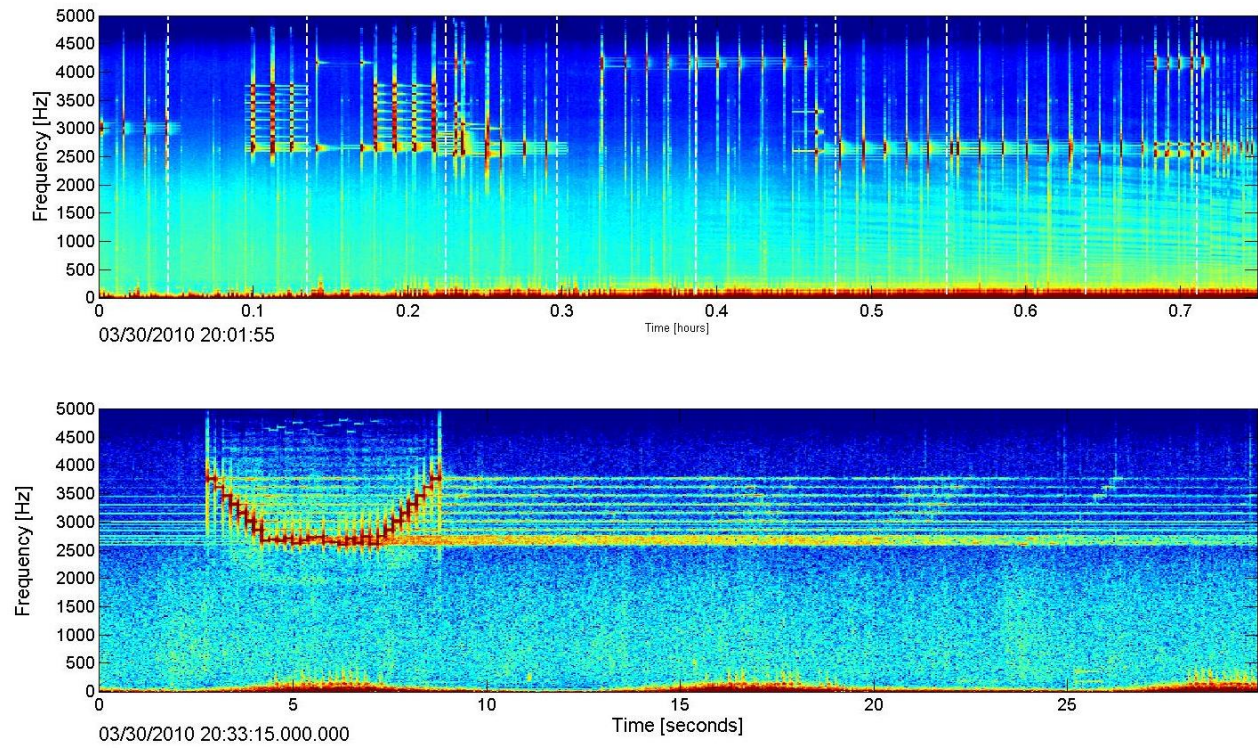


Figure 25: Unique variety of MFA seen in LTSA (above) and spectrogram (below)

