Passive Acoustic Monitoring for Marine Mammals in the Jacksonville Range Complex May 2013 – August 2014

Amanda J. Debich, Simone Baumann-Pickering, Ana Širović, John A. Hildebrand,
Alexa L. Alldredge, Rachel S. Gottlieb, Sean T. Herbert, Sarah C. Johnson, Ally C. Rice,
Jenny S. Trickey, Leah M. Varga, Sean M. Wiggins, Lynne E.W. Hodge, and Andrew Read

Marine Physical Laboratory
Scripps Institution of Oceanography
University of California San Diego
La Jolla, CA 92037

Risso's dolphin, photo by Amanda J. Debich

MPL TECHNICAL MEMORANDUM # 555
May 2015

Suggested Citation:

AJ Debich, S Baumann-Pickering, A Širović, JA Hildebrand, AL Alldredge, RS Gottlieb, ST Herbert, SC Johnson, AC Rice, JS Trickey, LM Varga, SM Wiggins, LEW Hodge, and AJ Read. 2015. Passive Acoustic Monitoring for Marine Mammals in the Jacksonville Range Complex May 2013 – August 2014. Final Report. Marine Physical Laboratory Technical Memorandum 555. March 2015. Submitted to Naval Facilities Engineering Command (NAVFAC) Atlantic, Norfolk, Virginia, under Contract No. N62470-10-D-3011- Task Order Number 051 issued to HDR, Inc.

Additional technical reports for HARP deployments in the Atlantic under the Navy's monitoring program are available at:
http://www.navymarinespeciesmonitoring.us/reading-room/

Funding for this work is provided by U.S. Fleet Forces Command.

Table of Contents

Executive Summary

High-frequency Acoustic Recording Packages (HARPs) were deployed from May 2013 to August 2014 to detect marine mammal and anthropogenic sounds in the Navy's Jacksonville Range Complex. The HARPs recorded sounds between 10 Hz and 100 kHz at a site located 60 nm east off the Florida coastline on the continental shelf. Technical malfunctions resulted in loss of data for the period from June 8, 2013 through February 16, 2014.

Data analysis consisted of analyst scans of long-term spectral averages (LTSAs) and spectrograms, and automated computer algorithm detection when possible. Three frequency bands were analyzed for marine mammal vocalizations and anthropogenic sounds: (1) Low-frequency, between 10-300 Hz, (2) Mid-frequency, between 10-5,000 Hz, and (3) High-frequency, between 1-100 kHz.

Three baleen whale species were detected: fin whales, humpback whales, and minke whales. Fin whale detections were limited to February 2014. Humpback whale calls were detected from February to June 2014 with a peak in March 2014. Minke whales were detected in late-February through March 2014. An additional sound called the 5-pulse signal, presumably from a baleen whale, was detected from February to September 2014, with a peak in July.

One known odontocete species was detected, Risso's dolphins, which were detected in low numbers in July 2014. Odontocete signals that could not be distinguished to species were common throughout the recordings. However, eight distinct click types of unknown species origin were found to be present (CT 17, CT 22, CT 25, CT 26, CT 27, CT 27A, CT 30 and CT32).

The following anthropogenic sounds were detected: broadband ship noise, Mid-Frequency Active (MFA) sonar, and echosounders. Broadband ships were common throughout the recordings with a peak in detections in May 2014. MFA sonar was detected during all months with recordings, with a peak in June 2013. Echosounder pings were prevalent throughout the recordings.

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 200 m water depth, and an outer zone extending to water depths of 2000 m. A diverse array of marine mammals are found in this region, including mysticete whales, 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. The goal of this effort was to characterize the vocalizations of marine mammal species present in the area, to determine their seasonal presence patterns, and to evaluate the potential for impact from naval operations. This report documents the analysis of data recorded by High-frequency Acoustic Recording Packages (HARPs) that were deployed at a site (designated site C), within the Jacksonville Range Complex and collected data from May through June 2013 and February through August 2014 (Figure 1).

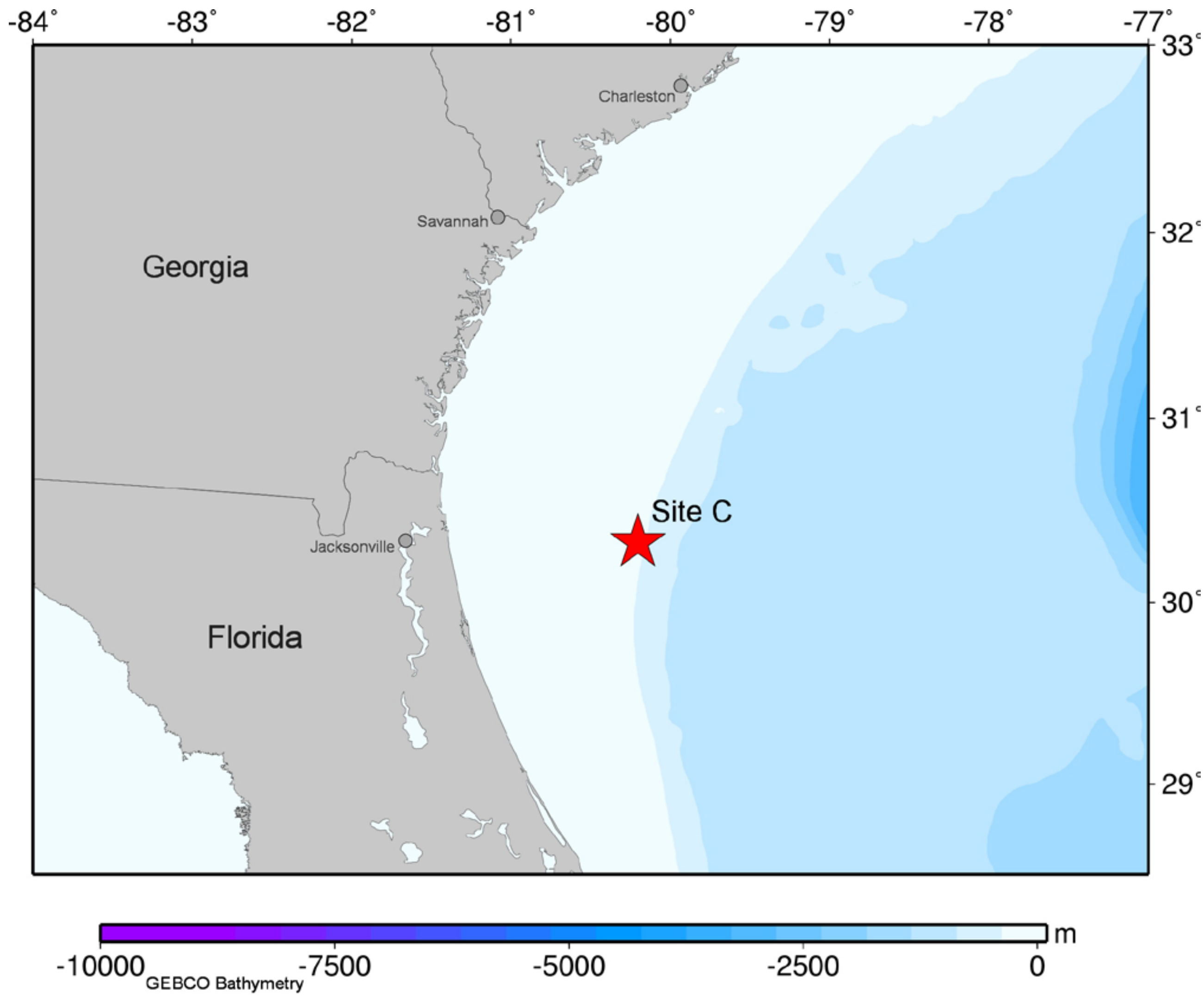


Figure 1. Location of High-frequency Acoustic Recording Package (HARP) at site C (30° 19.59N, 80° 12.30W, depth 90 m) deployed in the Jacksonville Range Complex study area May 2013 through August 2014.

Methods

High-frequency Acoustic Recording Package (HARP)

HARPs were used to detect marine mammal sounds and characterize anthropogenic sounds and ambient noise in the Jacksonville Range Complex. HARPs recorded underwater sounds from 10 Hz up to 100 kHz and are capable of approximately 300 days of continuous data storage. The HARPs were in a seafloor configuration with the hydrophone suspended 10-22 m above the seafloor. Each HARP is calibrated in the laboratory to provide a quantitative analysis of the received sound field. Representative data loggers and hydrophones were also calibrated at the Navy's TRANSDEC facility to verify the laboratory calibrations (Wiggins and Hildebrand, 2007).

Data Collected

HARPs were deployed from May 2013 to August 2014 at site C (30° 19.59N, 80° 12.30W, depth 90 m) and sampled continuously at 200 kHz to provide 100 kHz of effective bandwidth. A total of 5,414 hours, covering 226 days of acoustic data were recorded in the deployments analyzed in this report. Earlier data collection in the Jacksonville Range Complex is documented in previous annual reports (Debich *et al.*, 2013; Johnson *et al.*, 2014).

Data Quality

Data recovered for the 2013 deployment revealed disk skipping and 'buffer wrap around' concurrent with intense instrument strumming and full/new moon phases. This suggests a loose 10pin disk selection cable connector, which was observed on data logger Ether/IDE card after instrument recovery. Because of the loose connector, the data for the time period May 23 through June 7, 2013 appeared as if it were duty cycled, although the HARP was configured to record continuously throughout the deployment. The recording times during this period varied from 20-21 minutes on with 6-14 minutes off, resulting in a duty cycle of 60-80%. There was also a subsequent complete loss of data for the period from June 20, 2013 through February 16, 2014.

Data Analysis

To visualize the acoustic data, frequency spectra were calculated for all data using a time average of 5 seconds and variable size frequency bins (1, 10, and 100 Hz). These data, called Long-Term Spectral Averages (LTSAs) were then examined as a means to detect marine mammal and anthropogenic sounds. Data were analyzed by visually scanning LTSAs in source-specific frequency bands and, when appropriate, using automatic detection algorithms (described below). During visual analysis, when a sound of interest was identified in the LTSA but its origin was unclear, the waveform or spectrogram was examined to further classify the sounds to species or source. Signal classification was carried out by comparison to known species-specific spectral and temporal characteristics.

Recording over a broad frequency range of 10 Hz – 100 kHz allows detection of baleen whales (mysticetes), toothed whales (odontocetes), and anthropogenic sounds. The presence of acoustic signals from multiple marine mammal species and anthropogenic noise was evaluated in the data. To document the data analysis process, we describe the major classes of marine mammal calls and anthropogenic sound in the JAX region, and the procedures used to detect them. For effective analysis, the data were divided into three frequency bands: (1) Low-frequency, between 10-300 Hz, (2) Mid-frequency, between 10-5,000 Hz, and (3) High-frequency, between 1-100 kHz.

Each band was analyzed for the sounds of an appropriate subset of species or sources. Blue, fin, Bryde's, sei, minke, and North Atlantic right whale sounds were classified as low-frequency. Humpback, killer whale tonal and pulsed calls, nearby shipping, explosions, underwater communications, and mid-frequency active sonar sounds were classified as mid-frequency. The remaining odontocete and sonar sounds were considered high-frequency. Analysis of low-frequency recordings required decimation by a factor of 100. For the analysis of the mid-frequency recordings, the data were decimated by a factor of 20. The LTSAs were created using a 5 s time average with 1 Hz resolution for low-frequency analysis, 10 Hz resolution for mid-frequency analysis, and 100 Hz frequency resolution for high-frequency analysis.

We summarize acoustic data collected between May-June 2013 and February-August 2014 at site C. We discuss seasonal occurrence and relative abundance of calls for different species and anthropogenic sounds that were consistently identified in the acoustic data.

Low-Frequency Marine Mammals

The Jacksonville Range Complex is inhabited, at least for a portion of the year, by blue whales (*Balaenoptera musculus*), fin whales (*B. physalus),* Bryde's whales (*B. edeni*), sei whales (*B. borealis*), minke whales (*B. acutorostrata*), and North Atlantic right whales (*Eubalaena glacialis*). 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 (LTSAs) were created using a time average of 5 seconds and frequency bins of 1 Hz. The same LTSA and spectrogram parameters were used for manual detection of all call types using the custom software program *Triton*. During manual scrutiny of the data, the LTSA frequency was set to display between 1-300 Hz with a 1-hour plot length. To observe individual calls, the spectrogram window was typically set to display 1-250 Hz with a 60 second plot length. The FFT was generally set between 1500 and 2000 data points, yielding about 1 Hz frequency resolution, with an 85-95% overlap. When a call of interest was identified in the LTSA or spectrogram, its presence during that hour was logged.

The hourly presence of North Atlantic blue whale calls, blue whale arch sounds, fin whale 20 and 40 Hz calls, Bryde's whale Be7 and Be9 calls, minke whale pulse trains, and North Atlantic right whale up-calls was determined by manual scrutiny of low-frequency LTSAs and spectrograms.

Blue Whales

Blue whales produce a variety of calls worldwide (McDonald *et al.*, 2006). Blue whale calls recorded in the western North Atlantic include the North Atlantic A–B call and the arch call (Mellinger and Clark, 2003).

Blue Whale North Atlantic Calls

The A-B call is a 18-19 Hz tone lasting approximately 8 s (A), often followed by an 18-15 Hz downsweep (B) lasting approximately 11 s (Figure 2). There were no detections for blue whale North Atlantic A-B calls during these recording periods.

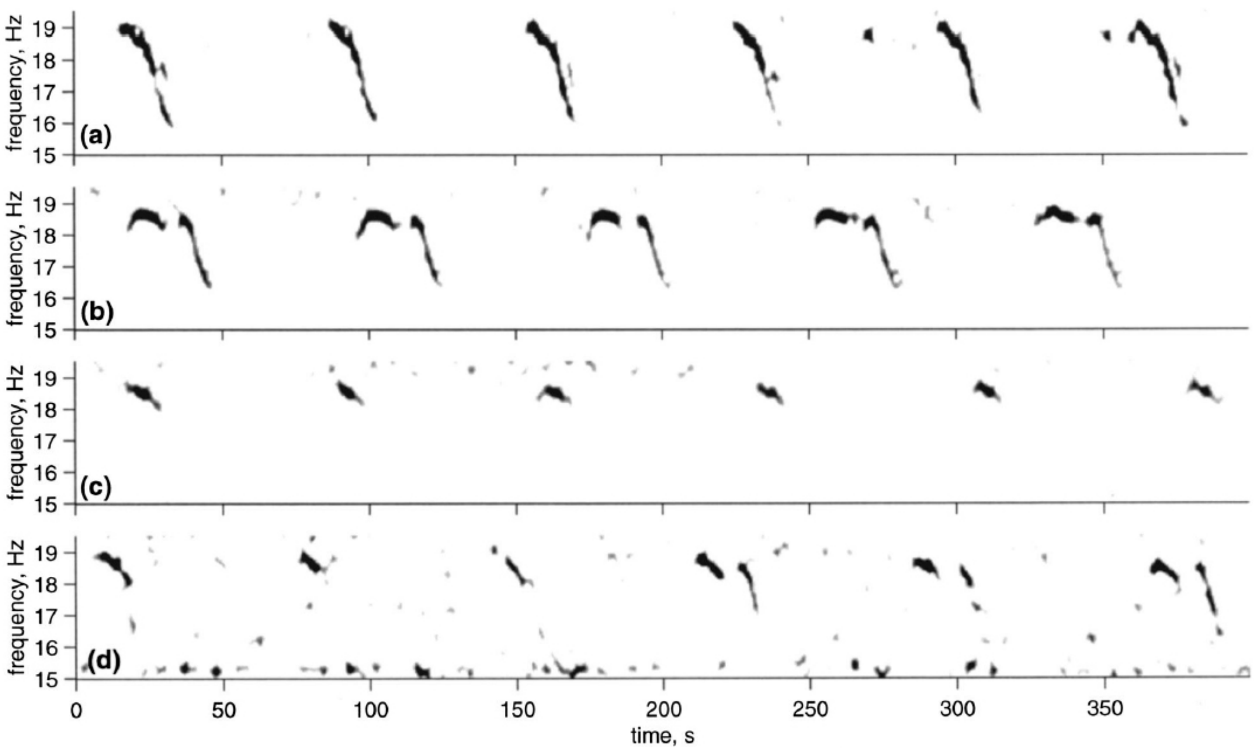


Figure 2. North Atlantic blue whale calls from Mellinger and Clark (2003).

Blue Whale Arch Calls

The blue whale arch call starts around 60 Hz, can ascend up to 70 Hz, then descends to approximately 35 Hz over a period of about 6 s (Figure 3). There were no detections for blue whale arch calls during these deployment periods.

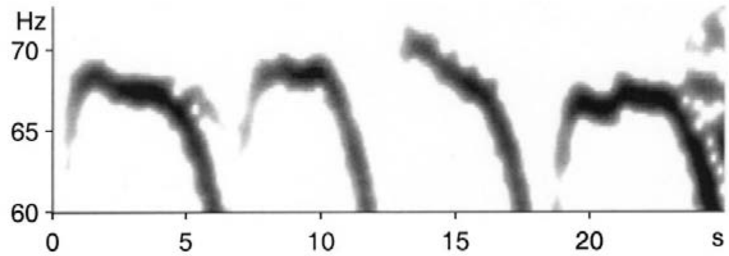


Figure 3. Blue whale arch calls from Mellinger and Clark (2003).

Fin Whales

Fin whales produce two types of short (approximately 1 s duration), low-frequency calls: downsweeps in frequency from 30-15 Hz, called 20 Hz calls (Watkins, 1981) (Figure 4), and downsweeps from 75-40 Hz, called 40 Hz calls (Figure 5). The 20 Hz calls can occur at regular intervals as song (Thompson *et al.*, 1992), or irregularly as call counter-calls among multiple, traveling animals (McDonald *et al.*, 1995). The 40 Hz calls most often occur in irregular patterns.

Fin whale 20 Hz calls

Fin whale 20 Hz calls (Figure 4) were detected via manual scanning of the LTSA and subsequent verification from a spectrogram of the frequency and temporal characteristics of the calls.

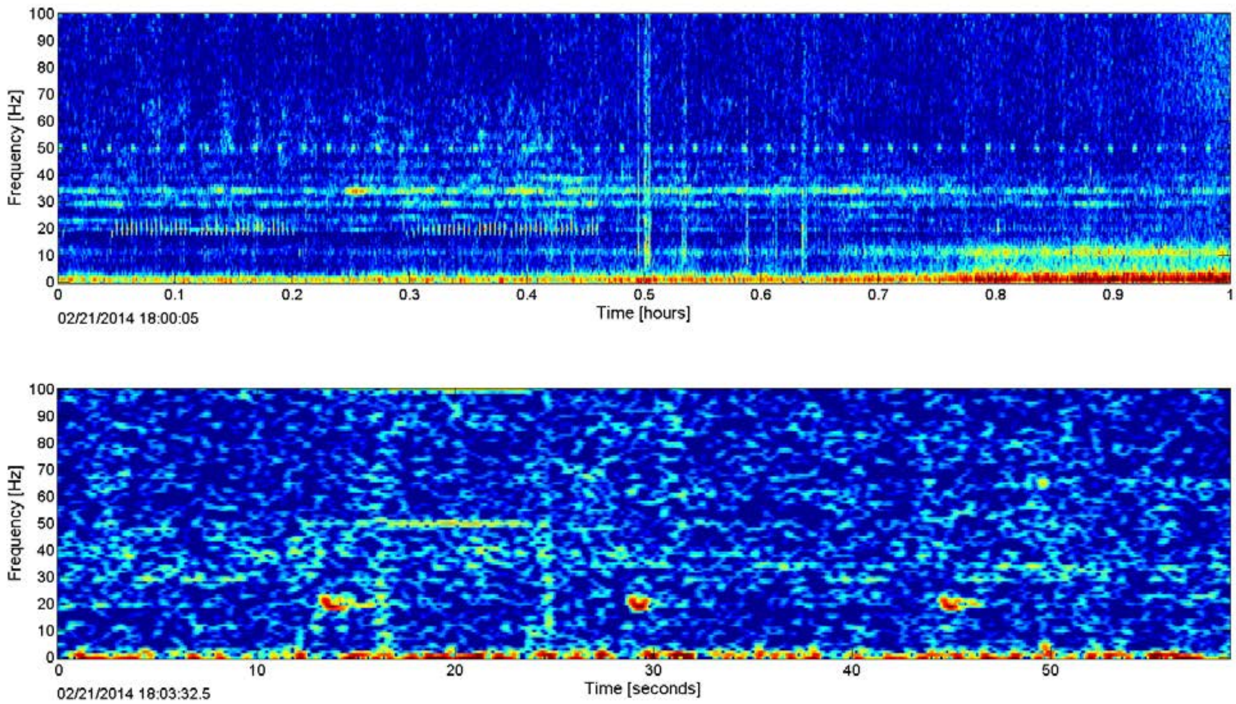


Figure 4. Fin whale 20 Hz calls in LTSA (top) and spectrogram (bottom) at site C.

Fin whale 40 Hz calls

The potential presence of fin whale 40 Hz calls (Figure 5) was examined via manual scanning of the LTSA and subsequent verification from a spectrogram of the frequency and temporal characteristics of the calls. There were no detections for fin whale 40 Hz calls during these recordings periods.

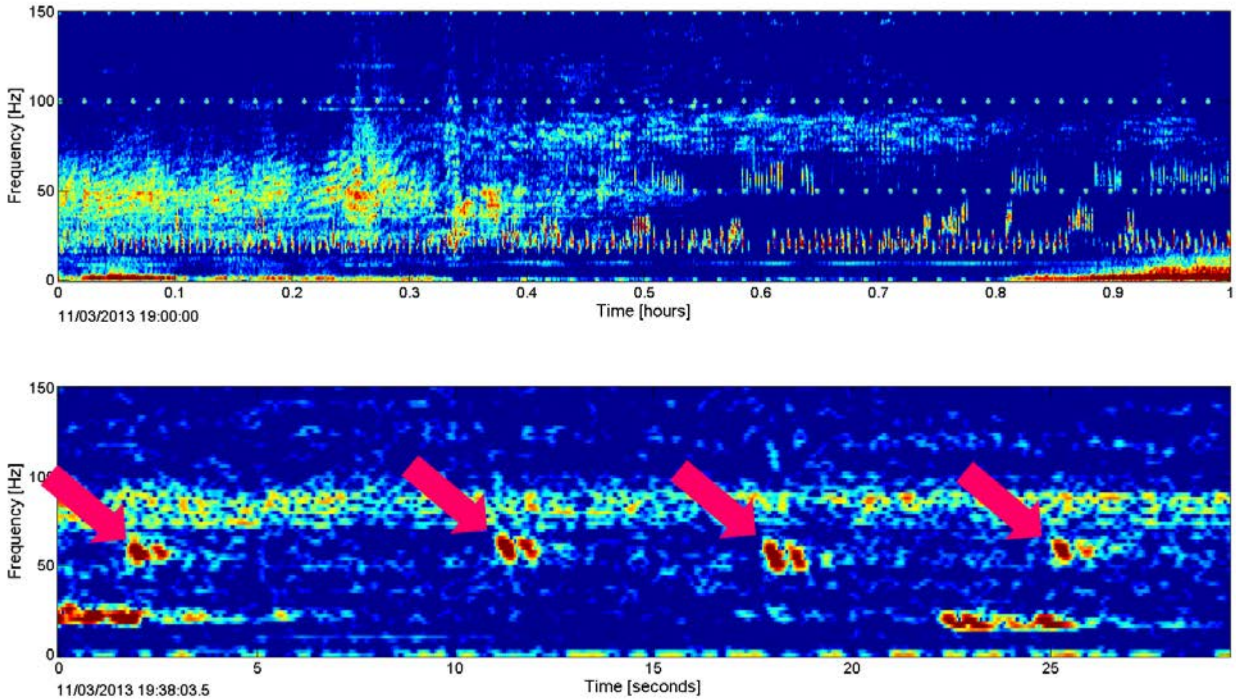


Figure 5. Fin whale 40 Hz calls in LTSA (top) and spectrogram (bottom) from southern California HARP data.

Bryde's Whales

Bryde's whales inhabit tropical and subtropical waters worldwide (Omura, 1959; Wade and Gerrodette, 1993), and the JAX HARP site is considered to be near to their northerly range limit.

Be 7 Calls

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 s with an average intercall interval of 2.8 minutes (Figure 6). There were no detections for Bryde's whale Be7 calls during these recordings periods.

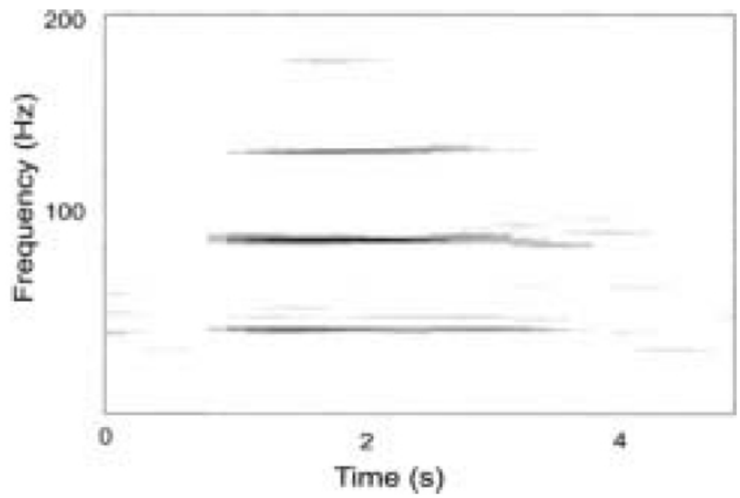


Figure 6. Bryde's whale Be7 call from Oleson *et al.*, 2003.

Be9 Calls

The Be9 call type, described for the Gulf of Mexico (Širović *et al.*, 2014), is a downswept pulse ranging from 143 to 85 Hz, with each pulse approximately 0.7 s long (Figure 7). There were no detections for the Bryde's whale Be9 call during these recording periods.

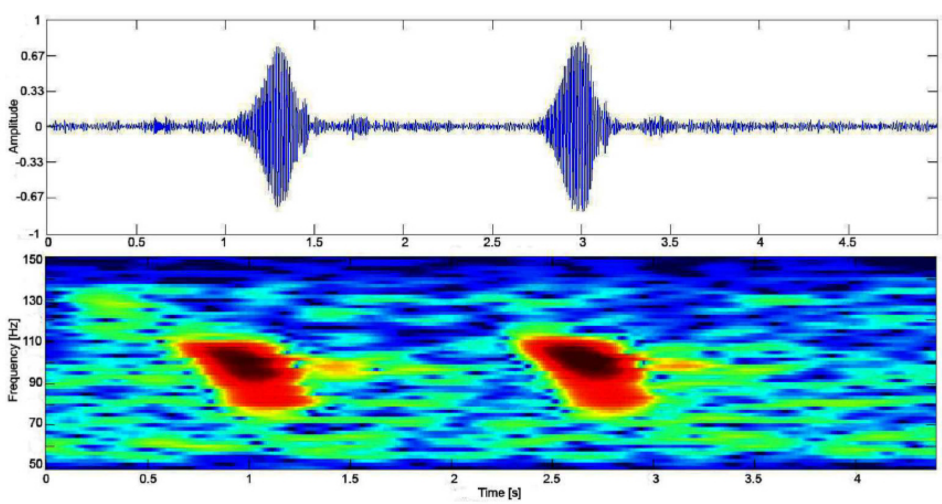


Figure 7. Bryde's whale Be9 call from the Gulf of Mexico (Širović et al., 2014).

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, including a low-frequency downsweep (Baumgartner and 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 8, Figure 9). There were no sei whale detections during these recordings periods.

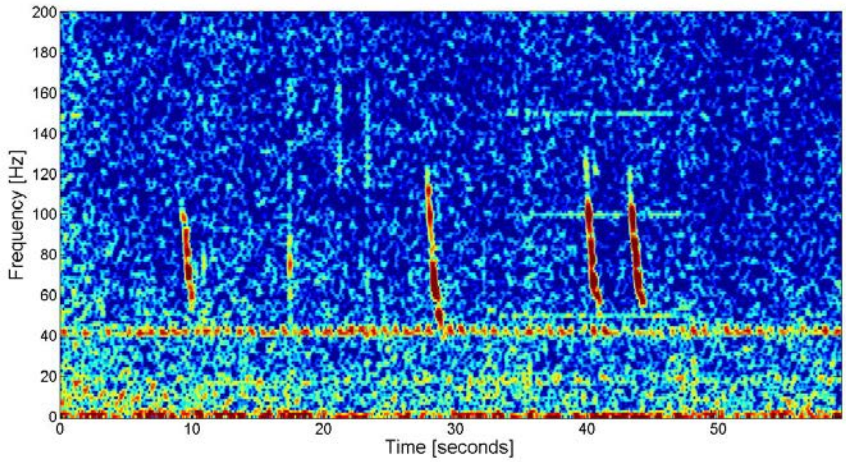


Figure 8. Downsweep calls reported to be from sei whales from another HARP recording site within the Jacksonville Range Complex, December, 2010.

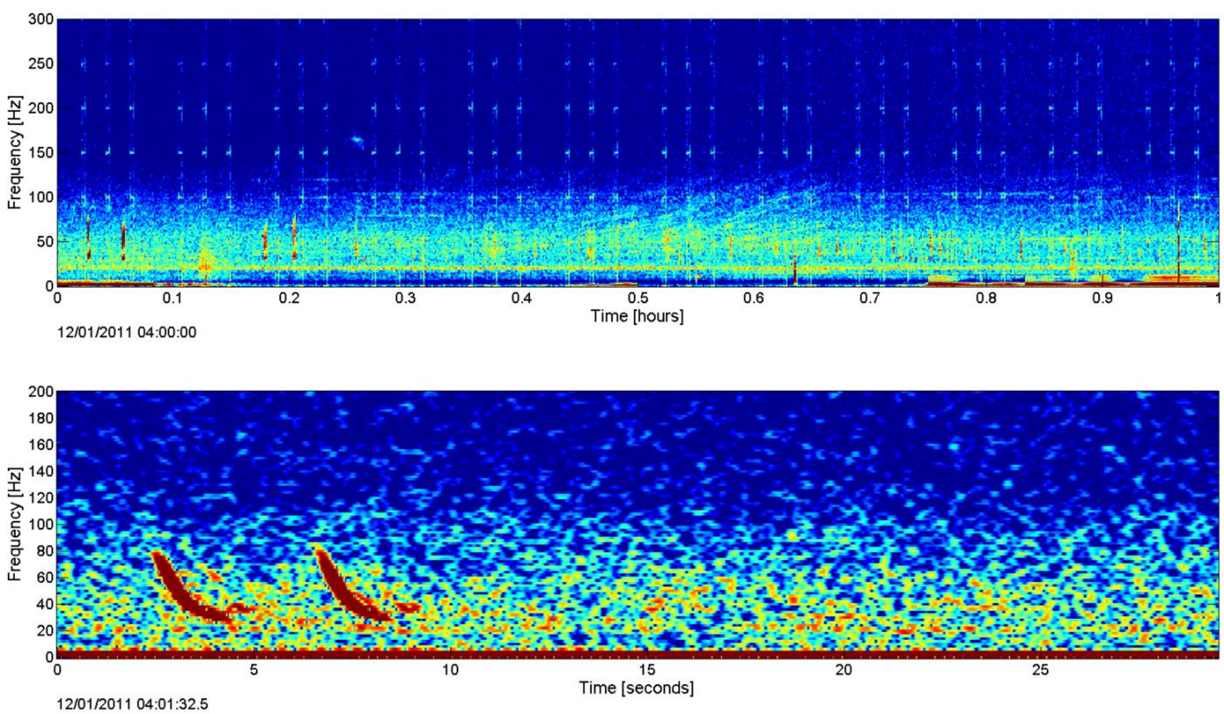


Figure 9. Downsweep calls reported to be from sei whales in the LTSA (top) and spectrogram (bottom) from a HARP recording site off North Carolina, December, 2011.

Minke Whales

Minke whales in the North Atlantic produce long pulse trains. Mellinger et al. (2000) describe minke whale pulse sequences near Puerto Rico as speed-up and slow-down pulse trains, with increasing and decreasing pulse rates respectively. Recently, these call types were detected in the North Atlantic and they were expanded to also include pulse trains with non-varying pulse rates (Risch *et al.*, 2013) (Figure 10).

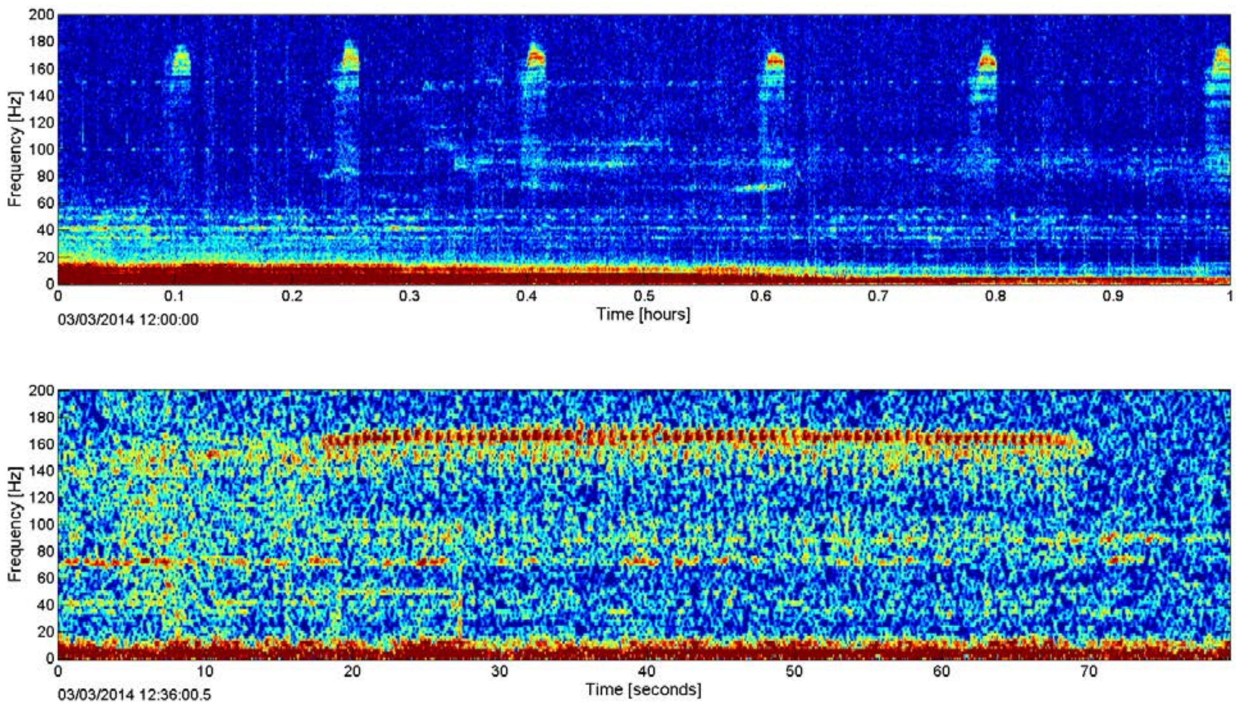


Figure 10. Minke whale pulse train in the LTSA (top) and spectrogram (bottom) at site C.

North Atlantic Right Whales

The critically endangered North Atlantic right whale is 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 and 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 11). There were no North Atlantic right whale up-call detections during these recording periods

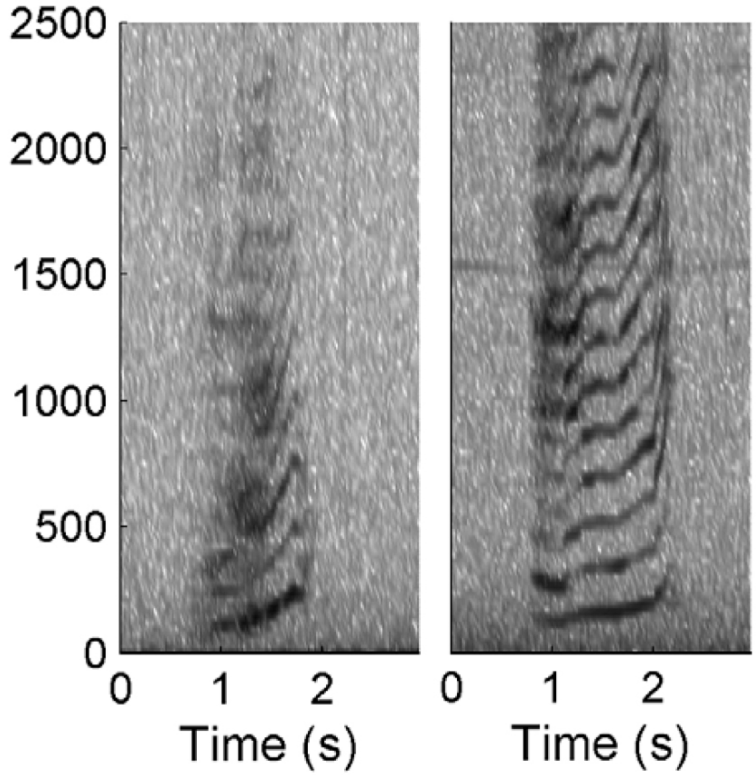


Figure 11. Right whale up-call from Trygonis et al., 2013.

5-pulse signal

The 5-pulse signal consists of one to five pulses over approximately two seconds. It has a starting frequency around 150 Hz with a very slight upsweep. However, 5 pulses can vary in fundamental frequency from 120 – 200 Hz (Figure 12). Because of its character, prevalence, and intensity, this sound is classified as the call of a baleen whale, but of unknown species.

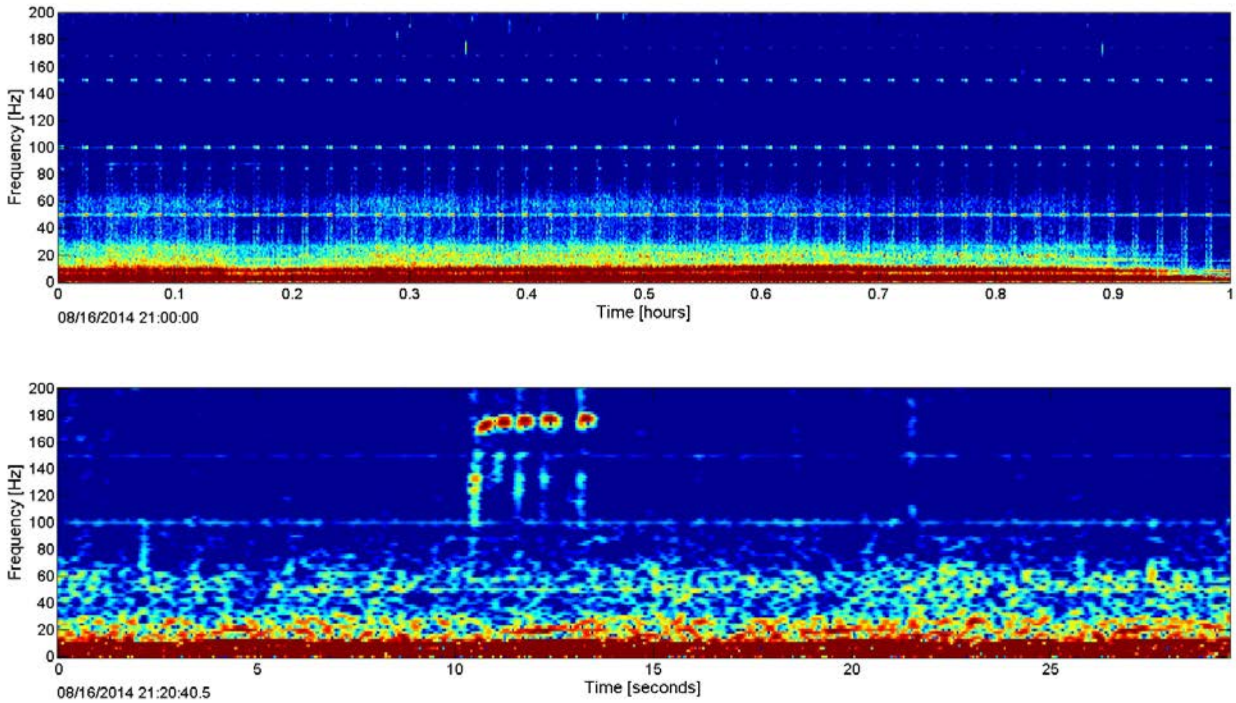


Figure 12. 5-pulse signal in the LTSA (top) and spectrogram (bottom) at site C.

Mid-Frequency Marine Mammals

Marine mammal species with sounds in the mid-frequency range expected in the Jacksonville Range Complex include humpback whales (*Megaptera novaeangliae*) and killer whales (*Orcinus orca*). For mid-frequency data analysis, the 100 kHz data were decimated by a factor of 20 for an effective bandwidth of 5 kHz. The LTSAs for mid-frequency analysis were created using a time average of 5 seconds, and a frequency bin size of 10 Hz. The presence of each call type was determined using an encounter-granularity, to one-minute precision, for each mid-frequency dataset. Humpback whales were detected automatically as described below. Automatic detections were subsequently verified for accuracy by a trained analyst. Whistles resembling those of killer whales were logged as unidentified odontocete whistles <5 kHz due to overlapping distributions with other large delphinids in the area.

Humpback Whales

Humpback whales produce both song and non-song calls (Payne & McVay 1971, Dunlop et al. 2007, Stimpert et al., 2011). The song is categorized by the repetition of units, phrases, and themes of a variety of calls as defined by Payne & McVay (1971). Most humpback whale vocalizations are produced between 100 - 3,000 Hz. We detected humpback calls using an automatic detection algorithm based on the generalized power law (Helble *et al.*, 2012). The detections were subsequently verified for accuracy by a trained analyst (Figure 13). There was no effort to separate song and non-song calls.

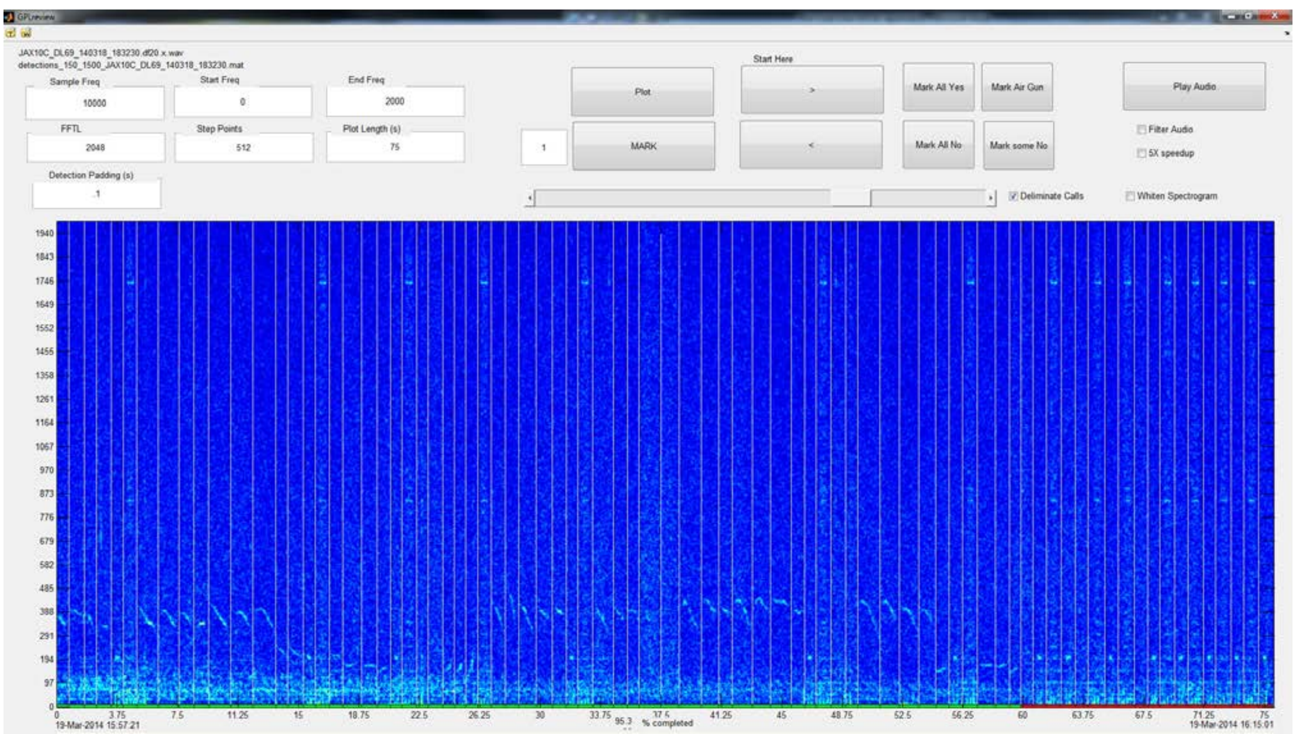


Figure 13. Humpback whale song from site C in the analyst verification stage of the detector. Green in the bottom evaluation line indicates true detections.

Killer Whales

Killer whale whistles are highly variable and not easily distinguished from other odontocete whistles (e.g. pilot whales and false killer whales). Therefore, whistles detected below 5 kHz were labeled as unidentified odontocete whistles <5 kHz (Figure 14). Manual effort was expended for killer whale pulsed calls, based on their abrupt and patterned shifts in repetition rate which are not present in click series (Ford and Fisher, 1983). Killer whale pulsed calls are well documented and are the best described of all killer whale call types. Pulsed calls' primary energy is between 1 and 6 kHz, with high frequency components occasionally >30 kHz and duration primarily between 0.5 and 1.5 seconds (Ford, 1989) (Figure 15). There were no killer whale pulsed calls detected in the data.

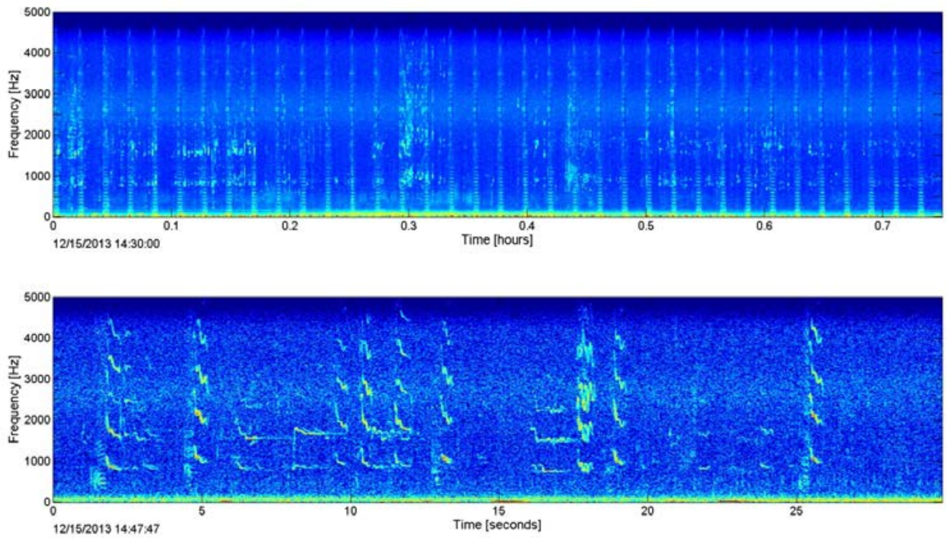


Figure 14. Unidentified odontocete whistles < 5 kHz in LTSA (top) and spectrogram (bottom) from a HARP recording site in southern California.

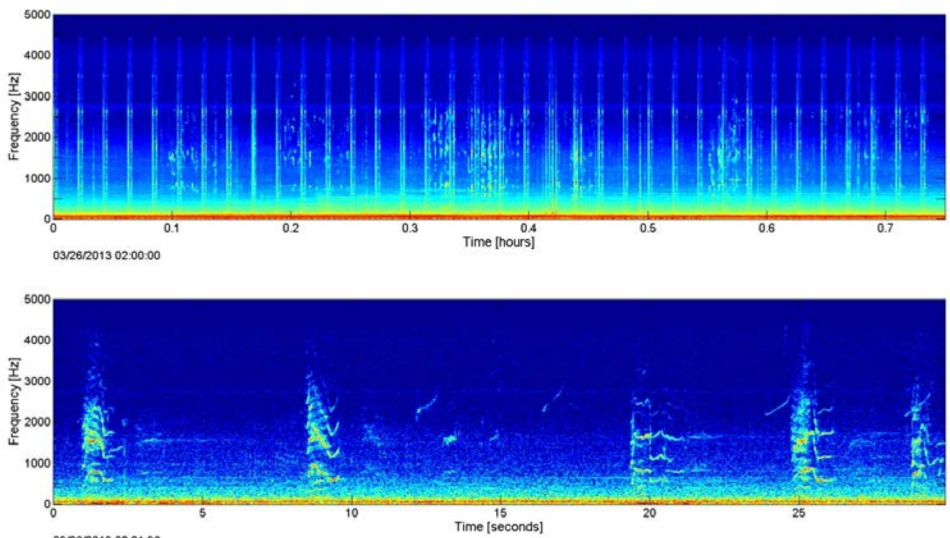


Figure 15. Killer whale pulsed calls in LTSA (top) and spectrogram (bottom) from a recording site off the coast of Washington state.

High-Frequency Marine Mammals

Marine mammal species with sounds in the high-frequency range and possibly found in the Jacksonville Range Complex include bottlenose dolphins (*Tursiops truncatus*), short-finned pilot whales (*Globicephala macrorhynchus*, long-finned pilot whales (*G. melas*), short-beaked common dolphins (*Delphinus delphis*), Atlantic spotted dolphins (*Stenella frontalis*), pantropical spotted dolphins (*Stenella frontalis*), spinner dolphins (*Stenella longirostris*), striped dolphins (*Stenella coeruleoalba*), Clymene dolphins (*Stenella clymene*), rough-toothed dolphins (*Steno bredanensis*), Risso's dolphins (*Grampus griseus*), Fraser's dophins (*Lagenodelphis hosei*), killer whales (*Orcinus orca*), pygmy killer whales (*Feresa attenuata*), melon-headed whales (*Peponocephala electra*), sperm whales (*Physeter macrocephalus*), dwarf sperm whales (*Kogia sima*), pygmy sperm whales (*Kogia breviceps*), Cuvier's beaked whales (*Ziphius cavirostris*), Gervais' beaked whales (*Mesoplodon europaeus*), Blainville's beaked whales (*Mesoplodon densirostris*), True's beaked whales (*Mesoplodon mirus*) and Sowerby's beaked whales (*Mesoplodon bidens*).

High-Frequency Call Types

Odontocete sounds can be categorized as echolocation clicks, burst pulses, or whistles. Echolocation clicks are broadband impulses with peak energy between 5 and 150 kHz, dependent upon the species. Buzz or burst pulses are rapidly repeated clicks that have a creak or buzz-like sound quality; they are generally lower in frequency than echolocation clicks. Dolphin whistles are tonal calls predominantly between 1 and 20 kHz that vary in frequency content, their degree of frequency modulation, as well as duration. These signals are easily detectable in an LTSA as well as the spectrogram (Figure 16).

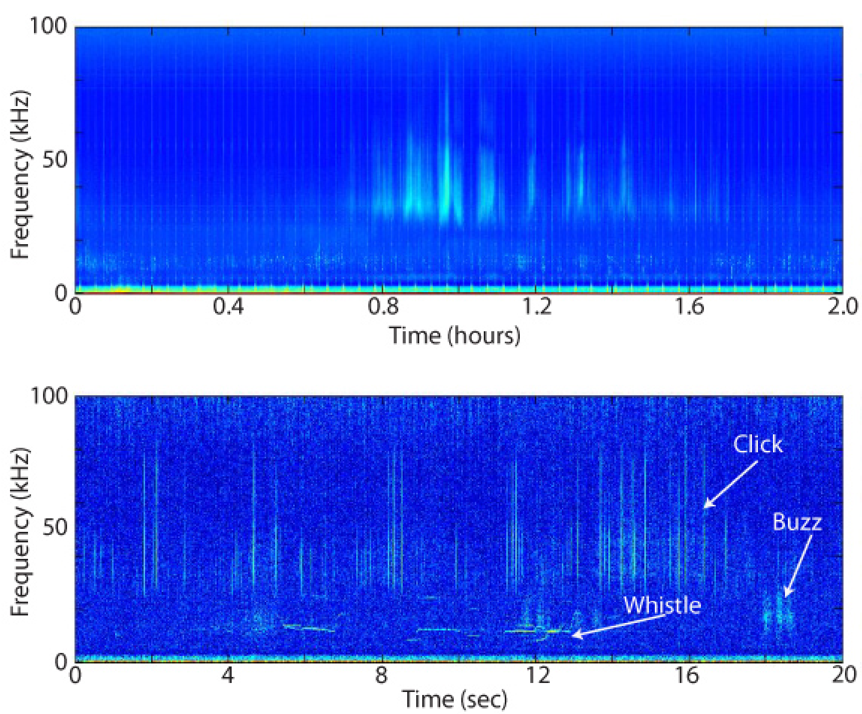


Figure 16. LTSA (top) and spectrogram (bottom) demonstrating odontocete signal types.

Unidentified Odontocetes

Many Atlantic delphinid sounds are not yet distinguishable to species based on the character of their clicks, buzz or burst pulses, or whistles (Roch *et al.*, 2011; Gillespie *et al.*, 2013). For instance, common dolphin species (short-beaked and long-beaked) and bottlenose dolphins make clicks and whistles that are thus far indistinguishable from each other (Soldevilla *et al.*, 2008). Since delphinid signals are detectable in an LTSA as well as the spectrogram (Figure 17), they were monitored during this analysis effort, but were characterized as unidentified odontocete signals.

Manual detection of periods with delphinid echolocation in the JAX09C dataset was difficult and seemed subjective due to an almost continuously strong activity of snapping shrimp producing impulsive, broadband signals very similar to echolocation clicks of delphinids. A Teager Kaiser energy click detector (Roch et al. 2011) was run over both deployments. In the case of JAX09C data, a large number of false detections occurred due to the above mentioned snapping shrimp activity. To determine time periods with acoustic encounters of dolphins, we defined a threshold where we were certain of no false detections yet accepted a number of missed detections (not quantifiable due to similarity with snapping shrimp signals). An iterative process showed success when an acoustic encounter had a duration of at least 2 or more consecutive segments of 75 seconds with 300 clicks each. This automated selection process of acoustic encounters was not necessary for JAX10C where no considerable detections of snapping shrimp were made.

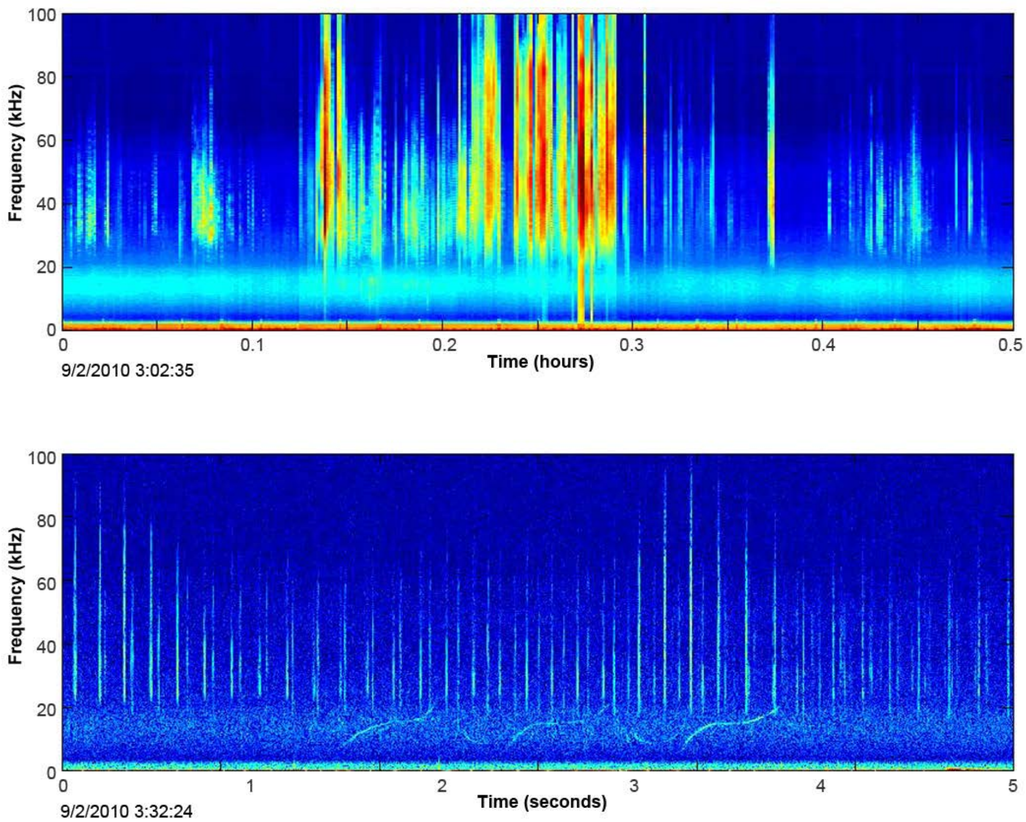


Figure 17. LTSA (top) and spectrogram (bottom) of unidentified odontocete signals from a HARP recording site within the Jacksonville Range Complex, September, 2010.