References

- Baumgartner, M. F., & Fratantoni, D. M. (2008). Diel periodicity in both sei whale vocalization rates and the vertical migration of their copepod prey observed from ocean gliders. *Limnol. Oceanogr.*, 53(5), 2197-2209.
- Baumgartner, M. F., Van Parijs, S. M., Wenzel, F. W., Tremblay, C. J., Esch, C. H., & Warde, A. M. (2008). Low frequency vocalizations attributed to sei whales (*Balaenoptera borealis*). *J. Acoust. Soc. Am.*, 124(2), 1339-1349.
- Debich, A. J., Baumann-Pickering, S., Sirovic, A., Kerosky, S. M., Roche, L. K., Johnson, S. C., et al. (2013). *Passive acoustic monitoring for marine mammals in the Jacksonville Range Complex 2010-2011*. Marine Physical Laboratory Technical Memorandum #541. La Jolla, CA: Scripps Institution of Oceanography, University of California, San Diego.
- Dunlop, R. A., Noad, M. J., Cato, D. H., & Stokes, D. (2007). The social vocalization repertoire of east Australian migrating humpback whales (*Megaptera novaeangliae*). *J. Acoust. Soc. Am.*, 122(5), 2893-2905.
- Helbe, T. A., Lerley, G. R., D'Spain, G. D., Roch, M. A., & Hildebrand, J. A. (2012). A generalized power-law detection algorithm for humpback whale vocalizations. *Journal of the Acoustical Society of America*, 131(4), 2682-2699.
- Hildebrand, J. A. (2009). Anthropogenic and natural sources of ambient noise in the ocean. *Marine Ecology Progress Series*, 395, 5-20.
- Mellinger, D. K., & Clark, C. W. (2003). Blue whale (*Balaenoptera musculus*) sounds from the North Atlantic. *The Journal of the Acoustical Society of America*, 114(2), 1108-1119.
- Mellinger, D. K., Carson, C. D., & Clark, C. W. (2000). Characteristics of minke whale (*Balaenoptera acutorostrata*) pulse trains recorded near Puerto Rico. *Marine Mammal Science*, 16(4), 739-756.
- Mizroch, S. A., Rice, D. W., & Breiwick, J. M. (1984). The Sei whale, *Balaenoptera borealis*. *Marine Fisheries Review*, 46(4), 25-29.
- Oleson, E. M., Barlow, J., Gordon, J., Rankin, S., & Hildebrand, J. A. (2003). Low frequency calls of Bryde's whales. *Marine Mammal Science*, 19(2), 160-172.
- Omura, H. (1959). Bryde's whale from the coast of Japan. *Sci. Rep. Whales Res. Inst.*, 14, 1-33.
- Parks, S. E., & Tyack, P. L. (2005). Sound production by North Atlantic right whales (*Eubalaena glacialis*) in surface active groups. *J. Acoust. Soc. Am.*, 117(5), 3297-3306.
- Payne, R. S., & McVay, S. (1971). Songs of humpback whales. *Science*, 173(3997), 585-597.

- Perry, S. L., DeMaster, D. P., & Silber, G. K. (1999). The great whales: History and status of six species listed endangered under the U.S. Endangered Species Act of 1973. *Marine Fisheries Review*, 61(1), 1-74.
- Risch, D., Clark, C. W., Dugan, P. J., Popescu, M., Siebert, U., & Van Parijs, S. M. (2013). Minke whale acoustic behavior and multi-year seasonal and diel vocalization patterns in Massachusetts Bay, USA. *Marine Ecology Progress Series*, 489, 279-295.
- Širović, A., Bassett, H. R., Johnson, S. C., Wiggins, S. M., & Hildebrand, J. A. (2013). Bryde's whale calls recorded in the Gulf of Mexico. *Marine Mammal Science*.
- Širović, A., Williams, L. N., Kerosky, S. M., Wiggins, S. M., & Hildebrand, J. A. (2013). Temporal separation of two fin whale call types across the eastern North Pacific. *Marine Biology*, 160, 47-57.
- Stimpert, A. K., Au, W. W., Parks, S. E., Hurst, T., & Wiley, D. N. (2011). Common humpback whale (*Megaptera novaeangliae*) sound types for passive acoustic monitoring. *J. Acoust. Soc. Am.*, 129(1), 476-482.
- Thompson, P. O., Findley, L. T., & Vidal, O. (1992). 20-Hz pulses and other vocalizations of fin whales, *Balaenoptera physalus*, in the Gulf of California, Mexico. *Journal of the Acoustical Society of America*, 92(6), 3051-3057.
- Wade, P. R., & Gerrodette, T. (1993). Estimates of cetacean abundance and distribution in the Eastern Tropical Pacific. *Report of the International Whaling Commission*, 43, 477-493.
- Watkins, W. A. (1981). Activities and underwater sounds of fin whales. *Scientific Reports of the Whales Research Institute*, 33, 83-117.
- Wiggins, S. M., & Hildebrand, J. A. (2007). High-frequency acoustic recording package (HARP) for broadband, long-term marine mammal monitoring. *Underwater Technology and Workshop on Scientific Use of Submarine Cables and Related Technologies*, 551-557.