Risso's Dolphins

Risso's dolphin echolocation clicks can be identified to species by their distinctive banding patterns observable in the LTSA (Figure 18). Studies show that spectral properties of Risso's dolphin echolocation clicks vary based on geographic region (Soldevilla *et al*., personal communication). The few Risso's dolphin clicks that were detected in this recording period had peaks at 23, 26, 30, and 36 kHz. Risso's dolphin detections in previous recordings from the Jacksonville Range complex had peaks at 23, 26, 35, and 44 kHz (Debich *et al*., 2013), while clicks recorded in the Cherry Point OPAREA had peaks at 21, 25, 30, and 42 kHz (Debich *et al*., 2014) In southern California, Risso's dolphin echolocation clicks have energy peaks at about 22, 26, 30, and 39 kHz (Soldevilla *et al*., 2008).

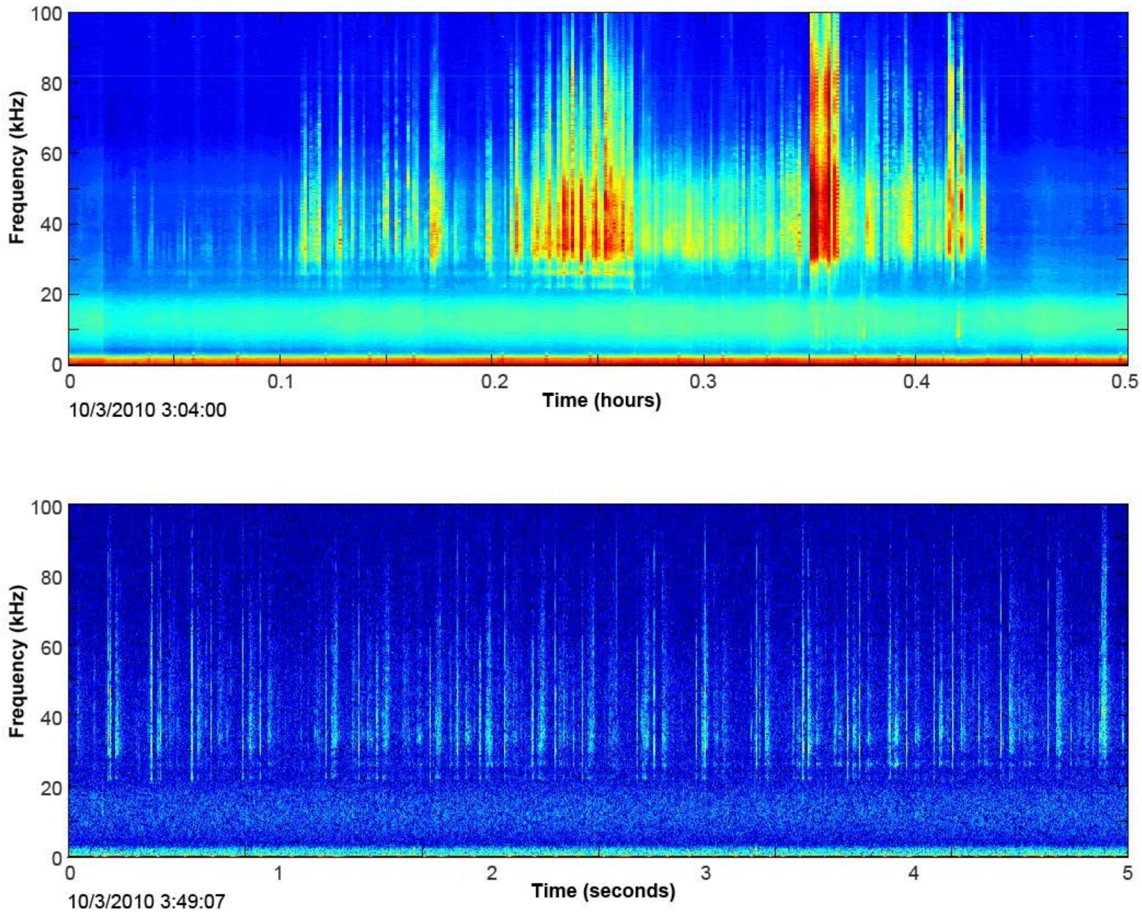


Figure 18. Risso's dolphin acoustic encounter in LTSA (top) and spectrogram (bottom) from a HARP recording site within the Jacksonville Range Complex, October, 2010.

Echolocation Click Types

An analysis was conducted to describe echolocation clicks from unidentified odontocetes (UO) and classify acoustic encounters to a certain click type (CT) of unknown origin. CT mean spectra from HARP recordings in the Gulf of Mexico, analyzed and defined by Kait Frasier, and off the coast of North Carolina, analyzed and defined by Lynne Hodge, were used as templates. These previous analyses were combined and provided thirteen distinct mean click spectra. All click types had dominant energy above 15 kHz. They differed in the prominence of spectral peaks between 10-25 kHz, and in the slope and onset of the lower frequency bound in their main spectral energy band. A custom software routine displayed mean click templates and overlaid novel spectra of manually detected acoustic encounters in JAX. These novel spectra were calculated based on echolocation clicks detected with the Teager Kaiser energy detector method mentioned above (Roch et al. 2011). Mean spectra per automatically determined acoustic encounter in JAX09C and manually defined acoustic encounter in JAX10C were computed over all detected clicks within the encounter period. A trained analyst determined from the overlay of template and novel spectra, based on spectral content, whether an acoustic encounter remained UO or was classifiable as a CT. Based on a complete analysis of all deployments reported here, 8 CT (Figure 19) were identified at least ten times within one deployment and will be described below. CT were then assigned names based on the frequency at which their spectra reached 50% of maximum energy (e.g. CT25 = 25 kHz for the 50% energy level).

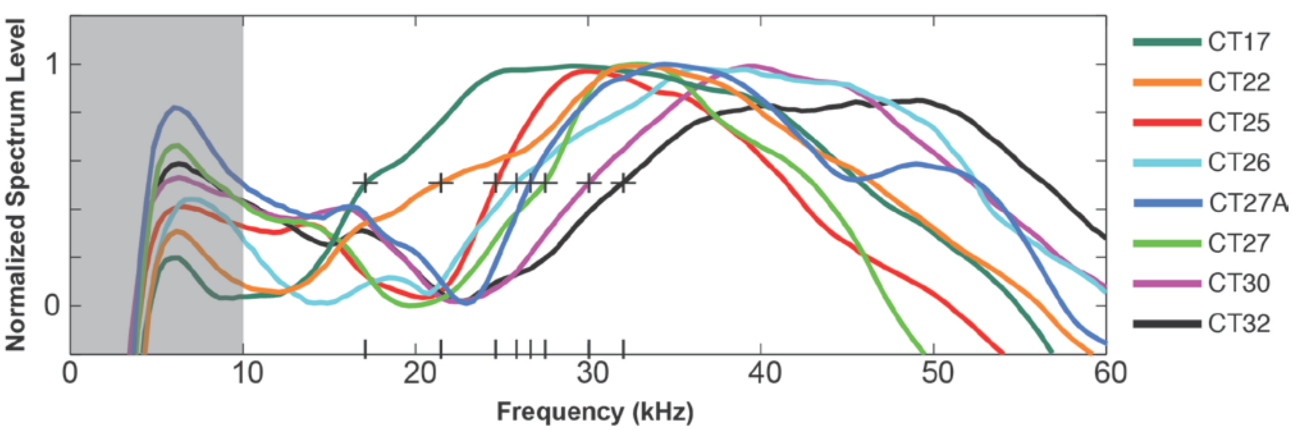


Figure 19. Echolocation click types (CT) that occurred in JAX recordings at least ten times within one deployment. Numerical values (e.g. CT25 = 25 kHz) refer to low end of 50% energy bandwidth.

Click Type 17

CT 17 (Figure 20) reaches its 50% maximum energy at approximately 17 kHz and has a peak frequency of about 25 to 30 kHz. It reaches its minimum energy at around 10 kHz and shows a slight peak at 17 and possibly 23 kHz (Figure 21), also see banding pattern in LTSA of Figure 20.

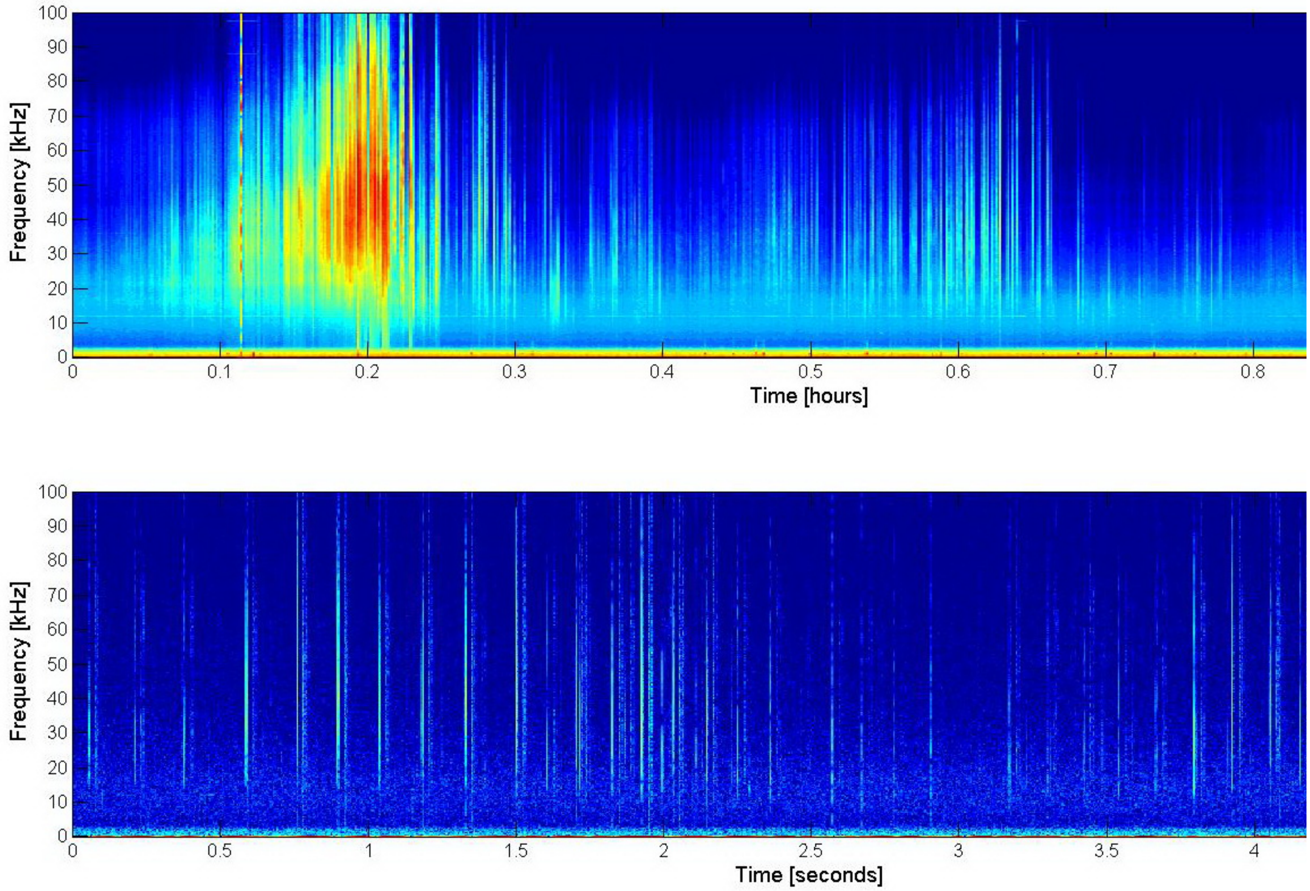


Figure 20. CT 17 in the LTSA (top) and spectrogram (bottom).

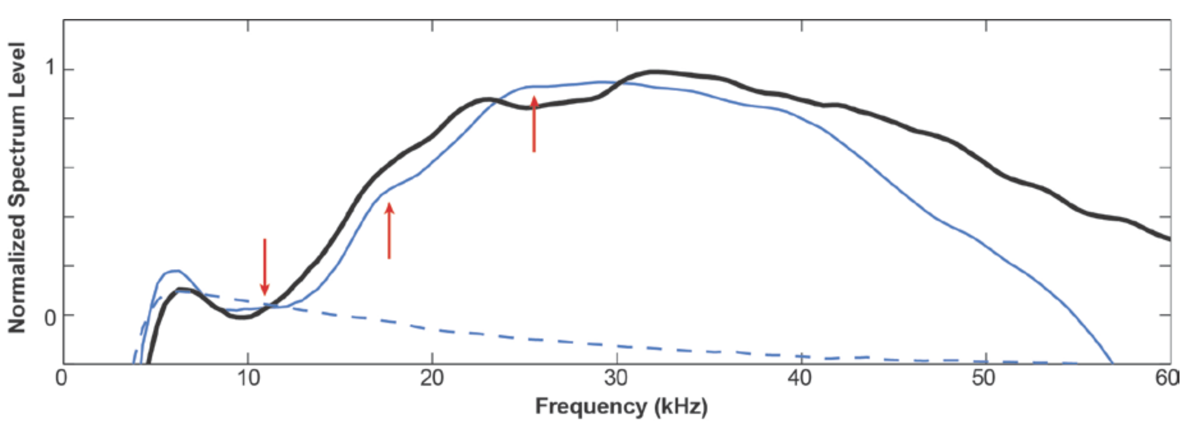


Figure 21. Mean spectra of CT17. Example (black line), template (blue line), and noise floor (dotted line). Arrows are spectral peaks or troughs.

Click Type 22

CT 22 (Figure 22) reaches its 50% maximum energy at approximately 22 kHz and has a peak frequency of about 32 kHz. In comparison to other CTs, energy in this CT increases relatively linear from a 12 kHz minimum to its peak energy (Figure 23).

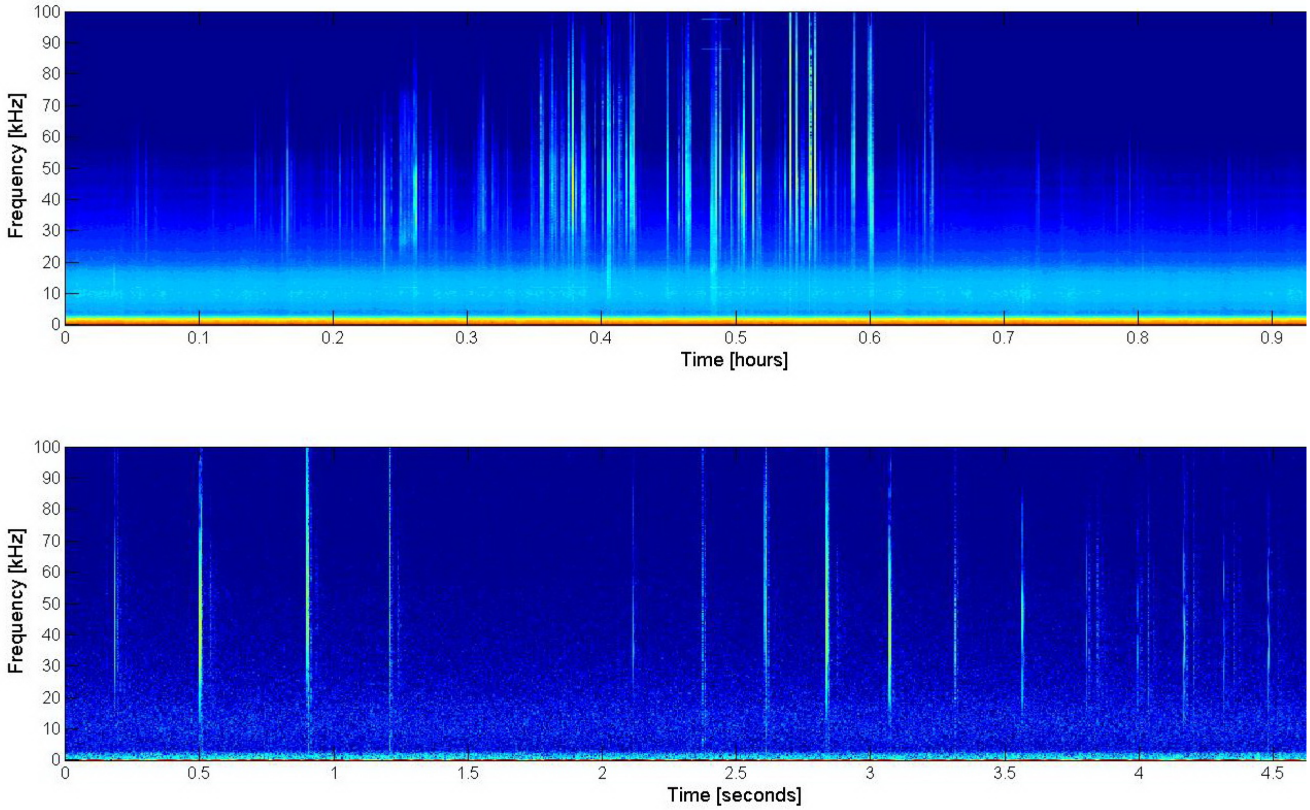


Figure 22. CT 22 in the LTSA (top) and spectrogram (bottom).

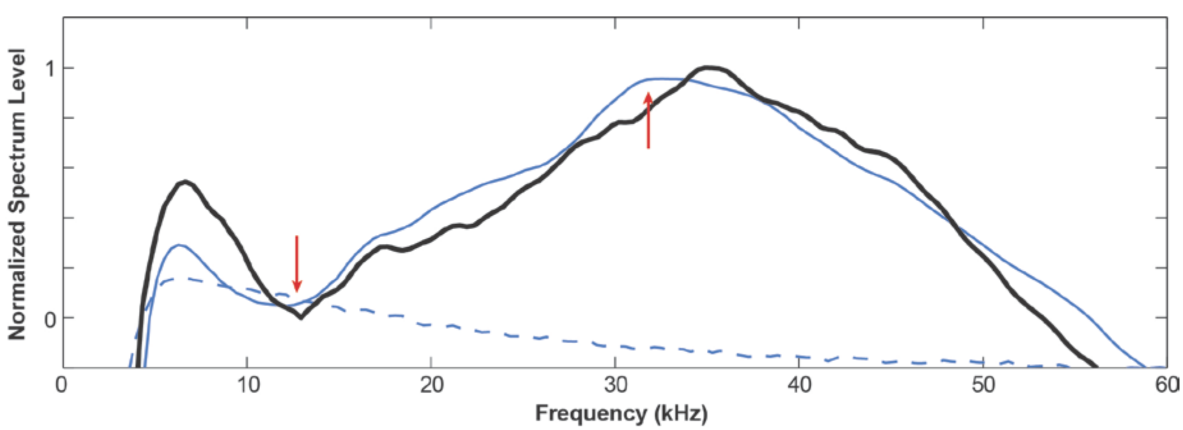


Figure 23. Mean spectra of CT22. Example (black line), template (blue line), and noise floor (dotted line). Arrows are spectral peaks or troughs.

Click Type 24

CT 24 (Figure 24) reaches its 50% maximum energy at approximately 24 kHz and has a peak frequency of about 32 kHz. It has a smaller peak at 21 kHz with troughs at 17 and 23 kHz (Figure 25).

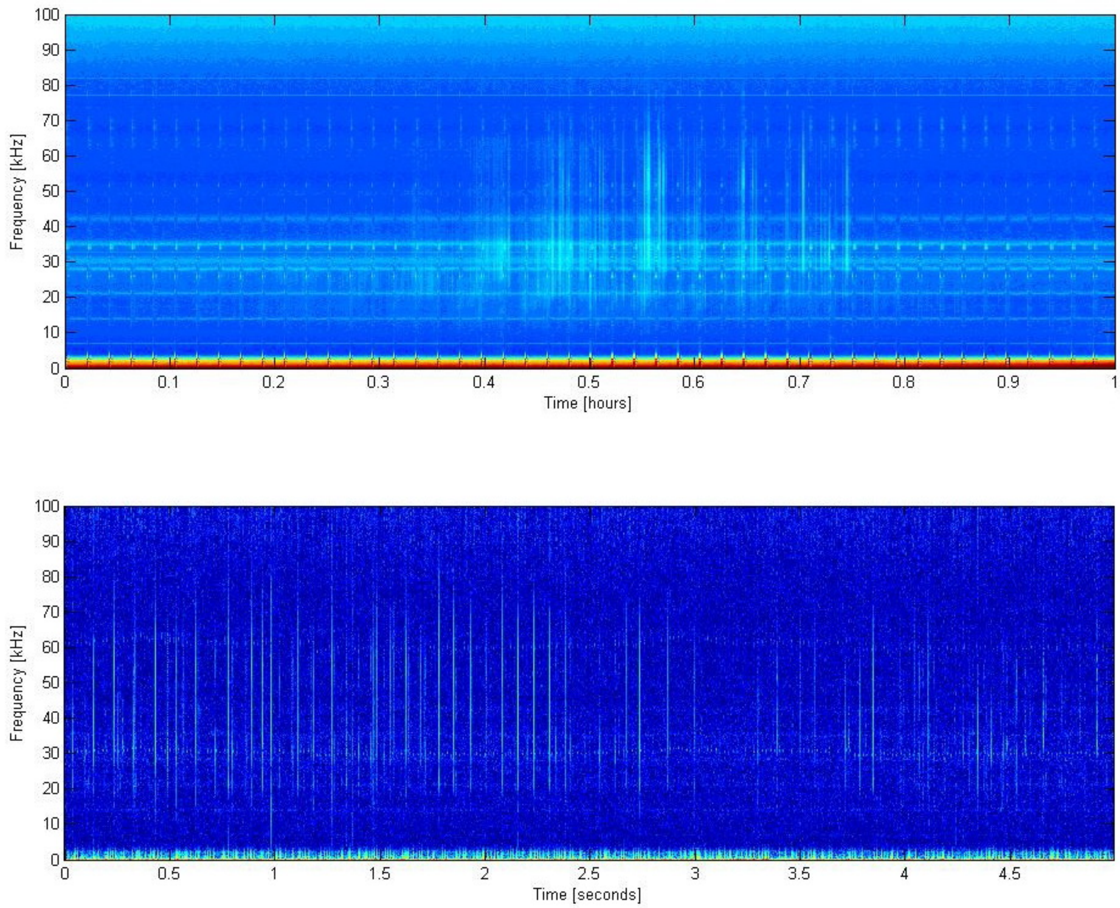


Figure 24. CT 24 in the LTSA (top) and spectrogram (bottom).

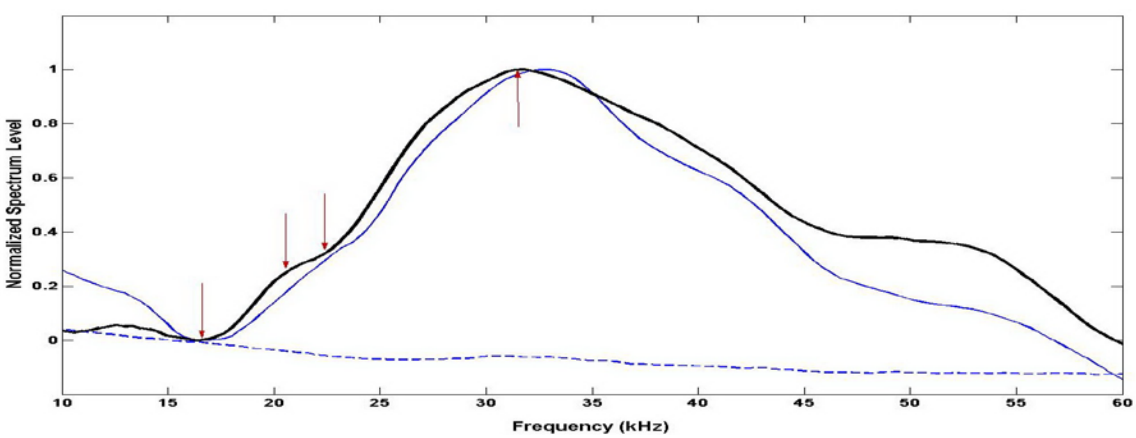
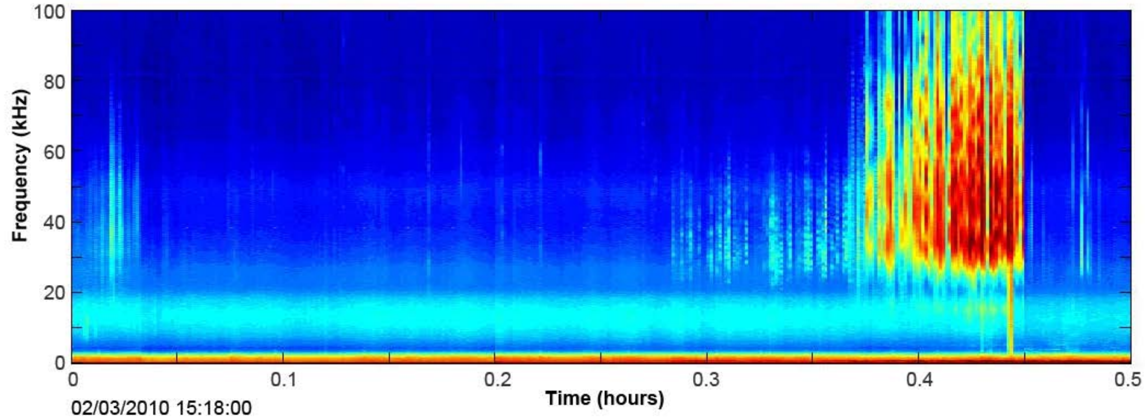


Figure 25. Mean spectra of CT24. Example (black line), template (blue line), and noise floor (dotted line). Arrows are spectral peaks or troughs.

Click Type 25

CT 25 (Figure 26) reaches its 50% maximum energy at approximately 25 kHz and has a peak frequency of about 33 kHz. It has a smaller peak at 15 kHz with troughs at 12 and 20 kHz (Figure 27).



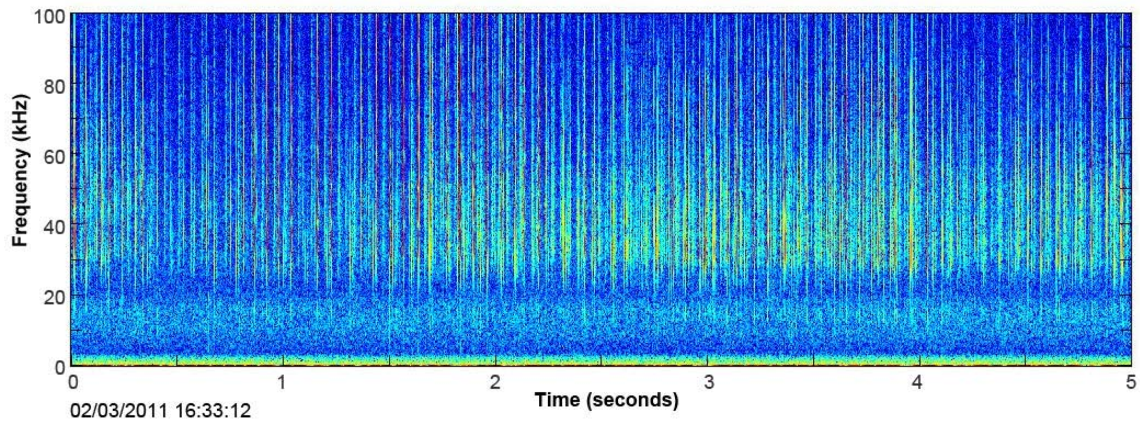


Figure 26. CT 25 in the LTSA (top) and spectrogram (bottom).

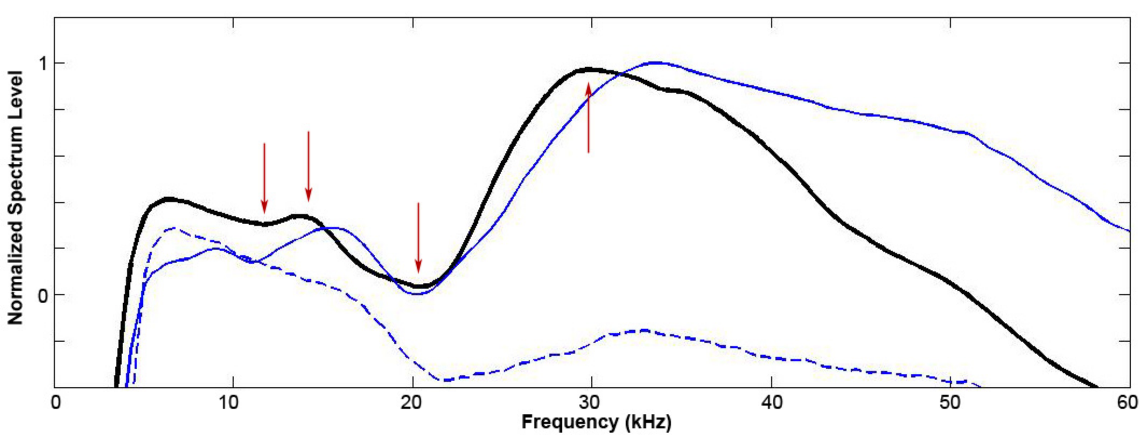


Figure 27. Mean spectra of clicks for CT 25. Example encounter (black line), template for CT (blue line from Gulf of Mexico and/or North Carolina), noise floor (dotted line). Arrows are spectral peaks or troughs.

Click Type 26

CT 26 (Figure 28) reaches its 50% maximum energy at approximately 26 kHz and has a peak frequency of about 35 kHz. It has a smaller peak at 18 kHz with troughs at 15 and 21 kHz (Figure 29).

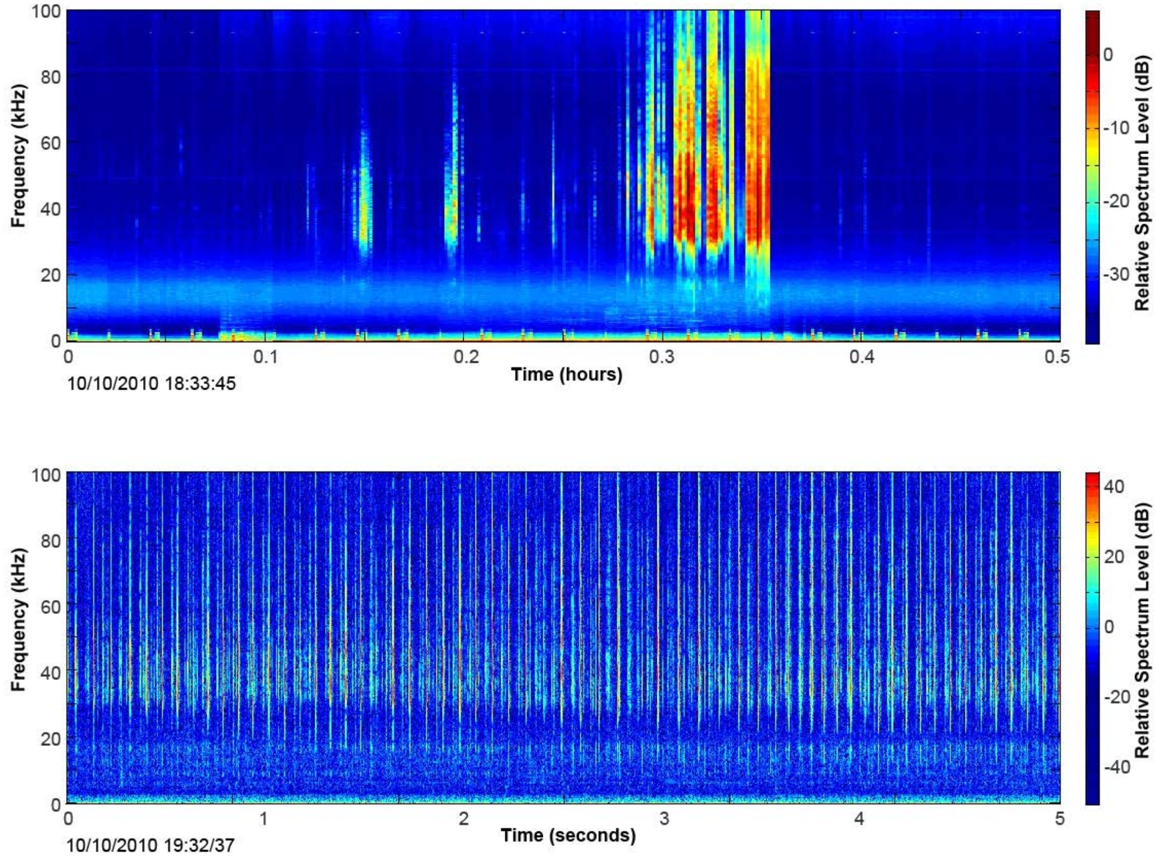


Figure 28. CT 26 in the LTSA (top) and spectrogram (bottom).

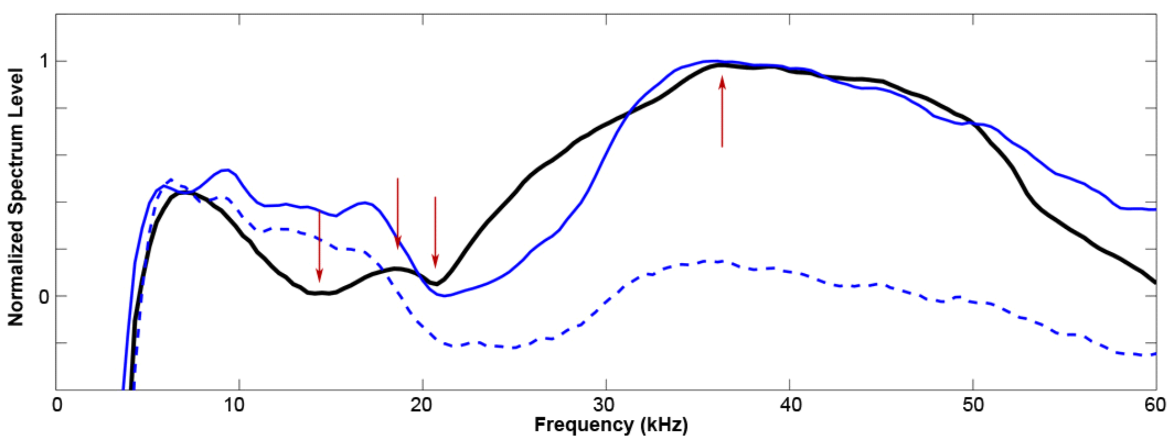


Figure 29. Mean Spectra of clicks for CT26. Example (black line), template (blue line), and noise floor (dotted line). Arrows are spectral peaks or troughs.

Click Type 27

CT 27 (Figure 30) reaches its 50% maximum energy at approximately 27 kHz and has a peak frequency of about 35 kHz. It has a smaller peak at 16 kHz ranging with troughs at 11 and 20 kHz (Figure 31).

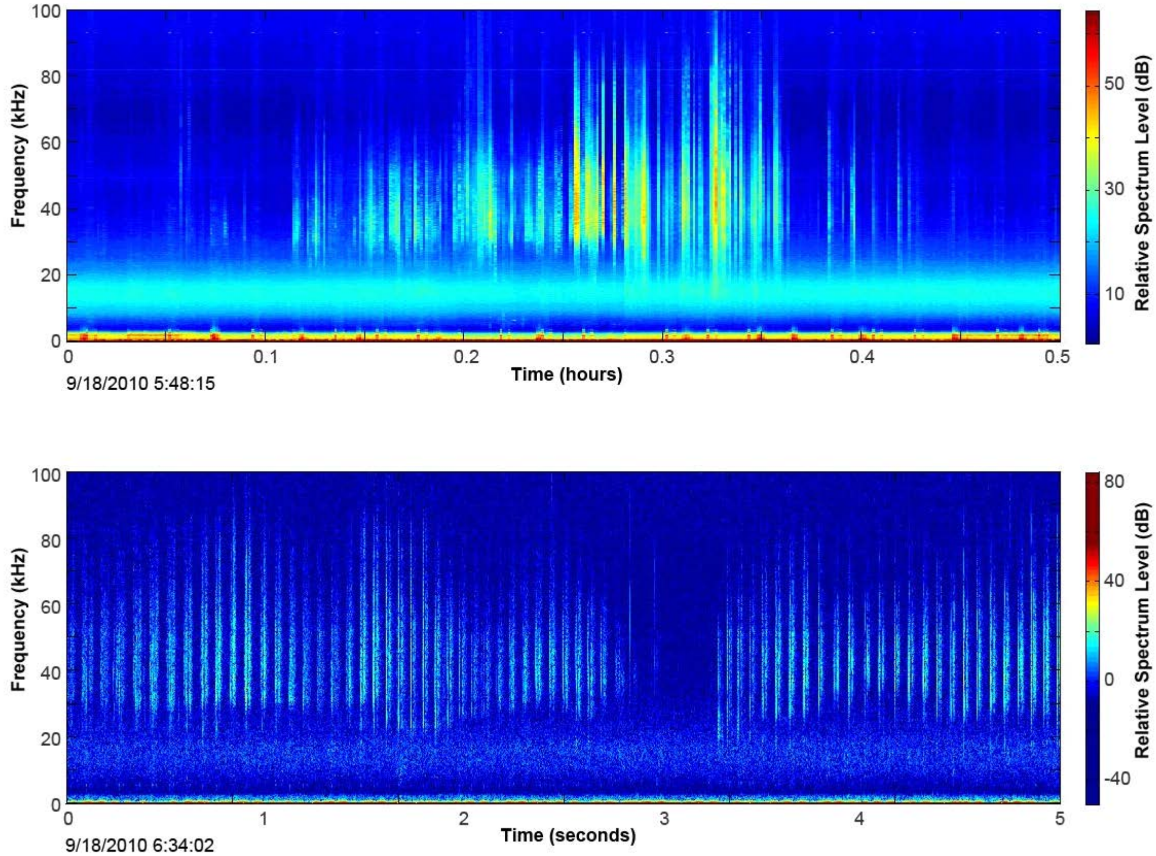


Figure 30. CT 27 in the LTSA (top) and spectrogram (bottom).

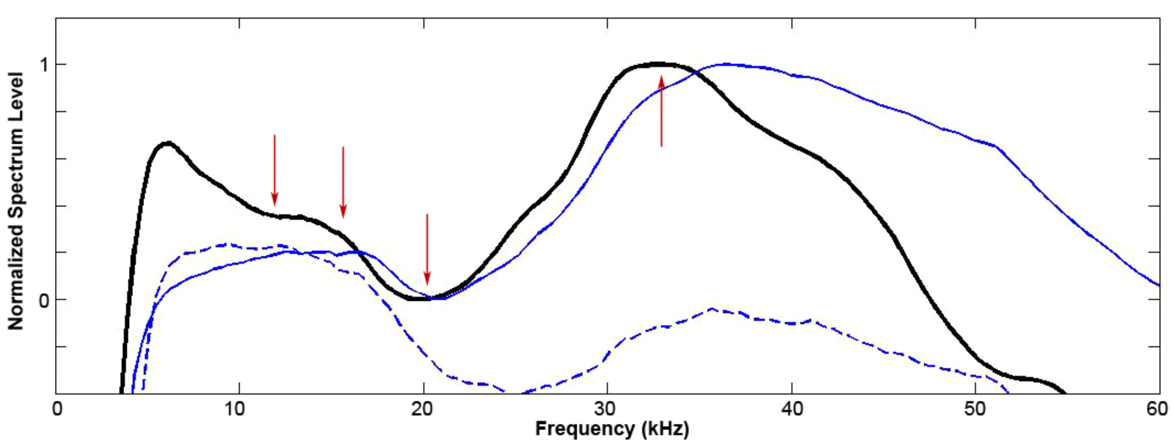


Figure 31. Mean spectra of CT27. Example (black line), template (blue line), and noise floor (dotted line). Arrows are spectral peaks or troughs.

Click Type 27A

CT 27A (Figure 32) reaches its 50% maximum energy at approximately 27 kHz. It has a peak frequency of about 35 kHz with a peak at 16 kHz and a trough at 23 kHz (Figure 33).

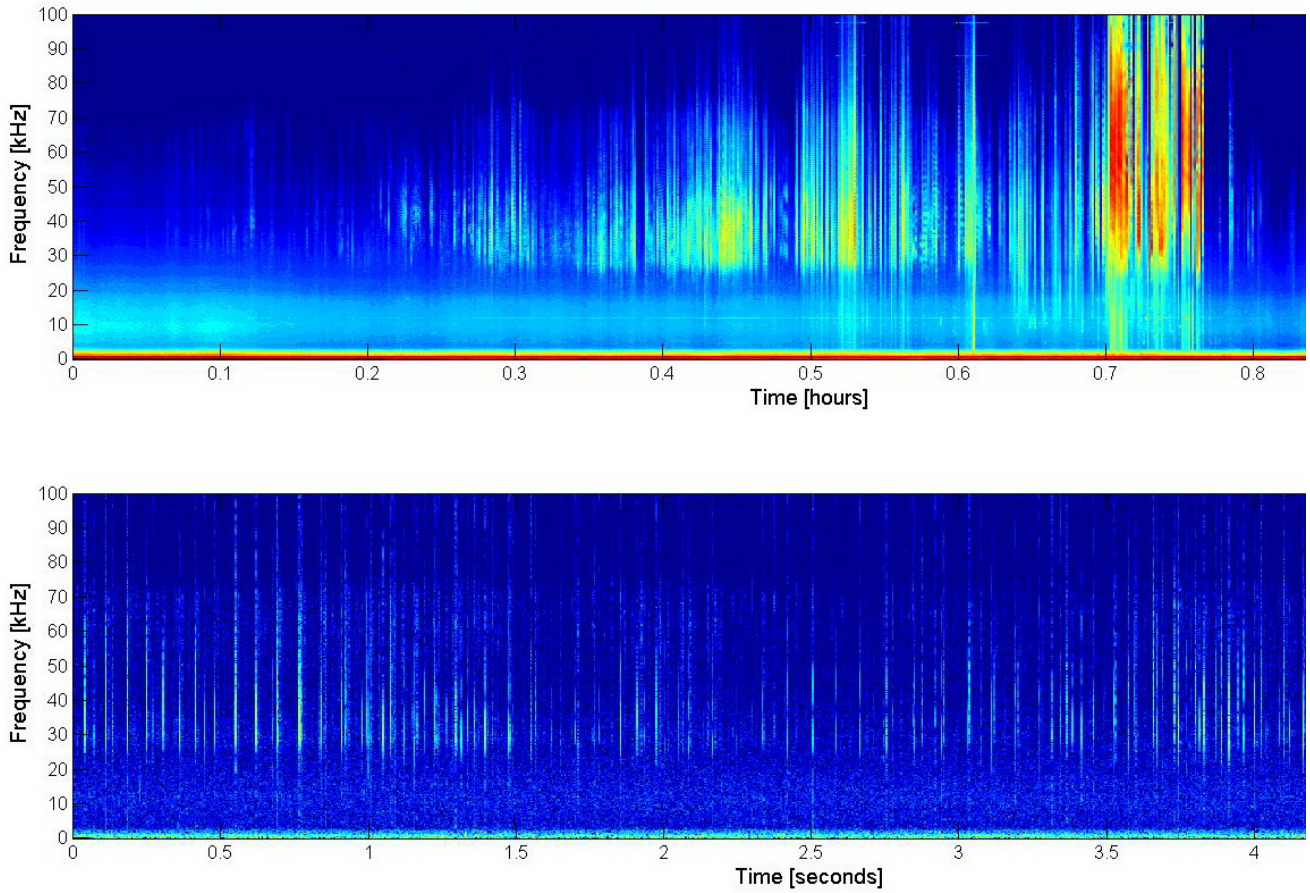


Figure 32. CT 27A in the LTSA (top) and spectrogram (bottom).

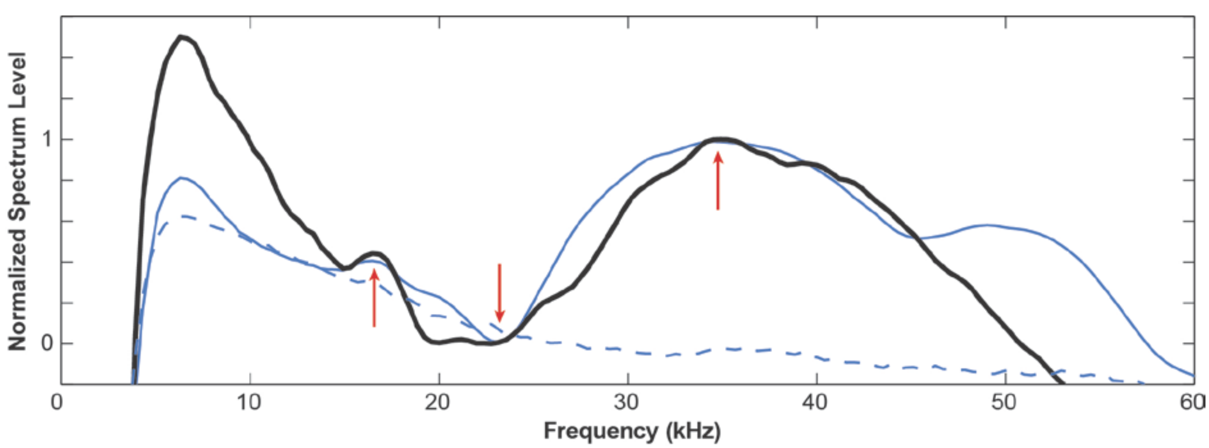


Figure 33. Mean spectra of CT27A. Example (black line), template (blue line), and noise floor (dotted line). Arrows are spectral peaks or troughs.

Click Type 30

CT 30 (Figure 34) reaches its 50% maximum energy at approximately 30 kHz and has a peak frequency of about 37 kHz. It has a smaller peak at 16 kHz with troughs at 12 and 22 kHz (Figure 35).

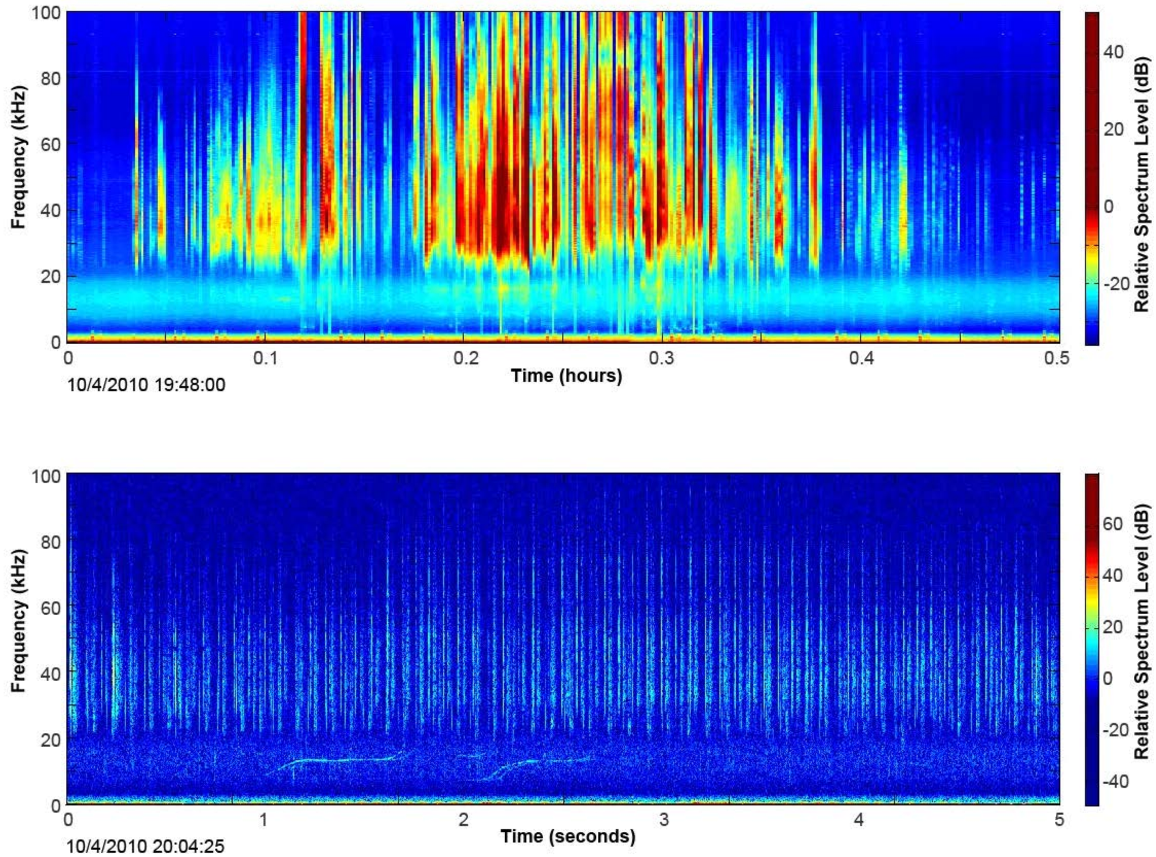


Figure 34. CT 30 in the LTSA (top) and spectrogram (bottom).

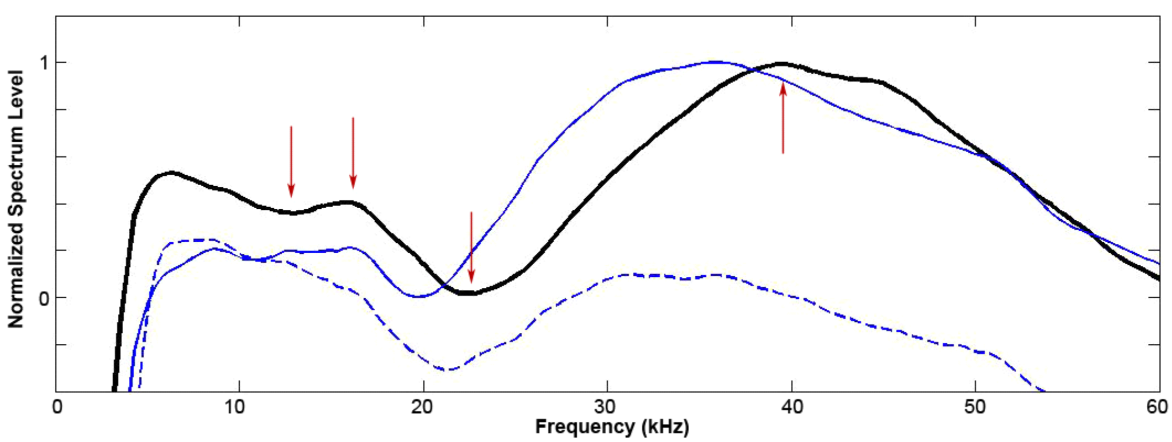


Figure 35. Mean Spectra of CT30. Example (black line), template (blue line), and noise floor (dotted line). Arrows are spectral peaks or troughs.

Click Type 32

CT 32 (Figure 36) reaches its 50% maximum energy at approximately 32 kHz and has a peak frequency of about 39 kHz. It has a smaller peak at 17 kHz with troughs at 15 and 22 kHz (Figure 37). Clicks with high received levels (Figure 38) show a peak between 4-6 kHz. This low peak becomes apparent in LTSAs but a high pass filter cuts it out in the mean spectra.

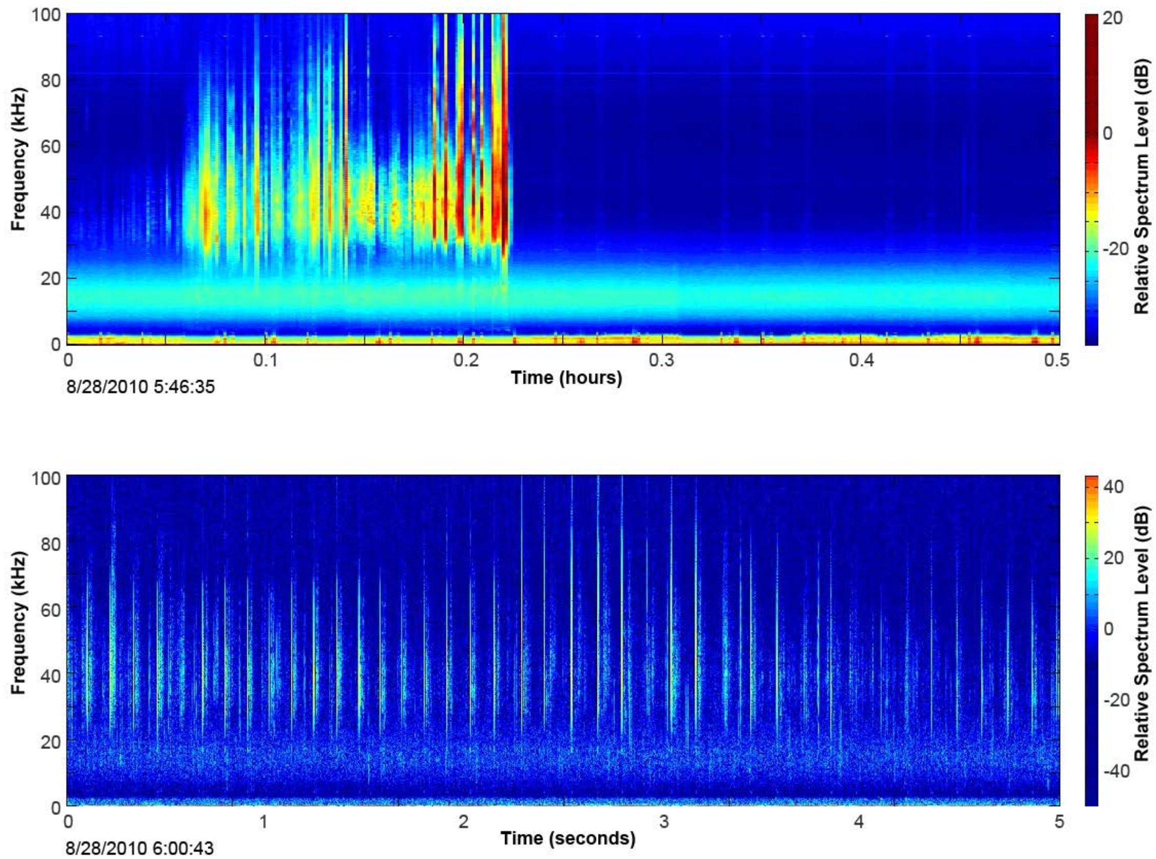


Figure 36. CT 32 in the LTSA (top) and spectrogram (bottom).

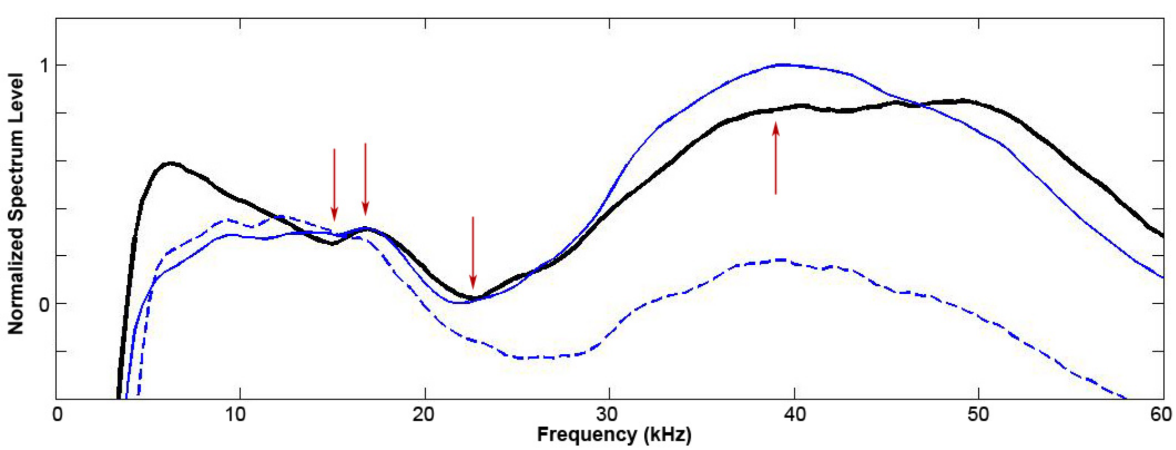


Figure 37. Mean Spectra of CT32. Example (black line), template (blue line), and noise floor (dotted line). Arrows are spectral peaks or troughs.

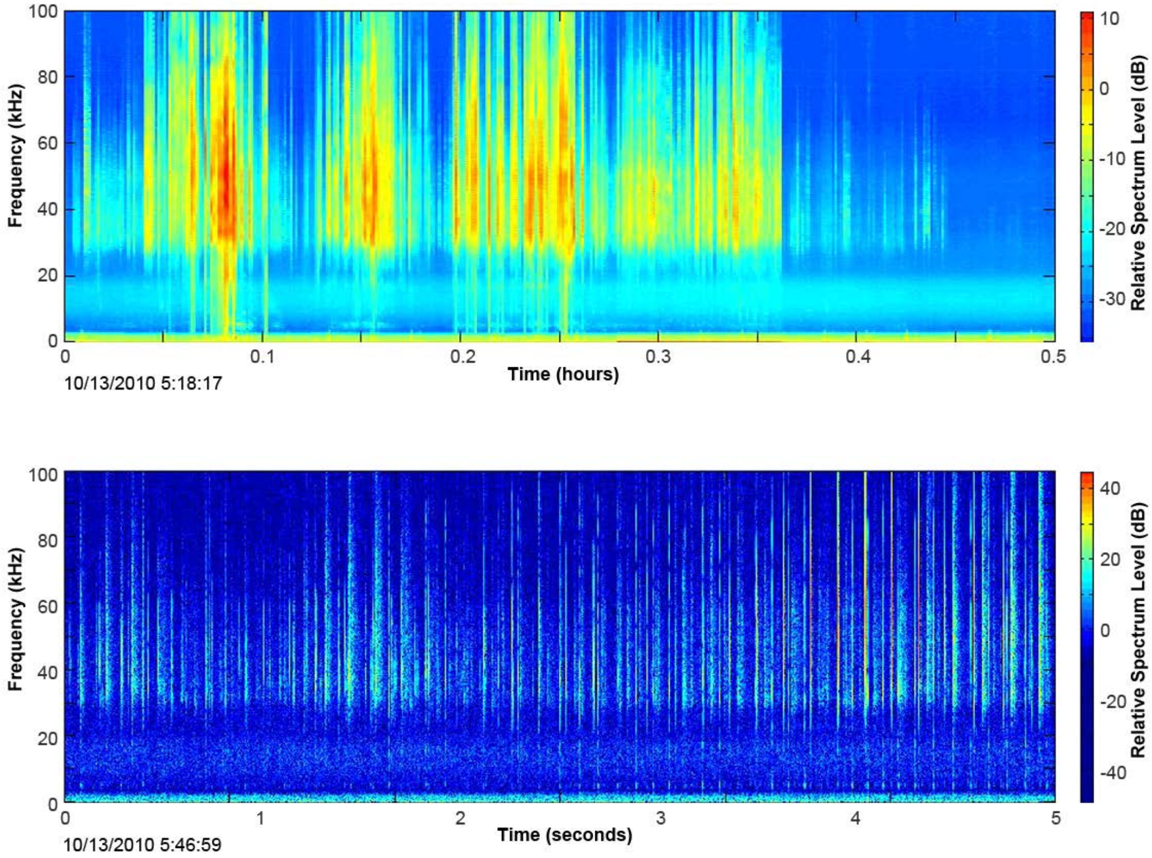


Figure 38. CT32 (emphasizing 4-6 kHz peak) in the LTSA (above) and spectrogram (below).

Beaked Whales

Beaked whales expected in the Jacksonville Range Complex include Cuvier's beaked whales, Gervais' beaked whales, Blainville's beaked whales, Sowerby's beaked whales, and Northern bottlenose whales. Additional beaked whale signals that have been detected in the Jacksonville Range Complex include frequency-modulated upsweep pulses known as BW31 and BW36, which appear to be species specific and distinguishable by their spectral and temporal features. In recent years, advances have been made in acoustically identifying beaked whales by their echolocation signals. Beaked whale FM pulses were detected with an automated method. After all echolocation signals were identified with a Teager Kaiser energy detector (Soldevilla *et al.* 2008, Roch *et al.* 2011), an expert system discriminated between delphinid clicks and beaked whale FM pulses. A decision about presence or absence of beaked whale signals was based on detections within a 75 second segment. Only segments with more than 7 detections were used in further analysis. All echolocation signals with a peak and center frequency below 32 and 25 kHz, respectively, a duration less than 355 μs, and a sweep rate of less than 23 kHz/ms were deleted. If more than 13% of all initially detected echolocation signals remained after applying these criteria, the segment was classified to have beaked whale FM pulses. A third classification step, based on computer assisted manual decisions by a trained analyst, labeled the automatically detected segments to pulse type level and rejected false detections. The rate of missed segments was approximately 5%, varying slightly between deployments. There were no beaked whale detections in this recording period based on the above analysis criteria, likely owing to the shallow depth of the HARP deployments.

Cuvier's Beaked Whales

Cuvier's echolocation signals are well differentiated from other species' acoustic signals as polycyclic, with a characteristic FM pulse upsweep, peak frequency around 40 kHz, and uniform inter-pulse interval of about 0.5 s (Johnson *et al.*, 2004; Zimmer *et al.*, 2005). An additional feature that helps with the identification of Cuvier's FM pulses is that they have two characteristic spectral peaks around 17 and 23 kHz (Figure 39).

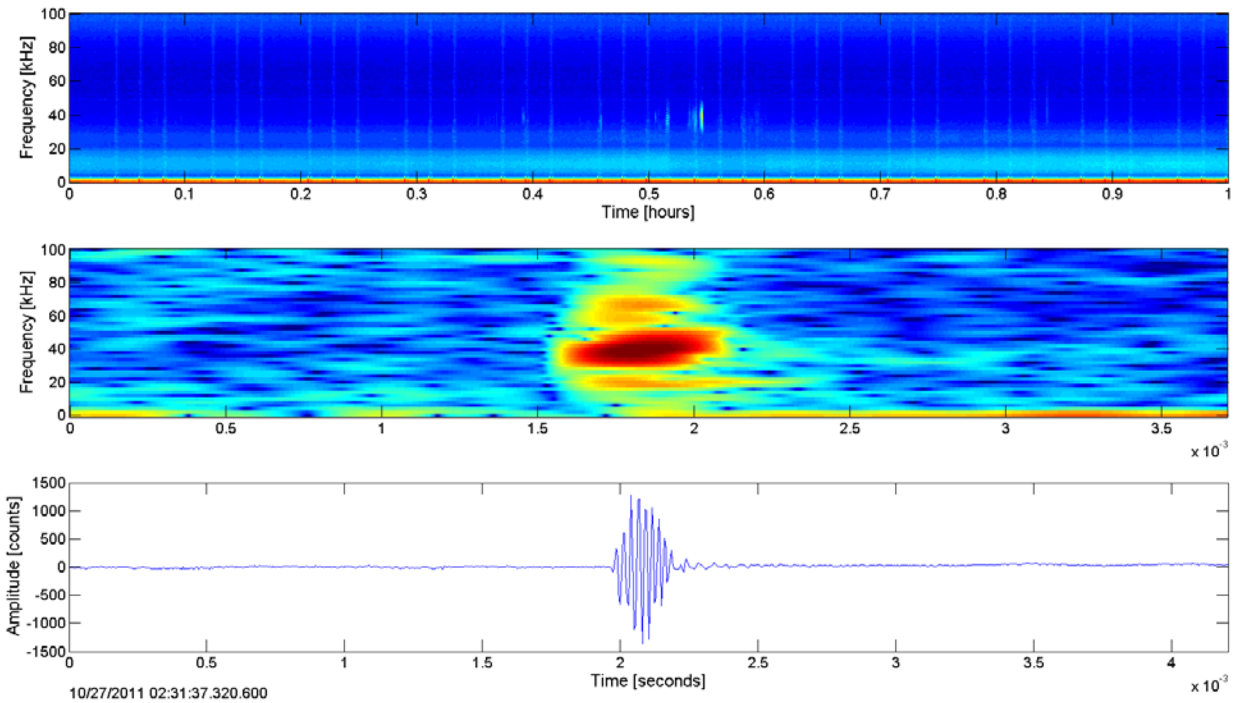


Figure 39. Echolocation sequence of Cuvier's beaked whale in LTSA (top) and example FM pulse in spectrogram (middle) and time series (bottom) at a HARP recording site off North Carolina.

Gervais' Beaked Whales

Gervais' beaked whale signals have energy concentrated in the 30 – 50 kHz band (Gillespie *et al.*, 2009) with a peak at 44 kHz (Baumann-Pickering *et al.*, 2013). While Gervais' beaked whale signals are similar to those of Cuvier's and Blainville's beaked whales, the Gervais' beaked whale FM pulses are at a slightly higher frequency than those of the other two species. Similarly, Gervais' beaked whale FM pulses sweep up in frequency (Figure 40).

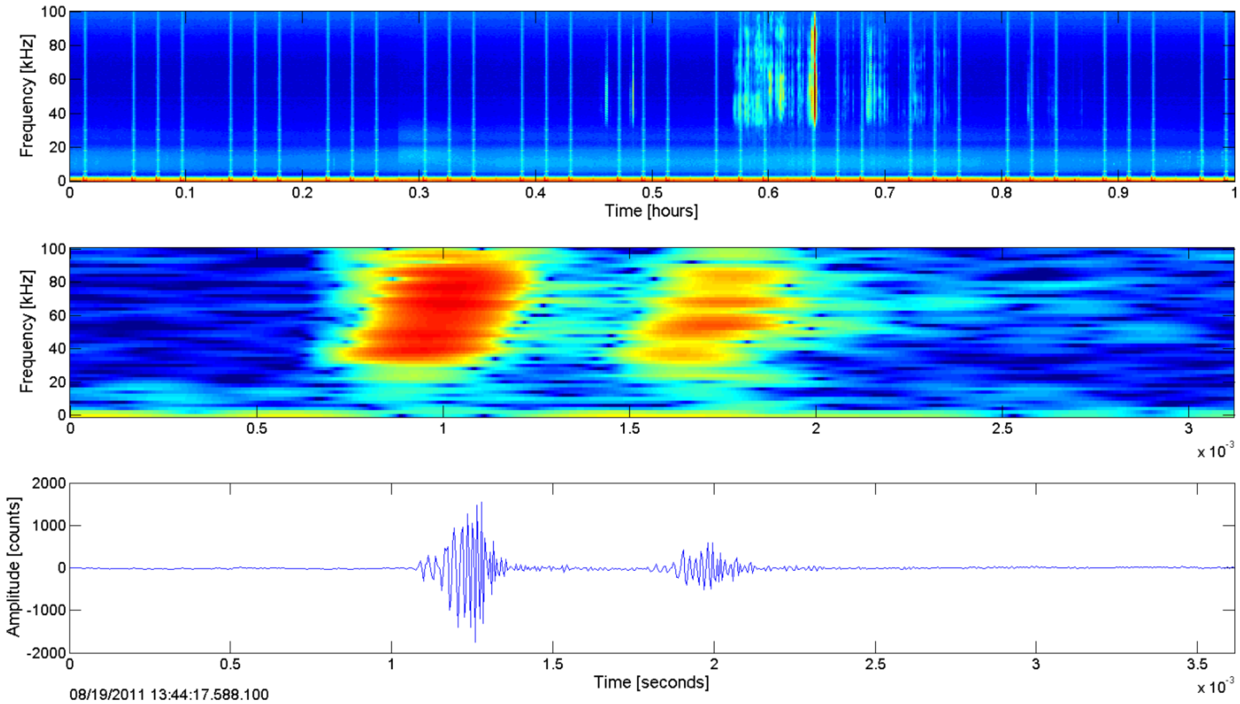


Figure 40. LTSA (top), spectrogram (middle), and time series (bottom) of a Gervais' beaked whale FM pulse from a HARP recording site off North Carolina.

Blainville's Beaked Whales

Blainville's beaked whale echolocation signals are, like most beaked whales' signals, polycyclic, with a characteristic frequency-modulated upsweep, peak frequency around 34 kHz and uniform inter-pulse interval (IPI) of about 280 ms (Johnson *et al.*, 2004; Baumann-Pickering *et al.*, 2013). Blainville's FM pulses are also distinguishable in the spectral domain by their sharp energy onset around 25 kHz with only a small energy peak at around 22 kHz (Figure 41).

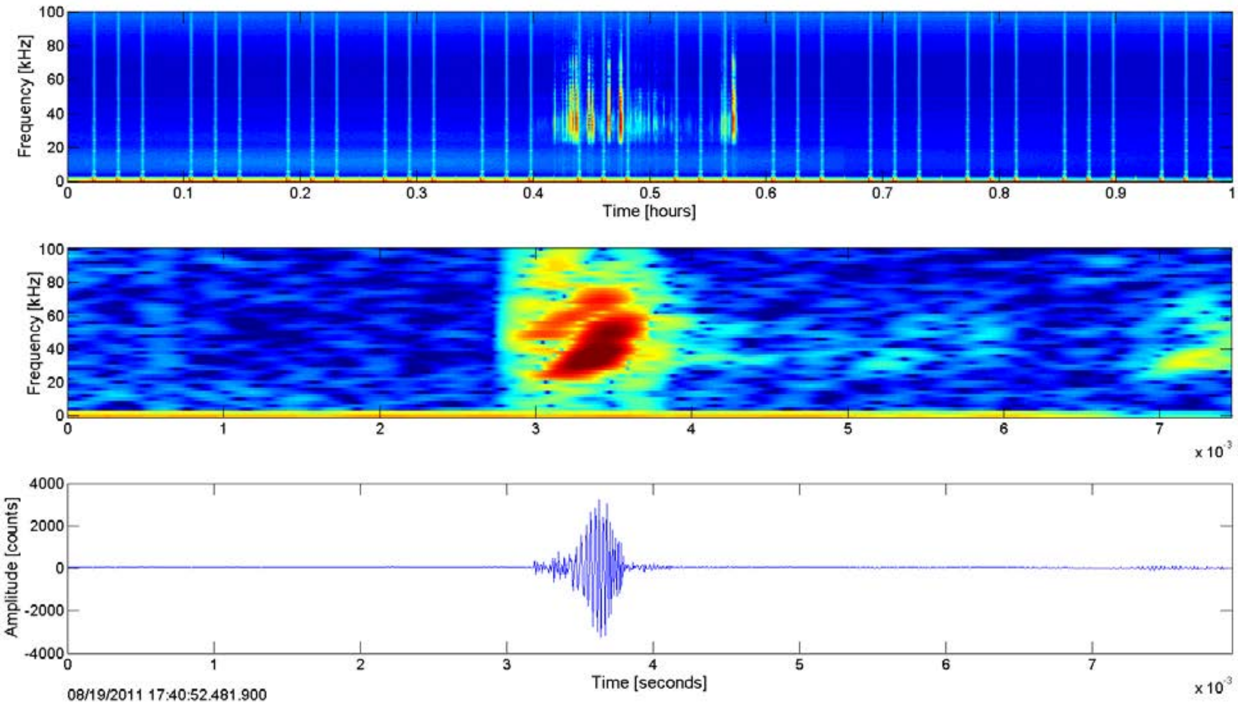


Figure 41. Blainville's beaked whale FM pulses in the LTSA (top), spectrogram (middle), and time series (bottom) from a HARP recording site off North Carolina.

Anthropogenic Sounds

Several anthropogenic sounds were monitored for this report: broadband ship noise, Mid-Frequency Active (MFA) sonar, echosounders, and explosions. The LTSA search parameters used to detect each sound at low and mid-frequencies are given in Table 1. The start and end of each sound or session was logged and their durations were added to estimate cumulative hourly presence.

Table 1. Low and mid-frequency anthropogenic sound data analysis parameters.

Sound Type	LTSA Search Parameters	
	Plot Length (hr)	Frequency Range (Hz)
Broadband Ship Noise	3.0	10 – 5,000
MFA Sonar	0.75	1,000 – 5,000
Echosounders	0.75	10 – 5,000
Underwater Communications	0.75	10 – 5,000
Explosions	0.75	10 – 5,000

Broadband Ship Noise

Broadband ship noise occurs when a ship passes within a few km of the hydrophone. Ship noise can occur for many hours at a time, but broadband ship noise typically lasts from 10 minutes up to 3 hours. Ship noise has a characteristic interference pattern in the LTSA (McKenna *et al.*, 2012). Combination of direct paths and surface reflected paths produce constructive and destructive interference (bright and dark bands) in the spectrogram that varies by frequency and distance between the ship and the receiver (Figure 43). Noise can extend above 10 kHz, though it typically falls off above a few kHz.

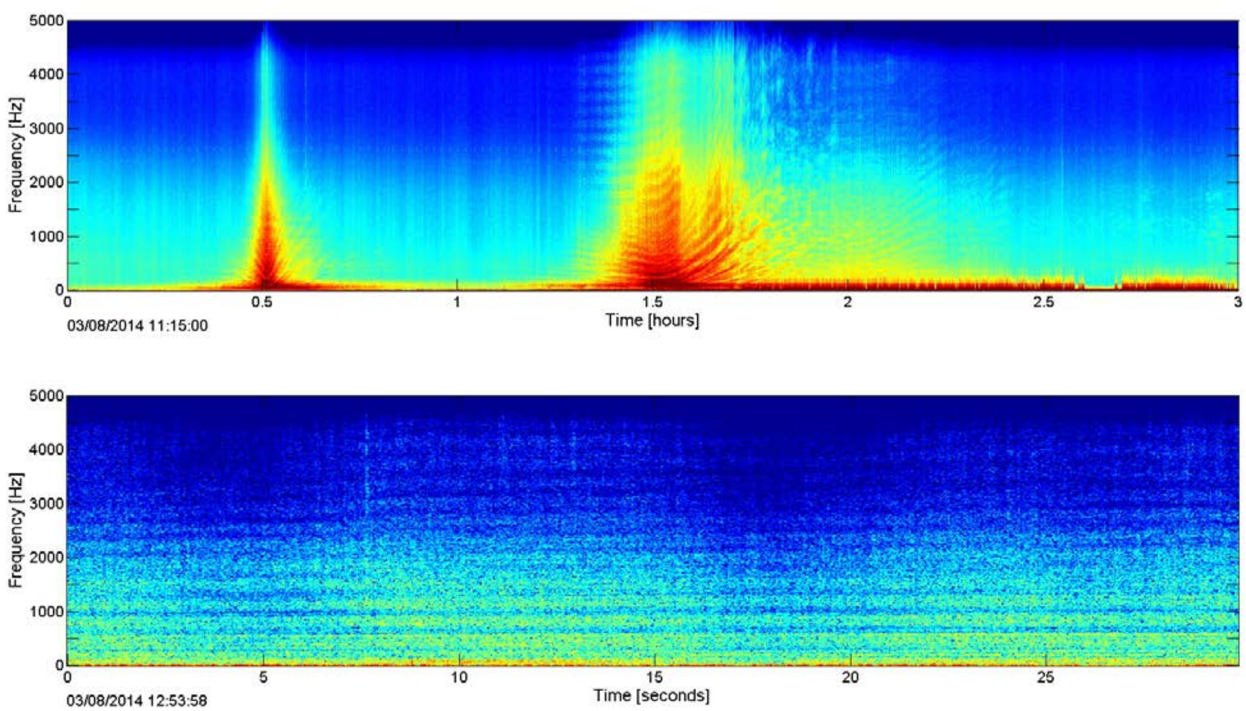


Figure 42. Broadband ship noise in LTSA (top) and spectrogram (bottom) at site C.

Mid-Frequency Active Sonar

Sounds from MFA sonar vary in frequency (1 – 10 kHz) and are composed of pulses of both frequency modulated (FM) sweeps and continuous wave (CW) tones grouped in packets with durations ranging from less than 1 s to greater than 5 s. Packets can be composed of single or multiple pulses and are transmitted repetitively as wave trains with inter-packet-intervals typically greater than 20 s (Figure 44). In the Jacksonville Range Complex, the most common MFA sonar packet signals are between 2 and 5 kHz and are known more generally as ‘3.5 kHz’ sonar. Analysts manually scanned LTSAs and logged sonar wave train event start and end times.

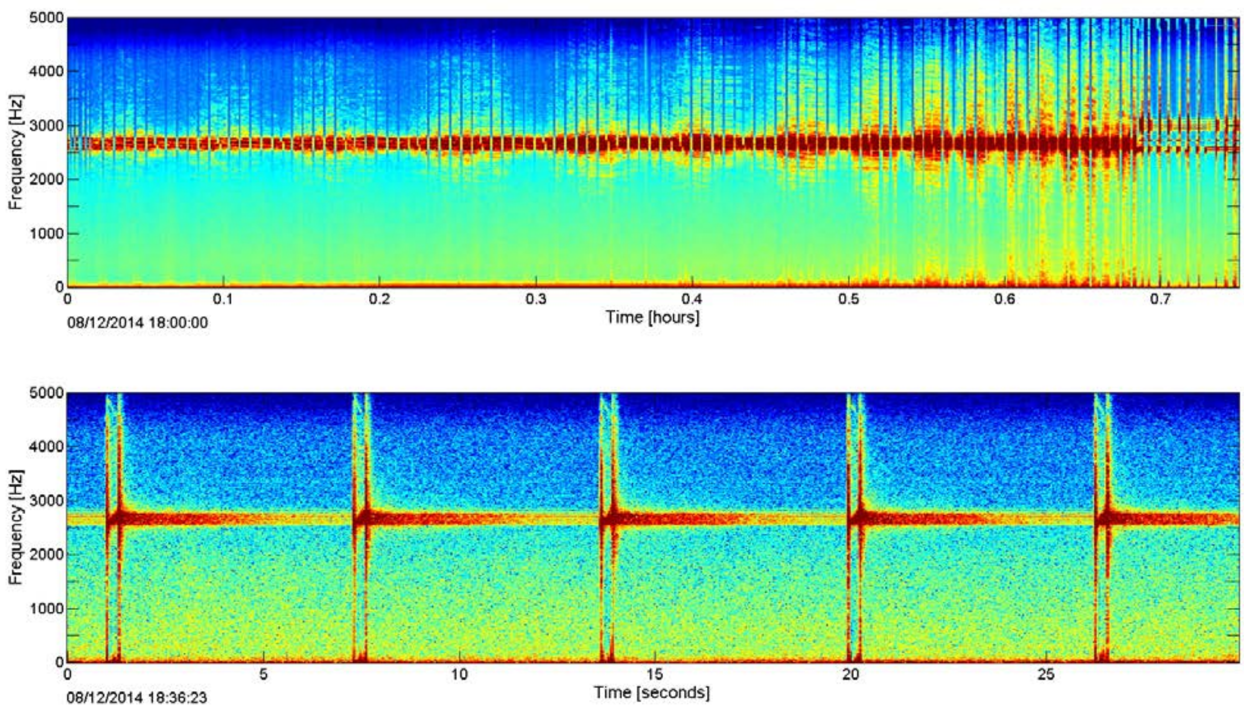


Figure 43. MFA in LTSA (top) and spectrogram (bottom) at site C.

Echosounders

Echosounding sonars transmit short pulses or frequency sweeps, typically in the high-frequency (above 10 kHz) band (Figure 45), though echosounders are occasionally found in the mid-frequency range (2-5 kHz). Many large and small vessels are equipped with echosounding sonar for water depth determination; typically these echosounders are operated much of the time a ship is at sea, as an aid for navigation. In addition, sonars may be used for sea bottom mapping, fish detection, or other ocean sensing. Echosounders were detected by analysts using the LTSA plots at both mid- and high-frequency.

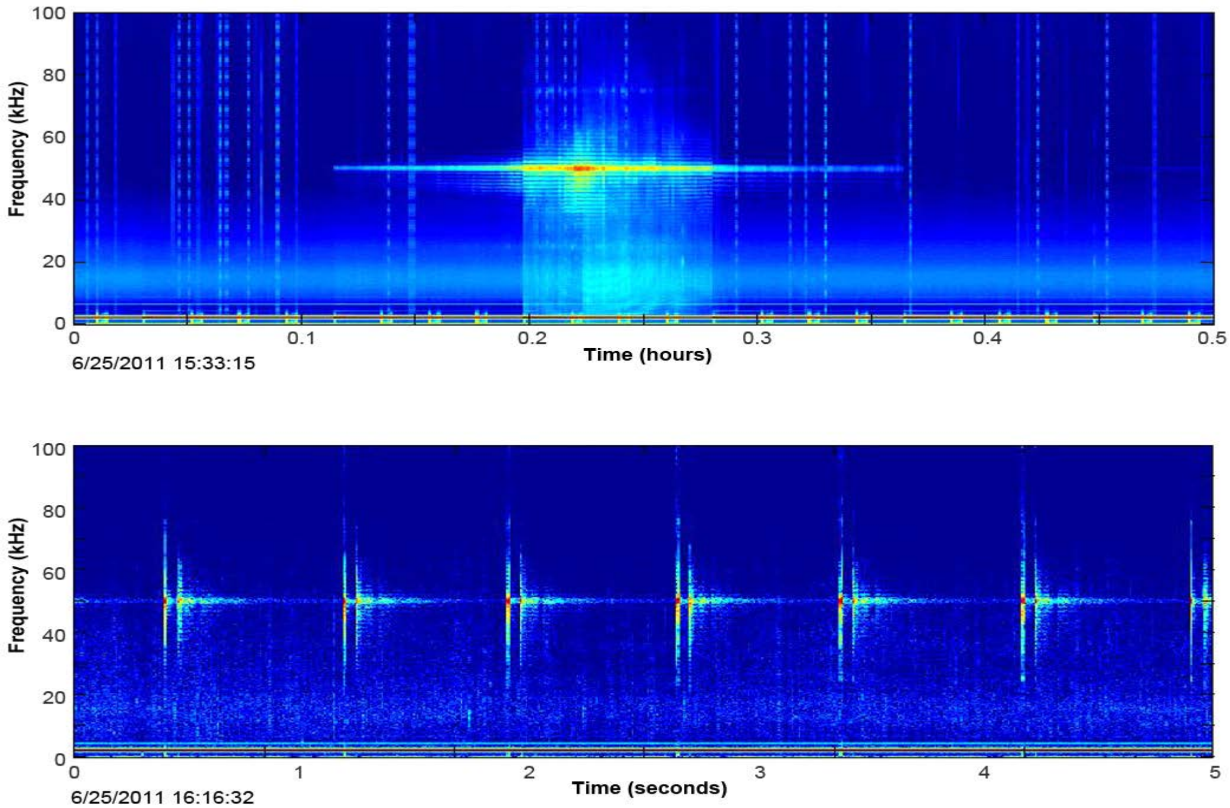


Figure 44. High-frequency echosounder pings in LTSA (top) and spectrogram (bottom) at a HARP recording site in the Gulf of Alaska.

Explosions

Effort was directed toward finding explosive sounds in the data including military explosions, shots from sub-seafloor exploration, and seal bombs used by the fishing industry. An explosion appears as a vertical spike in the LTSA that, when expanded in the spectrogram, has a sharp onset with a reverberant decay (Figure 46). Explosions were detected automatically using a matched filter detector on data decimated to 10 kHz sampling rate. The time series was filtered with a 10^{th} order Butterworth bandpass filter between 200 and 2,000 Hz. Cross correlation was computed between 75 seconds of the envelope of the filtered time series and the envelope of a filtered example explosion (0.7 s, Hann windowed) as the matched filter signal. The cross correlation was squared to 'sharpen' peaks of explosion detections. A floating threshold was calculated by taking the median cross correlation value over the current 75 seconds of data to account for detecting explosions within noise, such as shipping. A cross correlation threshold above the median was set. When the correlation coefficient reached above threshold, the time series was inspected more closely. Consecutive explosions were required to have a minimum time distance of 0.5 seconds to be detected. A 300-point (0.03 s) floating average energy across the detection was computed. The start and end above threshold was determined when the energy rose by more than 2 dB above the median energy across the detection. Peak-to-peak (pp) and rms received levels (RL) were computed over the potential explosion period and a time series of the length of the explosion template before and after the explosion. The potential explosion was classified as false detection and deleted if 1) the dB difference pp and rms between signal and time AFTER the detection was less than 4 dB or 1.5 dB, respectively; 2) the dB difference pp and rms between signal and time BEFORE signal was less than 3 dB or 1 dB, respectively; and 3) the detection was shorter than 0.03 and longer than 0.55 seconds of duration. The thresholds were evaluated based on the distribution of histograms of manually verified true and false detections. A trained analyst subsequently verified the remaining potential explosions for accuracy. Explosions have energy as low as 10 Hz and often extend up to 2,000 Hz or higher, lasting for a few seconds including the reverberation. There were no explosion detections during these recording periods.

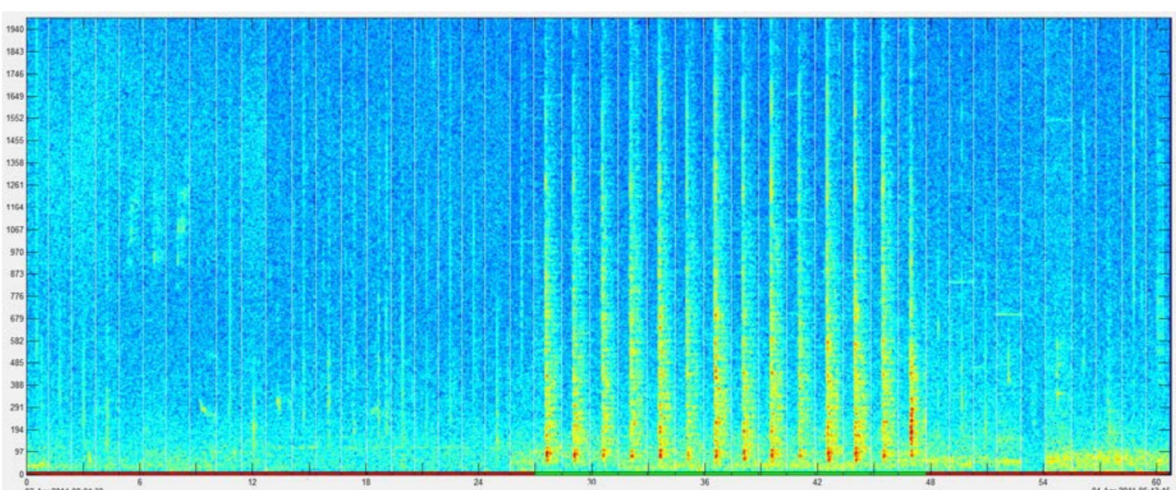


Figure 45. Explosions, from a HARP recording site in southern California, in the analyst verification stage of the detector. Green in the bottom evaluation line indicates true and red indicates false detections.

Underwater Communications

Underwater communications sonars are used to transmit information, such as when used for acoustic telemetry. They are highly modulated signals that can sound like distorted voices (Figure 47) or other electronic transmissions (Figure 48). There were no detections for underwater communications during these recordings periods.

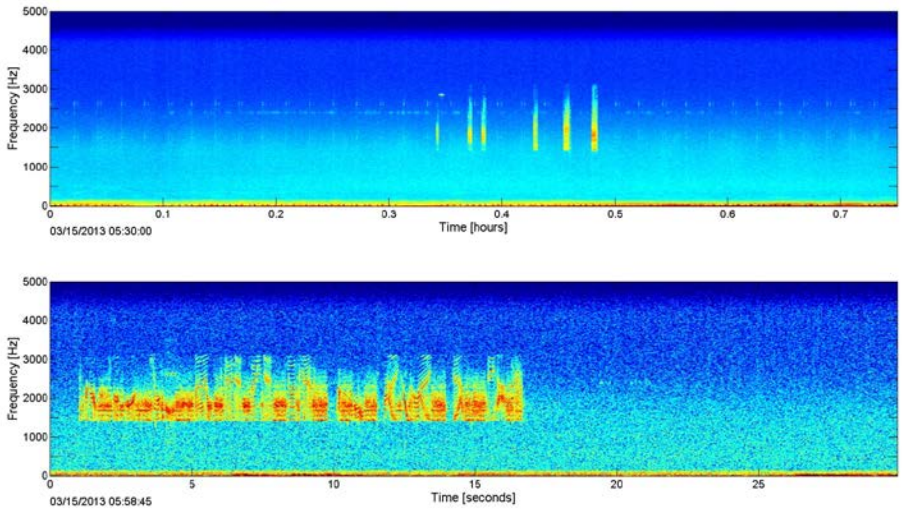


Figure 46. Underwater communications in LTSA (top) and spectrogram (bottom) at a HARP recording site in southern California.

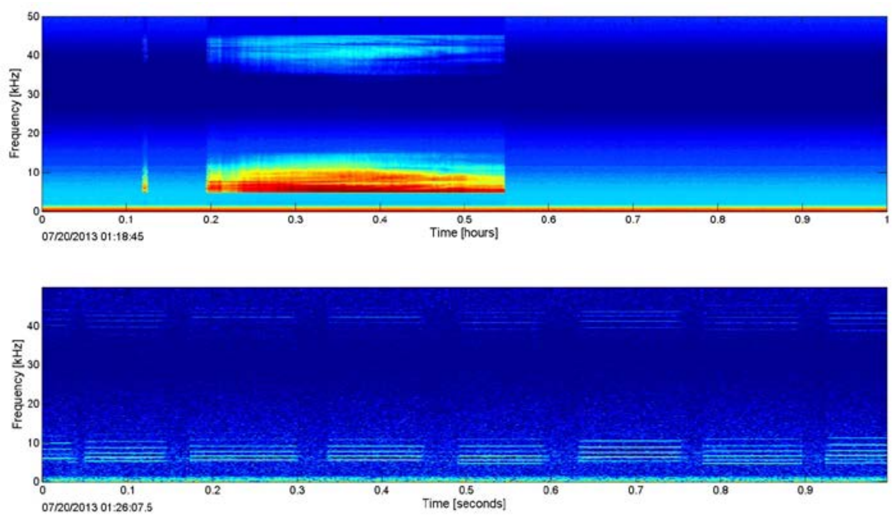


Figure 47. Electronic transmissions in the LTSA (top) and spectrogram (bottom) at a HARP recording site in southern California.

Results

The results of acoustic data analysis at site C from May-June 2013 and February-August 2014 are summarized. We describe ambient noise, the seasonal occurrence and relative abundance of marine mammal acoustic signals and anthropogenic sounds.

Mysticetes

Three known baleen whale species were recorded between May 2013 and August 2014: fin whales, humpback whales, and minke whales. In addition, the 5-pulse signal was recorded throughout 2014. More details of each species' presence at these sites are given below.

Fin Whales

- Fin whale 20 Hz calls, associated with singing and call-countercall among animals, were detected in late-February 2014 (Figure 49).
- There was no discernible diel period for fin whale 20 Hz calls (Figure 50).

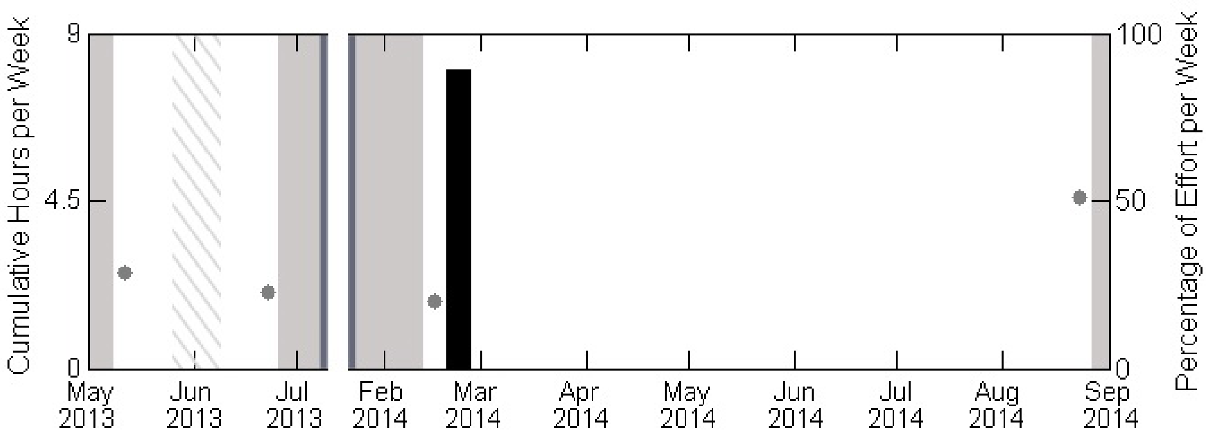


Figure 48. Weekly presence of fin whale 20 Hz calls between May-June 2013 and February-August 2014 at site C (black bars). Gray dots represent percent of effort per week in weeks with less than 100% recording effort, and gray shading represents periods with no data recorded due to technical issues with the HARP. Where gray dots or shading are absent, full recording effort occurred for the entire week. Gray diagonal bars represent the time period during which there was intermittent recording May 23 through June 7, 2013 reducing the weekly effort. A break in the plot between July 2013 and February 2014 represents the time period during which there was data loss from a technical malfunction.

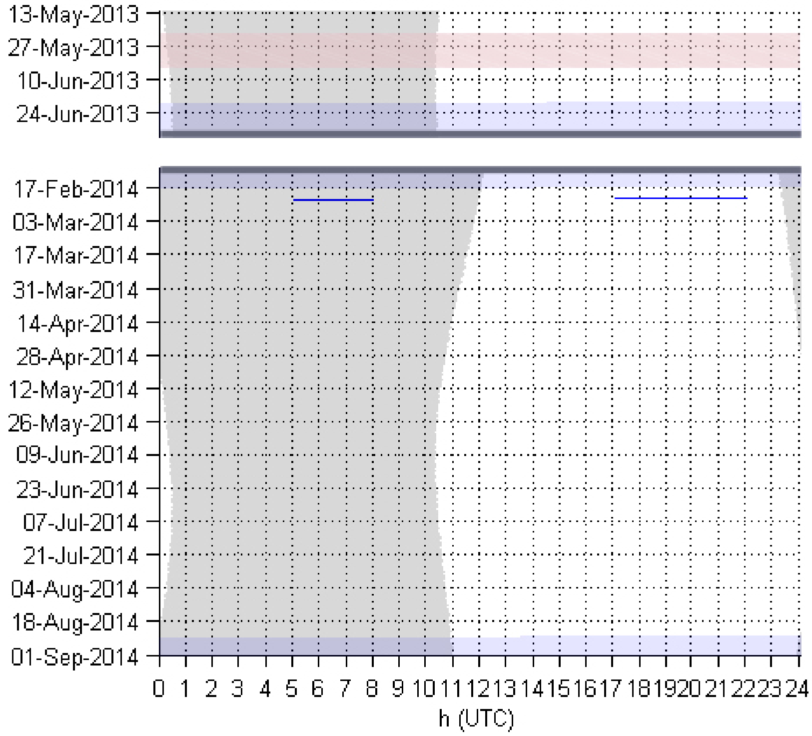


Figure 49. Fin whale 20 Hz calls in hourly bins at site C (blue bars). Gray vertical shading denotes nighttime. Light purple horizontal shading denotes absence of acoustic data (June 21, 2013 through February 16, 2014) and pink horizontal shading represents time period during which recordings were effectively duty-cycled due to malfunctions (May 23 through June 7, 2013).

Humpback Whales

- Humpback whales were detected February through June 2014 with a peak in detections in late March 2014 (Figure 51).
- There was slightly more calling during daytime hours (Figure 52).
- These results are similar to earlier reports (Debich *et al.*, 2013; Johnson *et al.*, 2014).

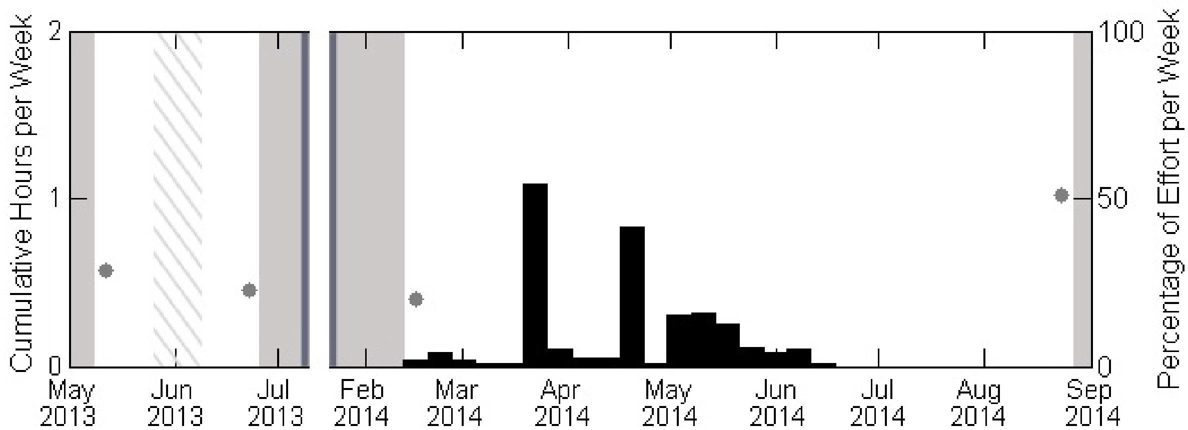


Figure 50. Weekly presence of humpback whale calls between May-June 2013 and February-August 2014 at site C. Effort markings are described in Figure 49.

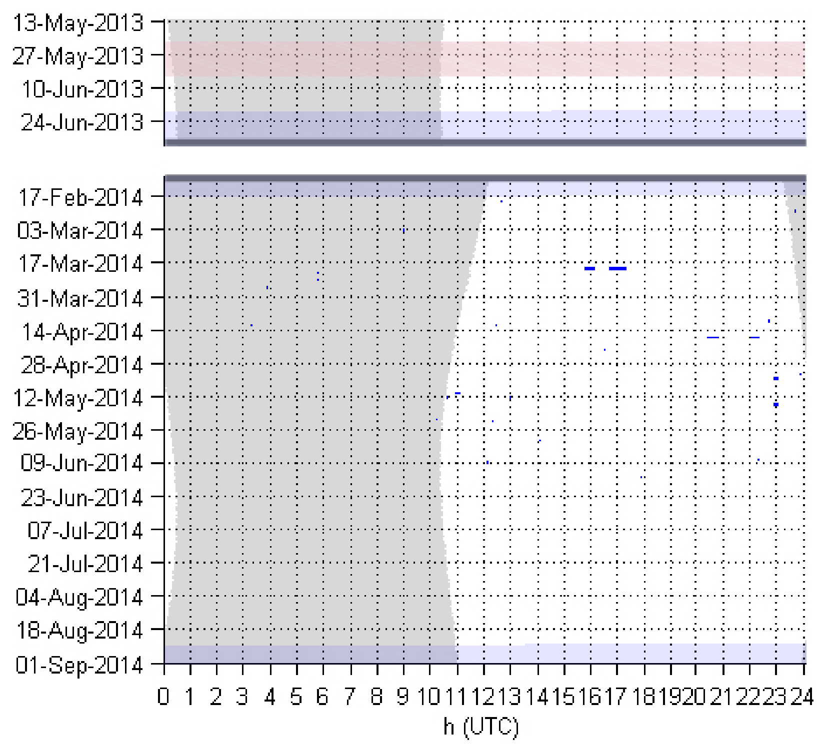


Figure 51. Humpback whale calls in one-minute bins at site C. Effort markings as in Figure 50.

Minke Whales

- Minke pulse trains were detected in February and March 2014. (Figure 53).
- There was no discernible diel pattern for minke pulse trains (Figure 54).

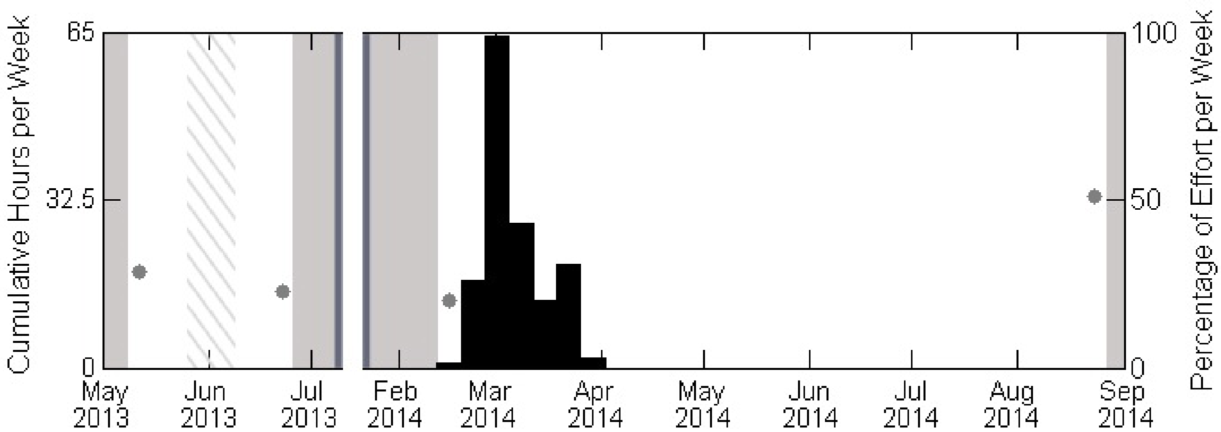


Figure 52. Weekly presence of minke whale pulse trains between May-July 2013 and February-August 2014 at site C. Effort markings are described in Figure 49.

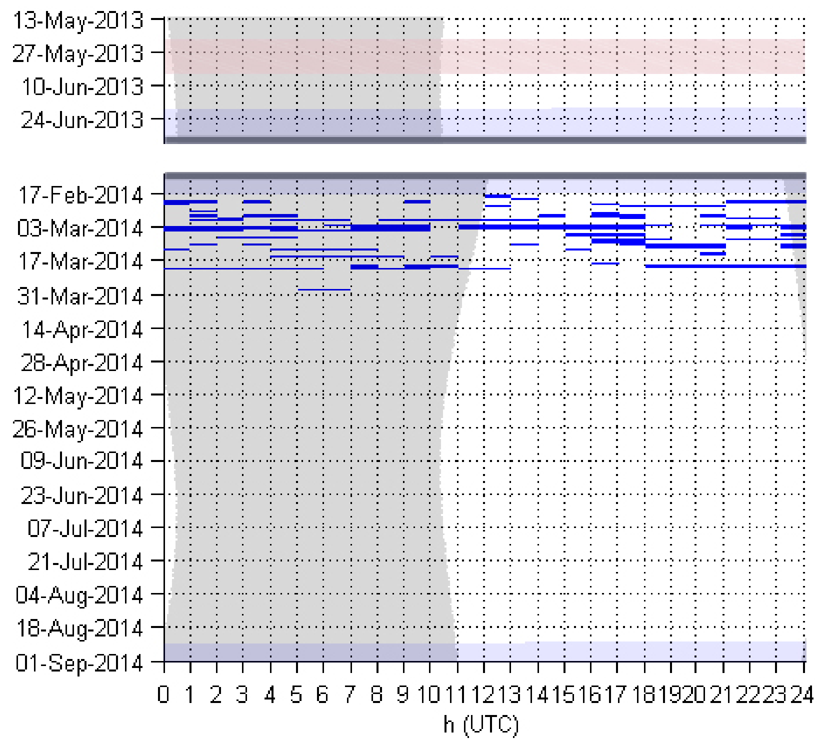


Figure 53. Minke whale pulse trains in hourly bins at site C. Effort markings as in Figure 50.

5-Pulse Signal

The 5-pulse signal was detected throughout 2014.

- A peak in 5-pulse signal detections occurred in July 2014 (Figure 55).
- Most 5-pulse signal detections occurred slightly before sunset and during nighttime hours. (Figure 56).

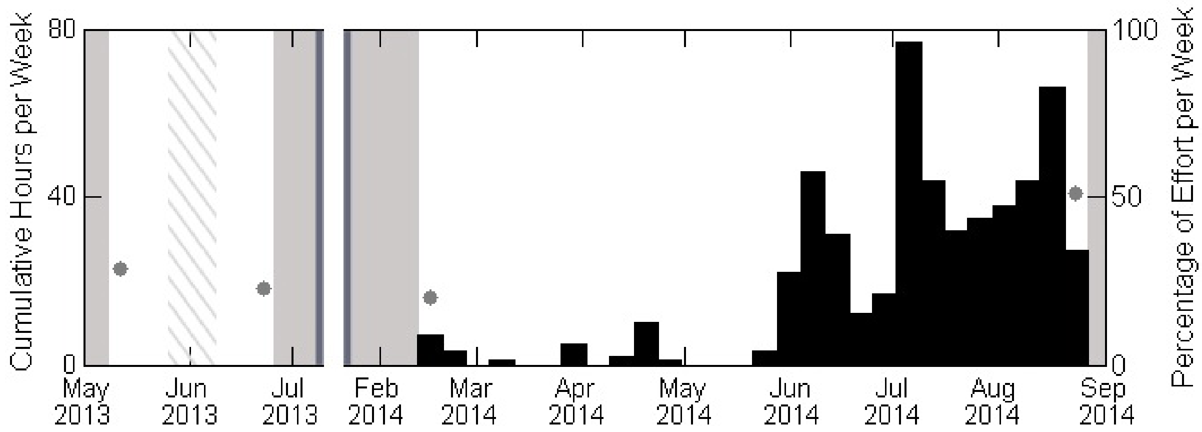


Figure 54. Weekly presence of the 5-pulse signal between May-July 2013 and February-August 2014 at site C. Effort markings are described in Figure 49.

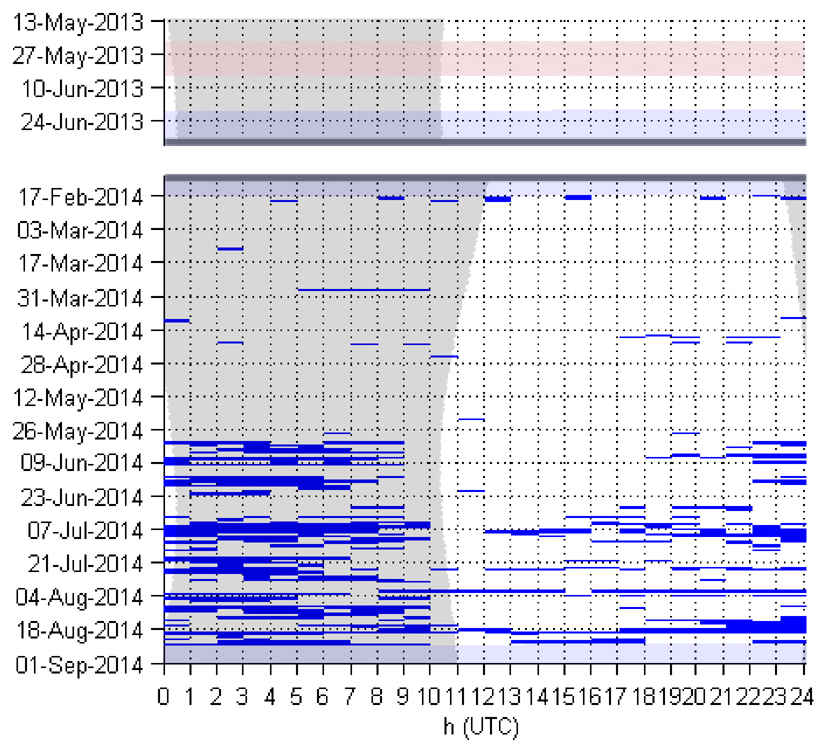


Figure 55. 5-pulse signals in hourly bins at site C. Effort markings as in Figure 50.

Odontocetes

Clicks from Risso's dolphins and eight click types that are not yet assigned to a species were detected. More details of each species' presence at these sites are given below.

Unidentified Odontocetes

Signals that had characteristics of odontocete sounds (both whistles and clicks), but could not be classified to species were grouped together as unidentified odontocetes. The plots include all CT acoustic encounters detailed below.

- Absolute numbers of unidentified odontocete click detections in 2013 and 2014 were not comparable due to the masking of acoustic encounters of delphinids with snapping shrimp in 2013 and reduced recording effort during some time periods.
- Unidentified odontocete clicks were detected throughout 2013 and 2014. A peak in detections occurred in February 2014 (Figure 57).
- There was a distinct diel pattern for unidentified clicks, with more echolocation activity at night, likely due to nighttime foraging (Figure 58).
- Unidentified odontocete whistle detections occurred throughout the recordings, with a peak in detections occurring March 2014 (Figure 59).
- There was no discernible diel pattern for unidentified odontocete whistles (Figure 60).

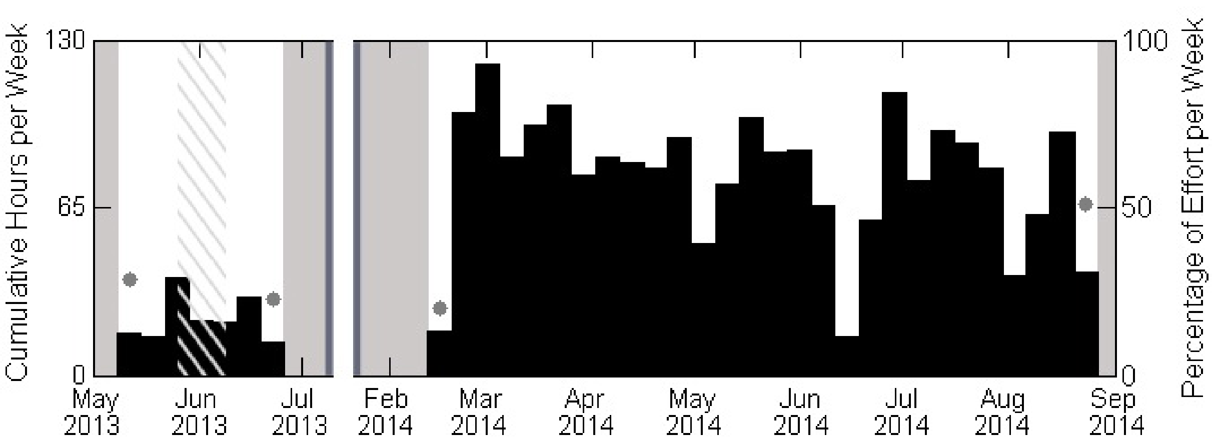


Figure 56. Weekly presence of unidentified odontocete clicks between May-July 2013 and February-August 2014 site C. Effort markings are described in Figure 49.

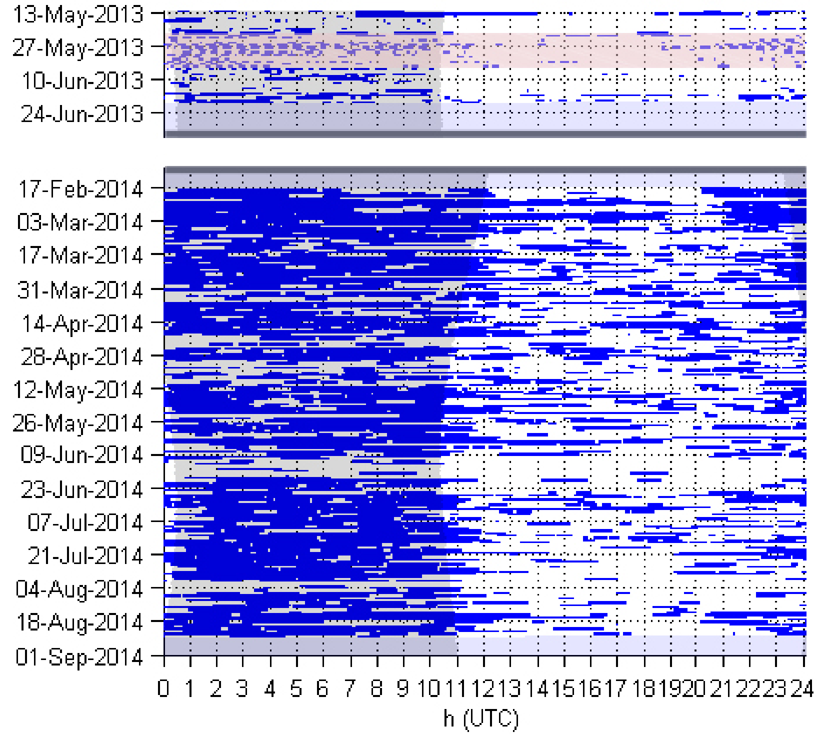


Figure 57. Unidentified odontocete clicks in one-minute bins at site C. Effort as in Figure 50.

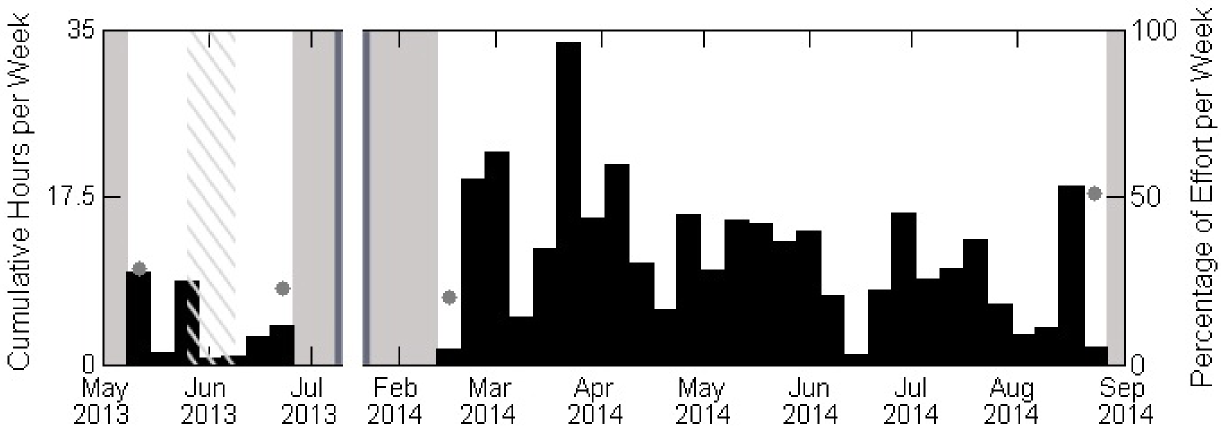


Figure 58. Weekly presence of unidentified odontocete whistles between May-July 2013 and February-August 2014 site C. Effort markings are described in Figure 49.

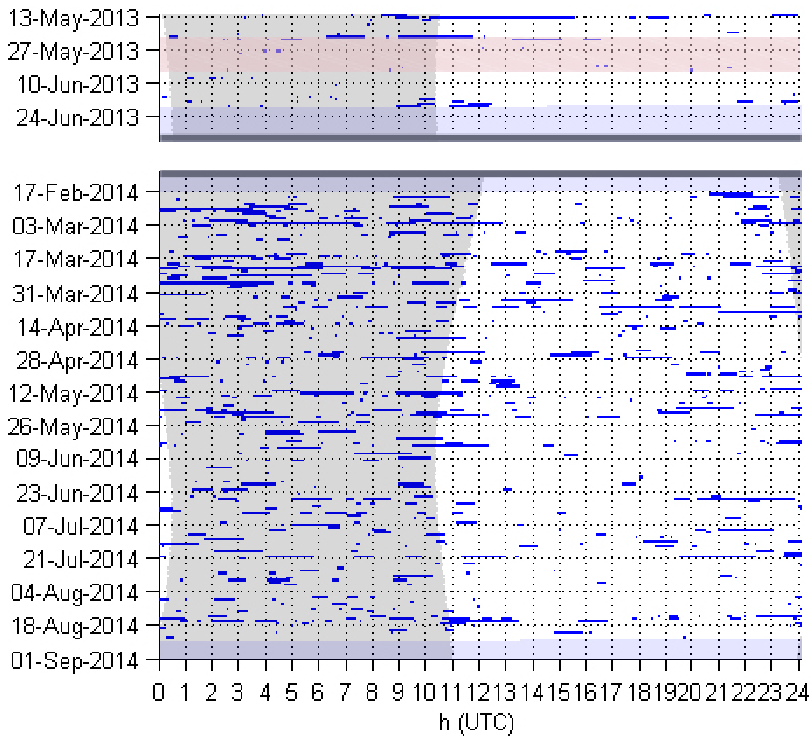


Figure 59. Unidentified odontocete whistles in one-minute bins at site C. Effort as in Figure 50.

Unidentified Odontocete Whistles Less Than 5 kHz
Whistles less than 5 kHz were detected in low numbers.

- Unidentified whistles less than 5 kHz were detected intermittently throughout the recordings. A peak in detections occurred in July 2014 (Figure 61).
- There was no discernible diel pattern for these detections (Figure 62).
- Pilot whales most likely produced these whistles, though it is possible they are from other blackfish that have overlapping distributions.

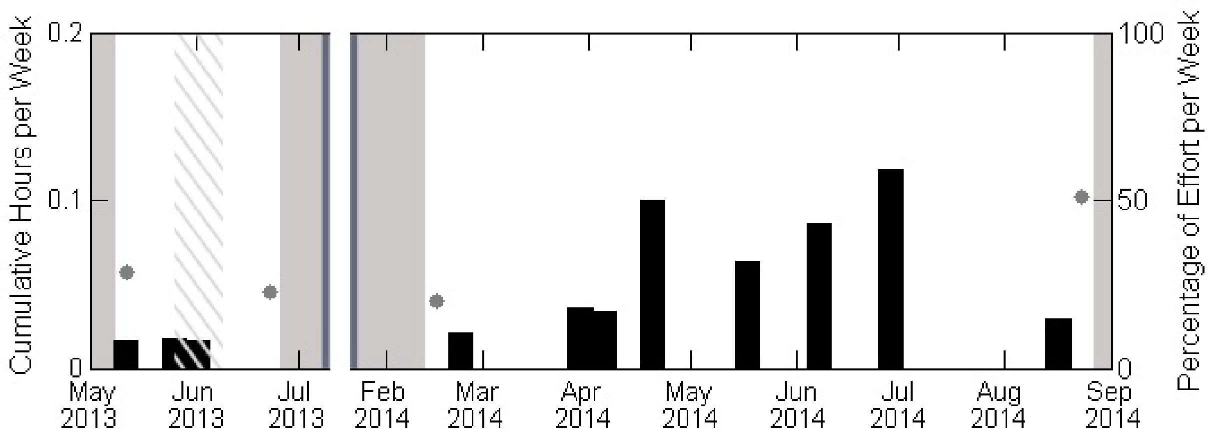


Figure 60. Weekly presence of unidentified odontocete whistles less than 5 kHz between May-July 2013 and February-August 2014 site C. Effort markings are described in Figure 49.

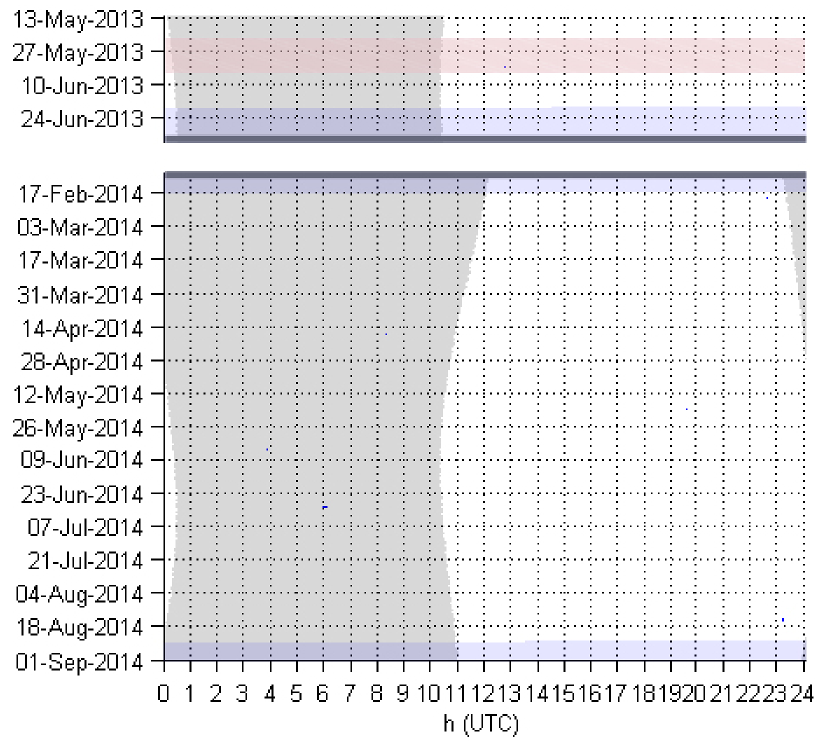


Figure 61. Unidentified odontocete whistles less than 5 kHz in one-minute bins at site C. Effort markings as in Figure 50.

Risso’s Dolphins

Risso’s dolphin echolocation clicks were detected in low numbers.

- Risso’s dolphin echolocation click detections were limited to a single bout on July 3, 2014 (Figure 63).
- There were too few Risso’s dolphin detections to determine a diel pattern (Figure 64).
- The few Risso’s dolphin clicks that were detected in this recording period had peaks at 23, 26, 30, and 36 kHz.

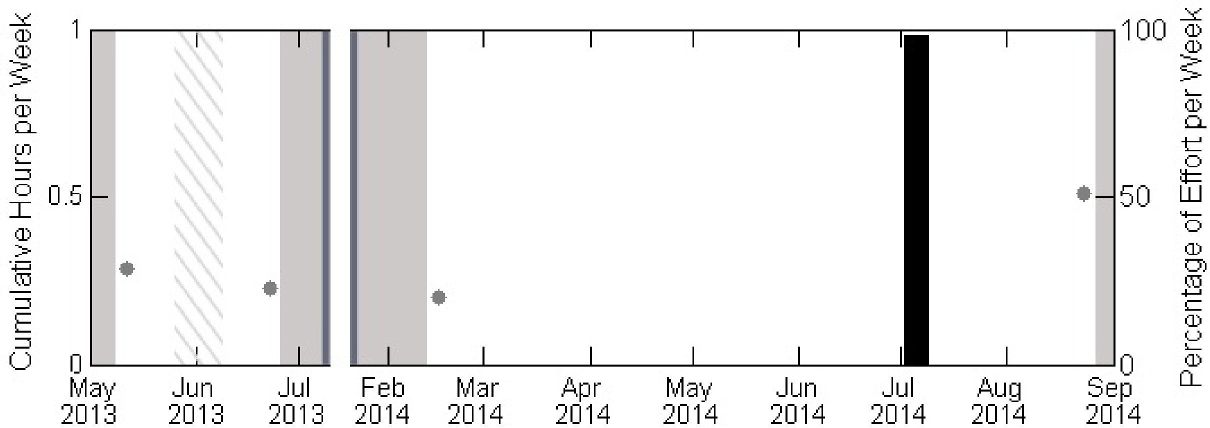


Figure 62. Weekly presence of Risso’s dolphin echolocation clicks between May-July 2013 and February-August 2014 site C. Effort markings are described in Figure 49.

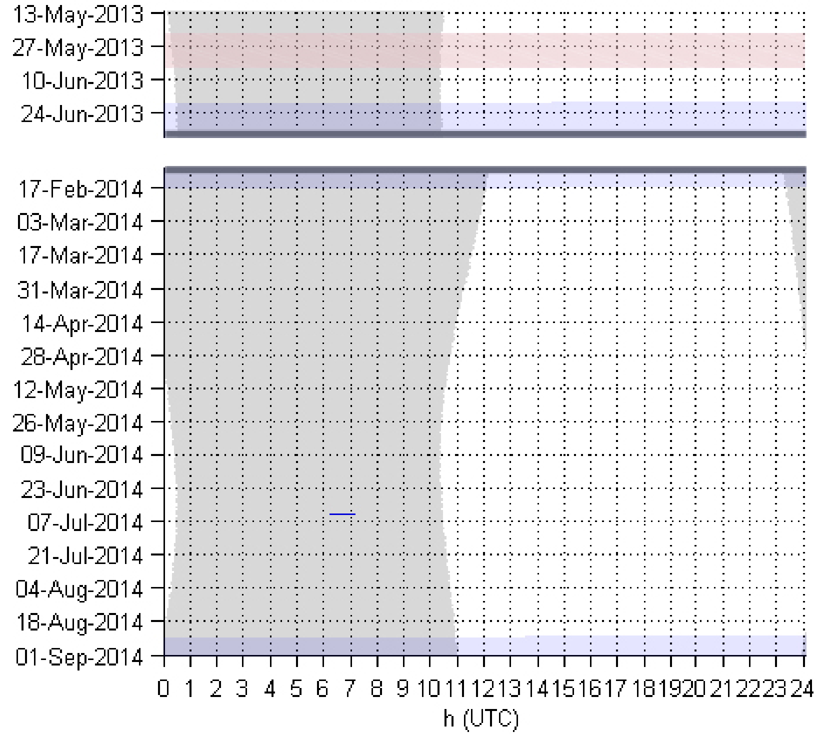


Figure 63. Risso's dolphin echolocation clicks in one-minute bins between May 2013 and August 2014 at site C. Effort markings as in Figure 50.

Click Type 17

- CT 17 was detected in low numbers March through July 2014 and was one of the least prevalent click types (Figure 65).
- There was no discernible diel pattern for CT 17 (Figure 66).

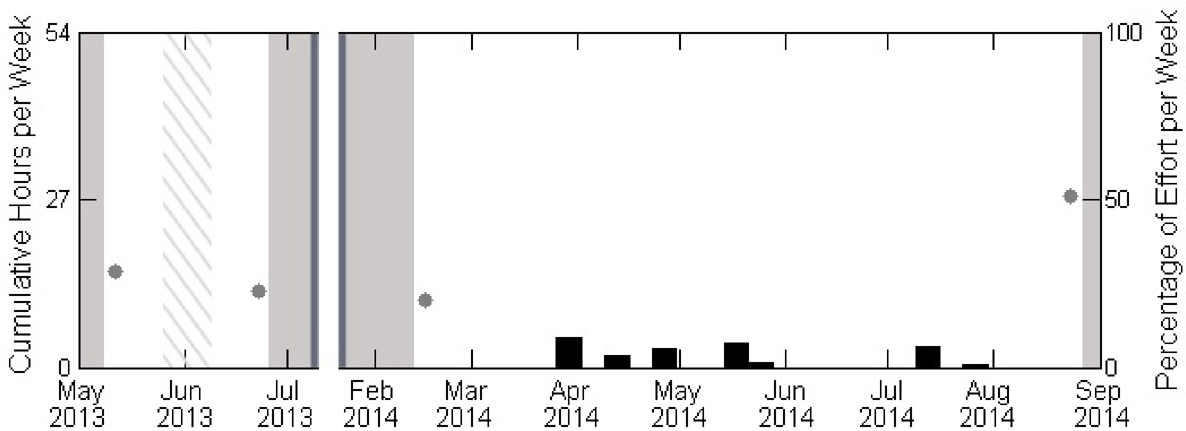


Figure 64. Weekly presence of CT 17 between May-July 2013 and February-August 2014 site C. Effort markings are described in Figure 49.

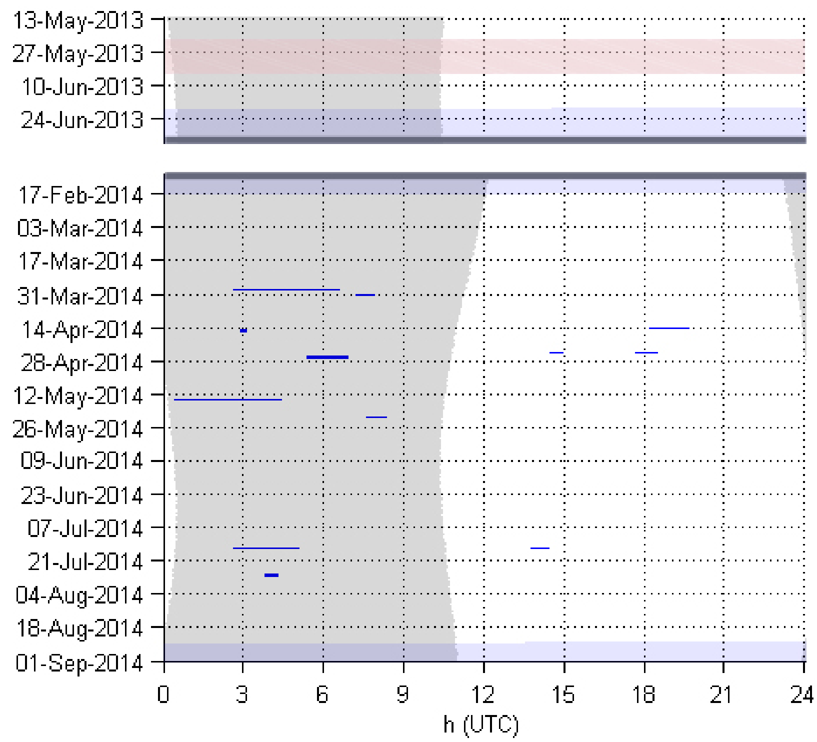


Figure 65. CT 17 in one-minute bins between May 2013 and August 2014 at site C. Effort markings as in Figure 50.

Click Type 22

- CT 22 was also detected in low numbers May through June 2013 and February through June 2014 (Figure 67).
- There was no discernible diel pattern for CT 22 (Figure 68).

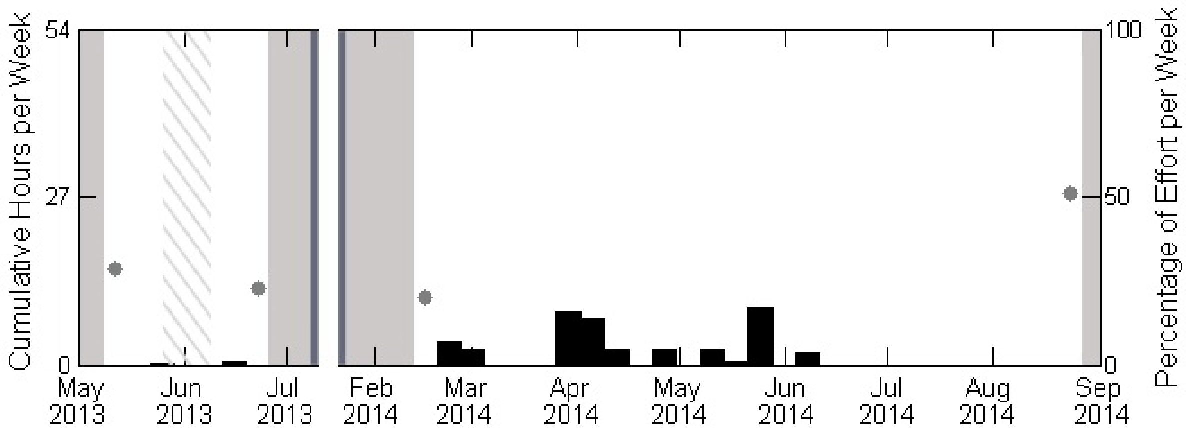


Figure 66. Weekly presence of CT 22 between May-July 2013 and February-August 2014 site C. Effort markings are described in Figure 49.

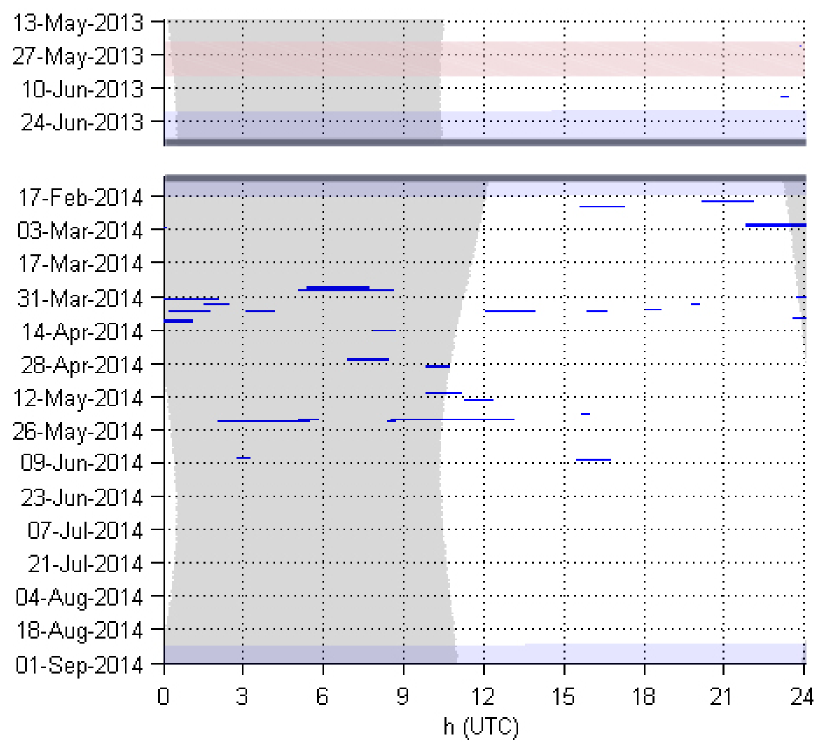


Figure 67. CT 22 in one-minute bins between May 2013 and August 2014 at site C. Effort markings as in Figure 50.

Click Type 25

- CT 25 was detected May through June 2013, and February through August 2014 (Figure 69).
- There was no discernible diel pattern for CT 25 (Figure 70).

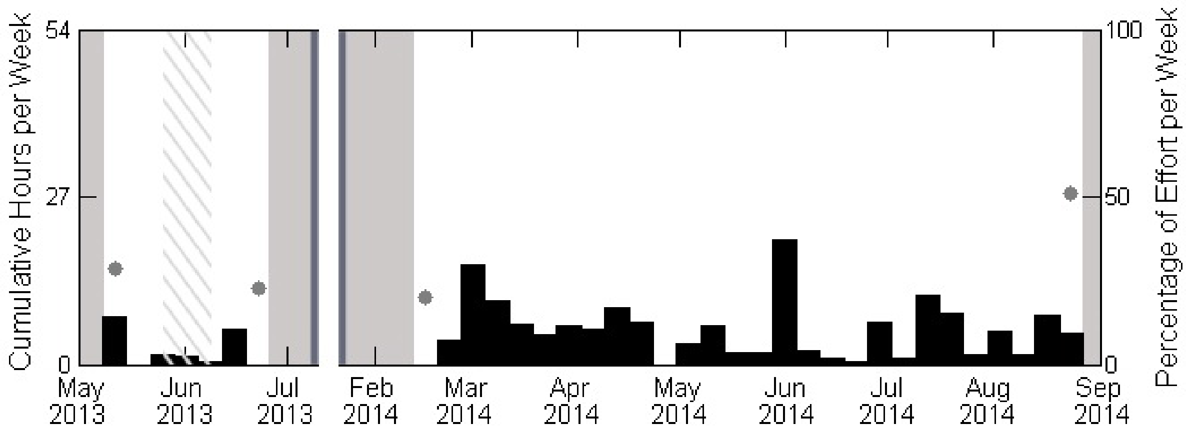


Figure 68. Weekly presence of CT 25 between May-July 2013 and February-August 2014 site C. Effort markings are described in Figure 49.

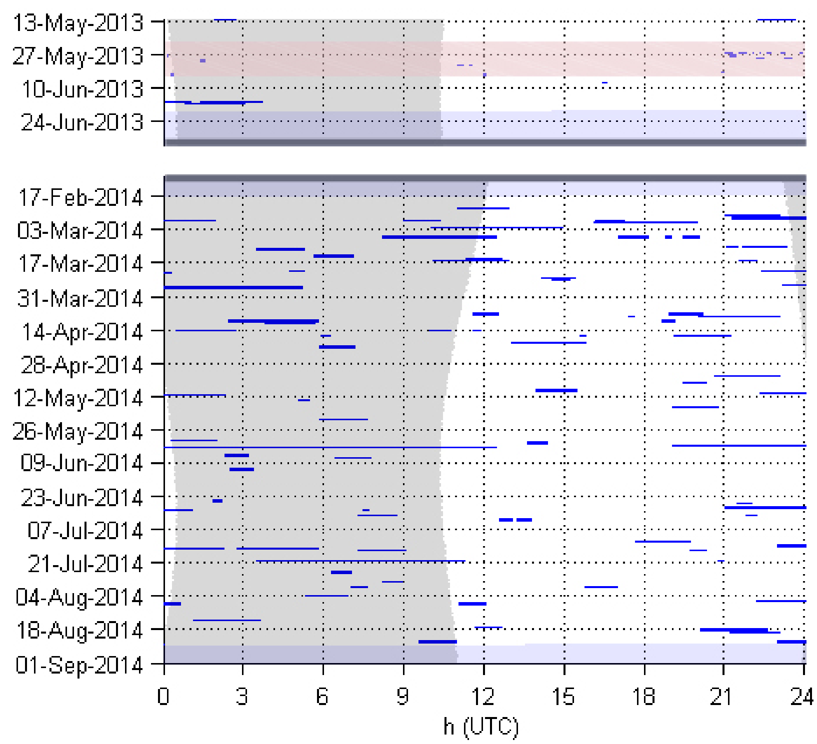


Figure 69. CT 25 in one-minute bins between May 2013 and August 2014 at site C. Effort markings as in Figure 50.

Click Type 26

- CT 26 was one of the most commonly detected click types and was detected May through June 2013 and February through August 2014 (Figure 71).
- The majority of CT 26 detections occurred during nighttime hours, indicating foraging at night (Figure 72).

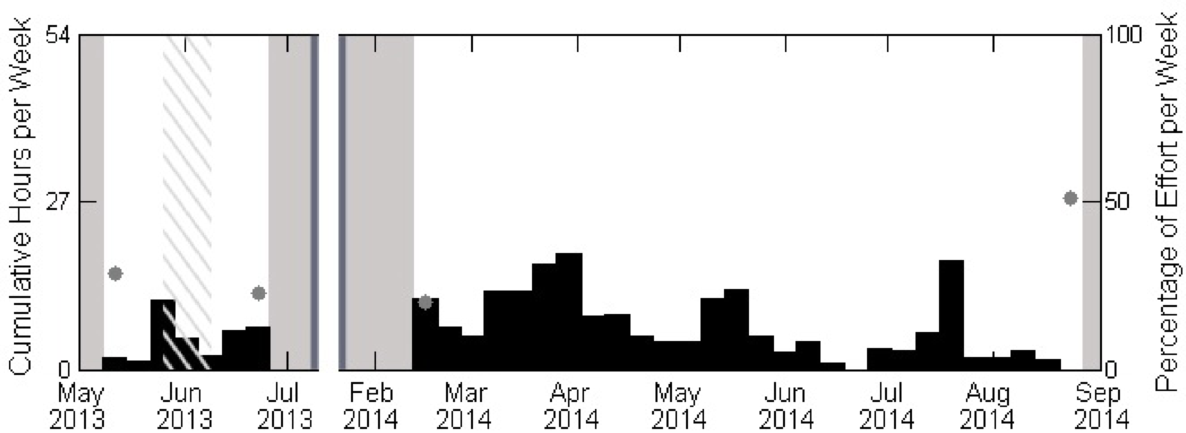


Figure 70. Weekly presence of CT 26 between May-June 2013 and February-August 2014 site C. Effort markings are described in Figure 49.

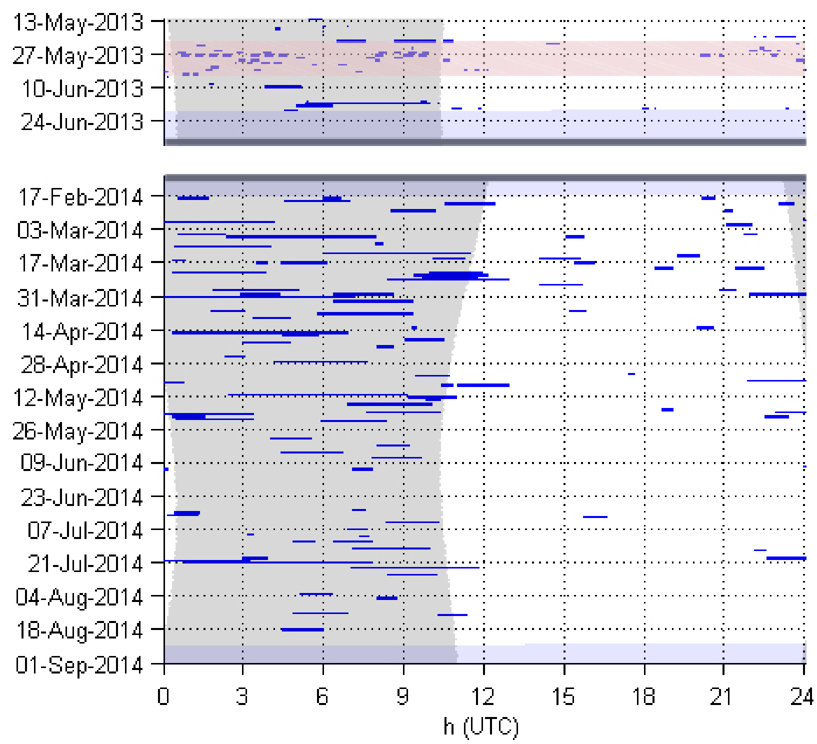


Figure 71. CT 26 in one-minute bins between May 2013 and August 2014 at site C. Effort markings as in Figure 50.

Click Type 27

- CT 27 was the most commonly detected click type. This signal was detected May through June 2013 and February through August 2014 with a peak in detections in February 2014 (Figure 73).
- While CT 27 occurred during the day and night, detections were more prevalent at night, suggesting nighttime foraging (Figure 74).

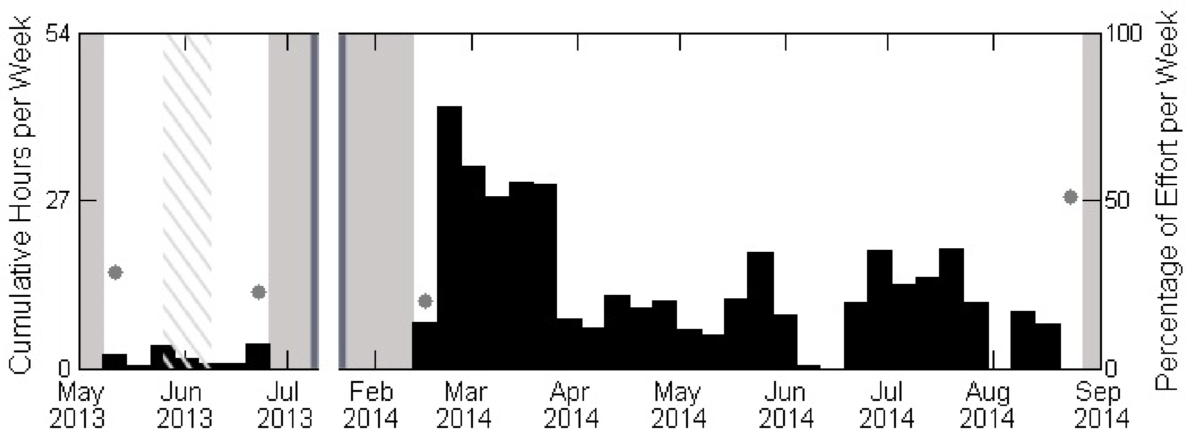


Figure 72. Weekly presence of CT 27 between May-July 2013 and February-August 2014 site C. Effort markings are described in Figure 49.

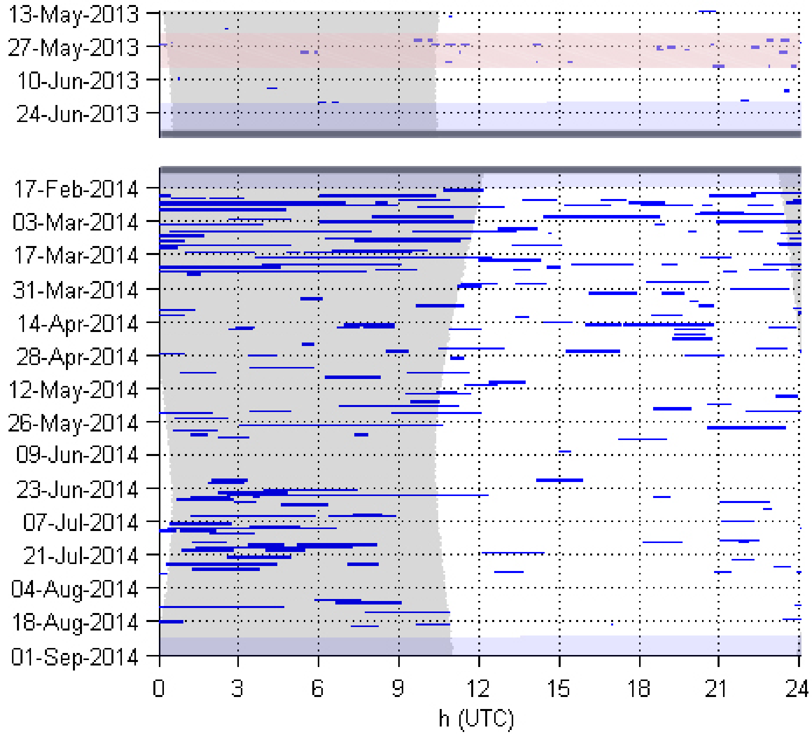


Figure 73. CT 27 in one-minute bins between May 2013 and August 2014 at site C. Effort markings as in Figure 50.

Click Type 27A

- CT 27A was detected in low numbers May through June 2013 and February through August 2014 (Figure 75).
- There was no discernible diel pattern for CT 27A (Figure 76).

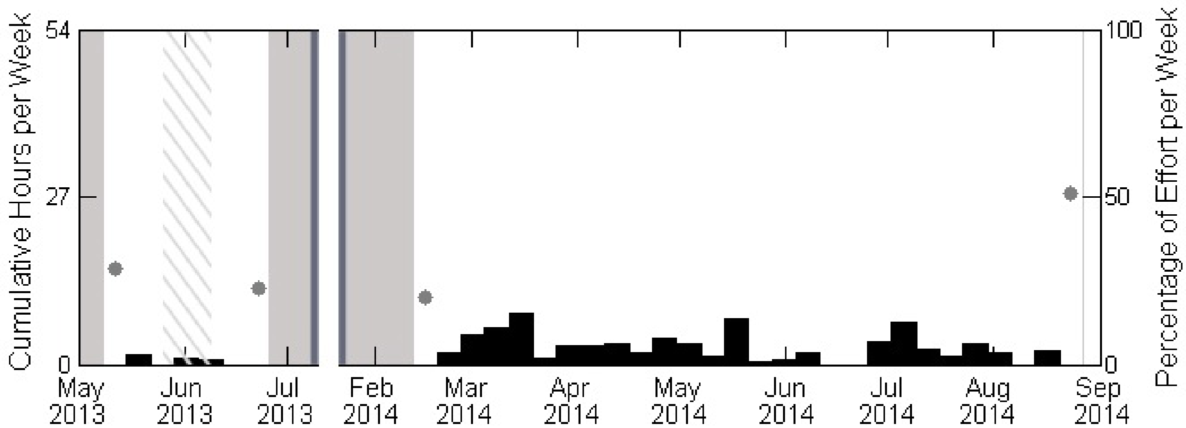


Figure 74. Weekly presence of CT 27A between May-July 2013 and February-August 2014 site C. Effort markings are described in Figure 49.

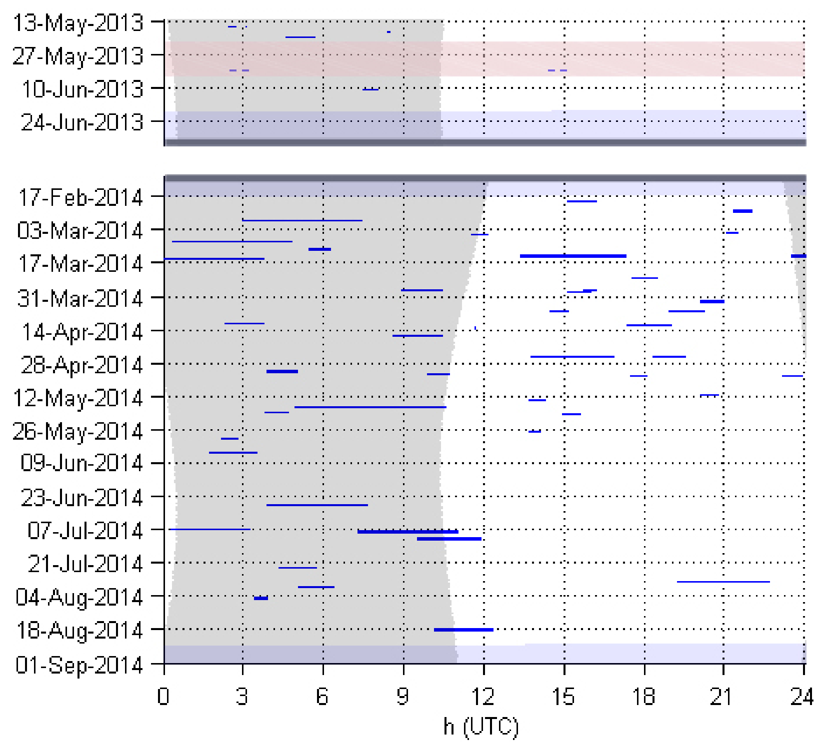


Figure 75. CT 27A in one-minute bins between May 2013 and August 2014 at site C. Effort markings as in Figure 50.

Click Type 30

- CT 30 was detected in low numbers May through June 2013 and February through August 2014 (Figure 77).
- CT 30 detections showed a nighttime diel pattern, suggesting foraging at night (Figure 78).

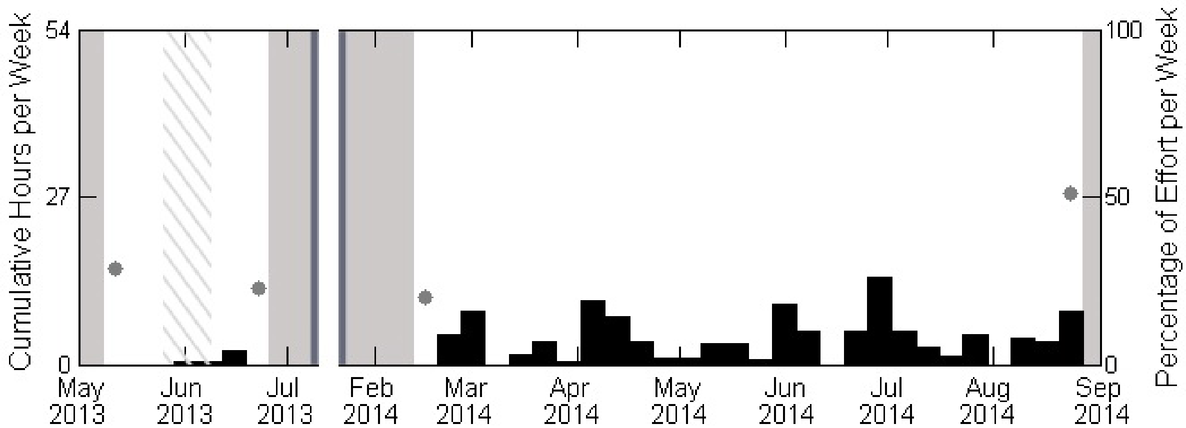


Figure 76. Weekly presence of CT 30 between May-July 2013 and February-August 2014 site C. Effort markings are described in Figure 49.

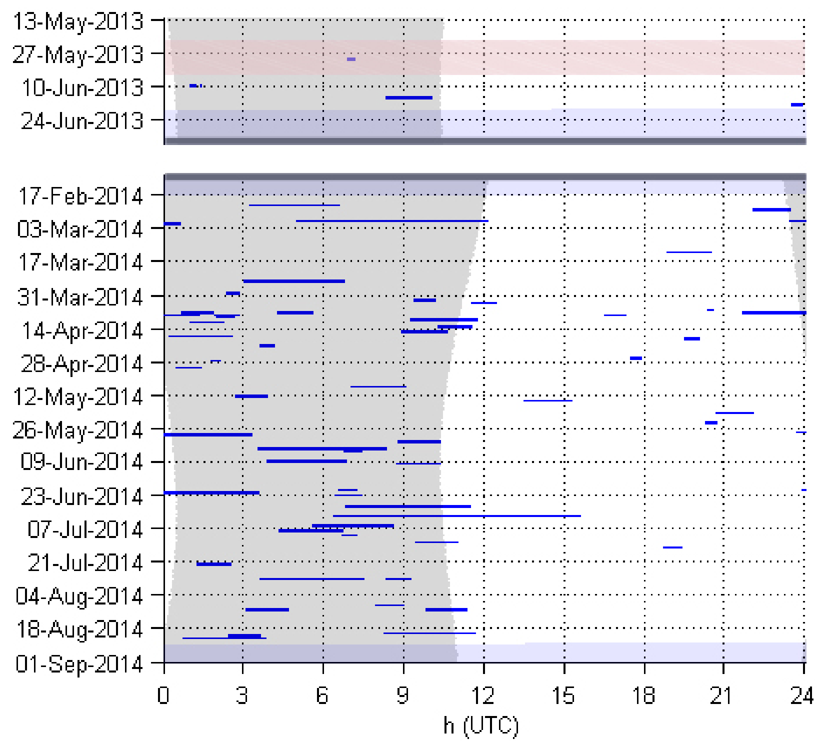


Figure 77. CT 30 in one-minute bins between May 2013 and August 2014 at site C. Effort markings as in Figure 50.

Click Type 32

- CT 32 was detected May through June 2013 and sporadically from February through August 2014 (Figure 79).
- The majority of CT 32 detections occurred at night, suggesting nighttime foraging (Figure 80).

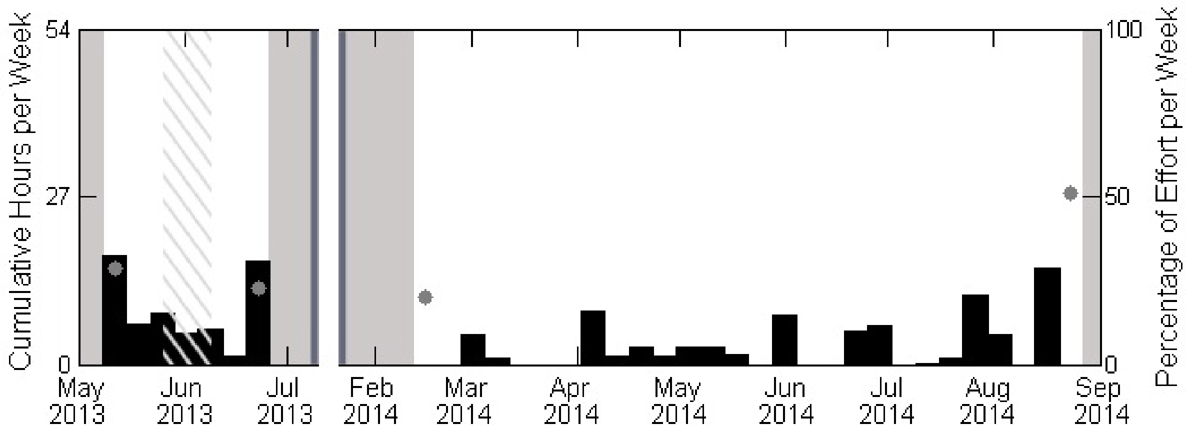


Figure 78. Weekly presence of CT 32 between May-July 2013 and February-August 2014 site C. Effort markings are described in Figure 49.

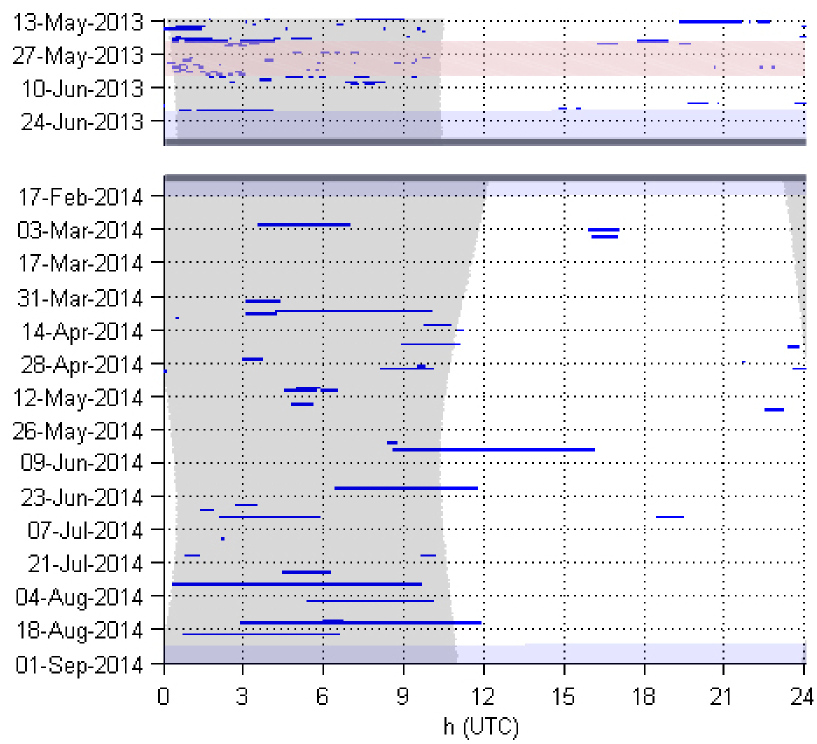


Figure 79. CT 32 in one-minute bins between May 2013 and August 2014 at site C. Effort markings as in Figure 50.

Anthropogenic Sounds

Three types of anthropogenic sounds were detected between May-June 2013 and February-August 2014: broadband ship noise, MFA sonar, and echosounders.

Broadband Ship Noise

Broadband ship noise was a common anthropogenic sound.

- Broadband ship noise was detected throughout the recordings. A peak in detections occurred in late May 2014 (Figure 81).
- There was no discernible diel pattern for broadband ships (Figure 82).

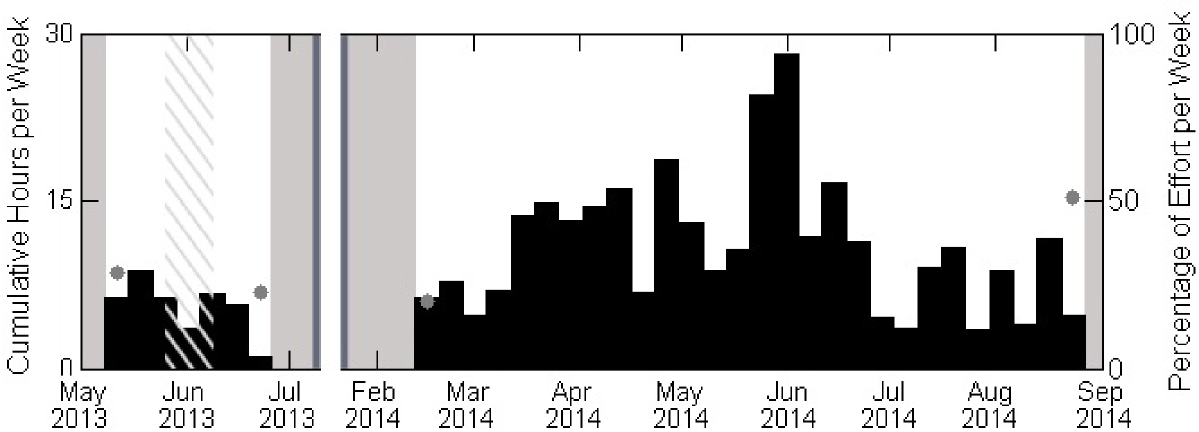


Figure 80. Weekly presence of broadband ships between May-July 2013 and February-August 2014 at site C. Effort markings are described in Figure 49.

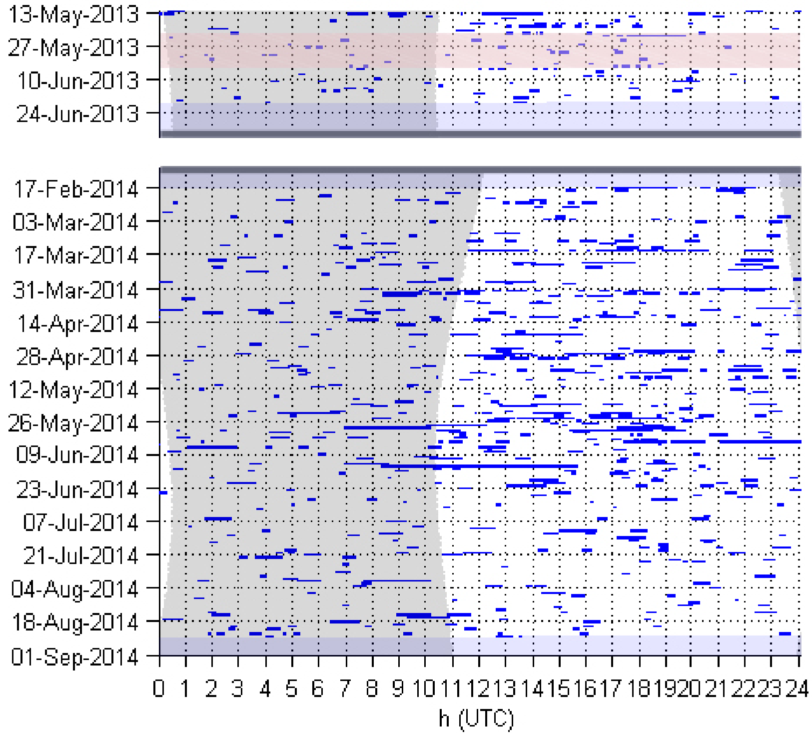


Figure 81. Broadband ship noise in one-minute bins at site C. Effort markings as in Figure 50.

MFA Sonar

MFA sonar was a common anthropogenic sound detected during these deployments. Sonar usage outside of designated major exercises is likely attributable to unit-level training. MFA sonar was detected intermittently with peaks in June (less than 5 kHz) and May (more than 5 kHz). There was no apparent diel pattern for MFA sonar detections (Figures 84 and 86).

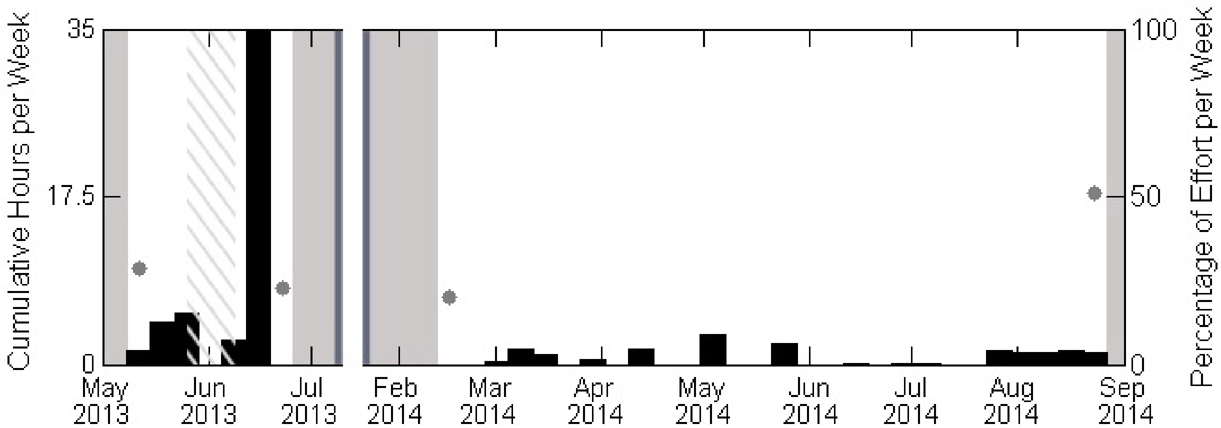


Figure 82. Weekly presence of MFA sonar less than 5 kHz between May-June 2013 and February-August 2014 at site C. Effort markings are described in Figure 49.

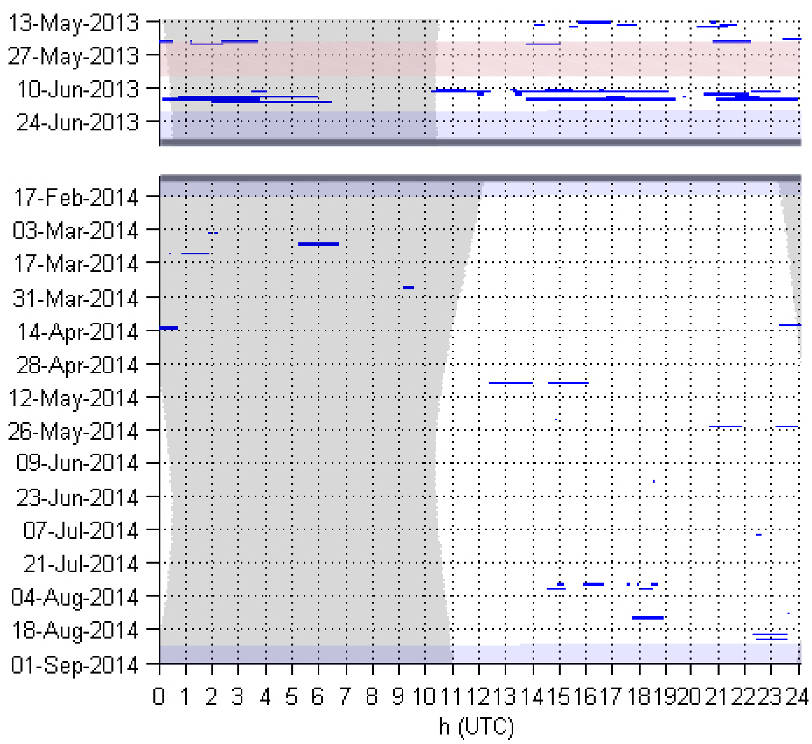


Figure 83. MFA sonar less than 5 kHz signals in one-minute bins at site C. Effort markings as in Figure 50.

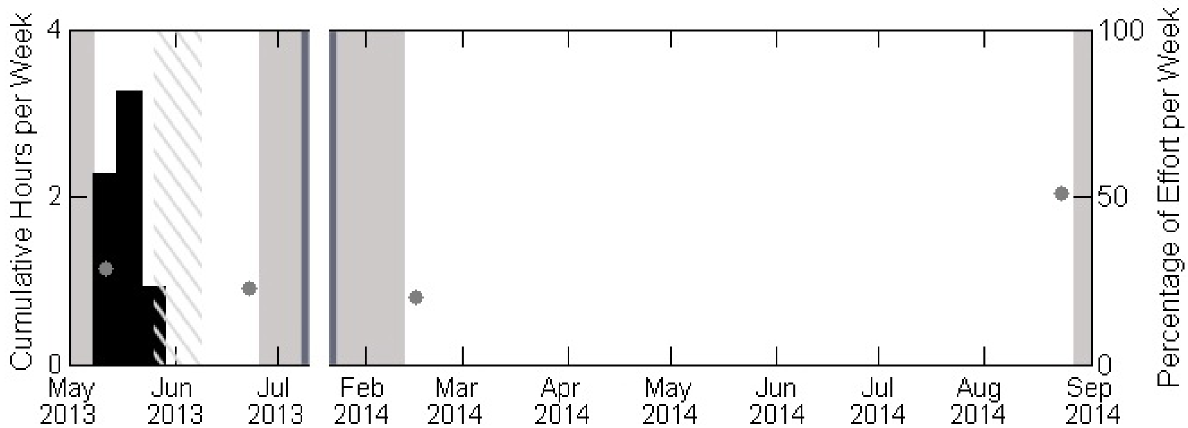


Figure 84. Weekly presence of MFA sonar greater than 5 kHz between May-June 2013 and February-August 2014 at site C. Effort markings are described Figure 49.

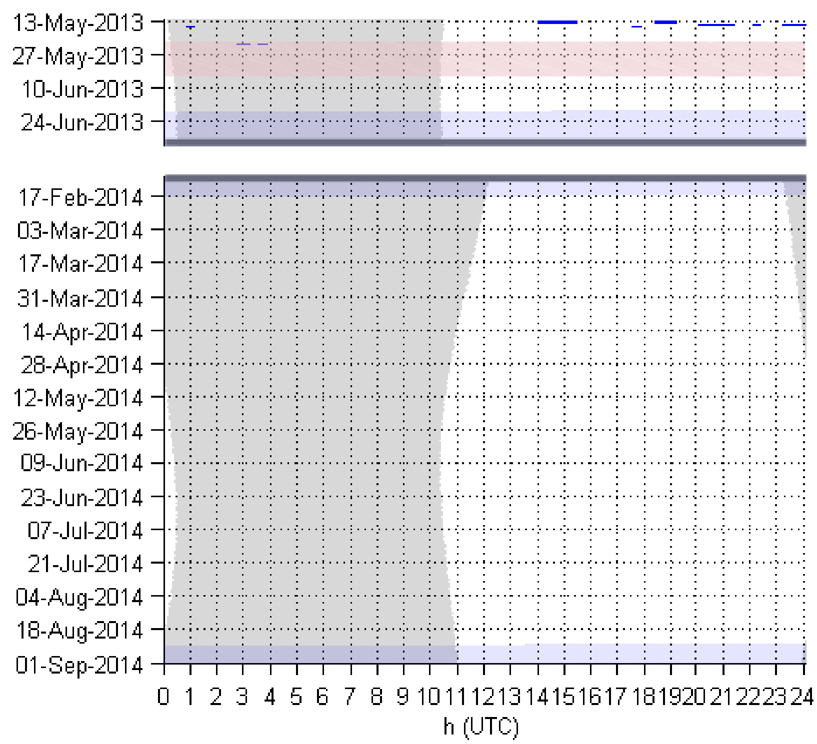


Figure 85. MFA sonar greater than 5 kHz signals in one-minute bins at site C. Effort markings as in Figure 50.

Echosounders

Echosounder pings from a variety of frequencies were detected.

- Echosounder pings were prevalent throughout the recordings. A slight peak in detections occurred in May 2013 (Figure 87).
- The majority of echosounder pings occurred during daytime hours (Figure 88).

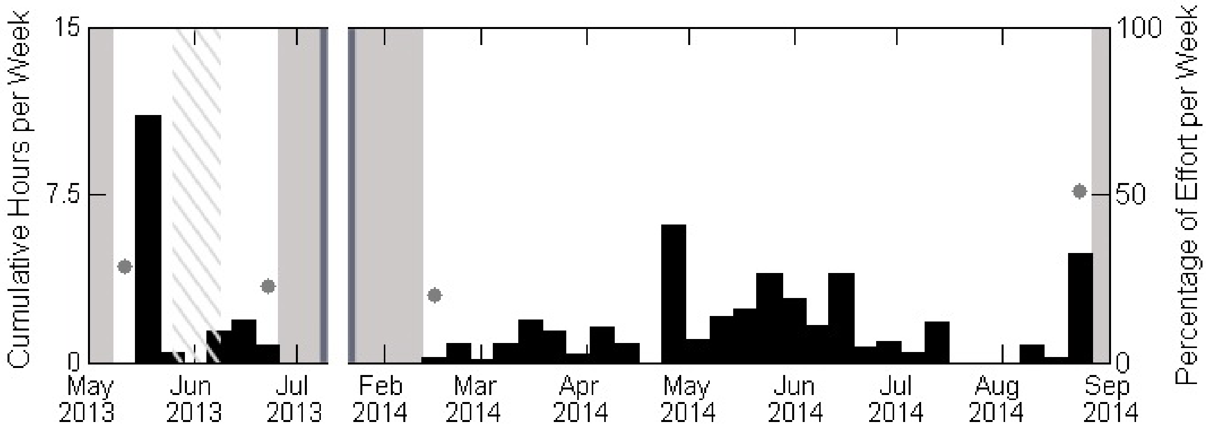


Figure 86. Weekly presence of echosounders between May-June 2013 and February-August 2014 at site C. Effort markings are described in Figure 49.

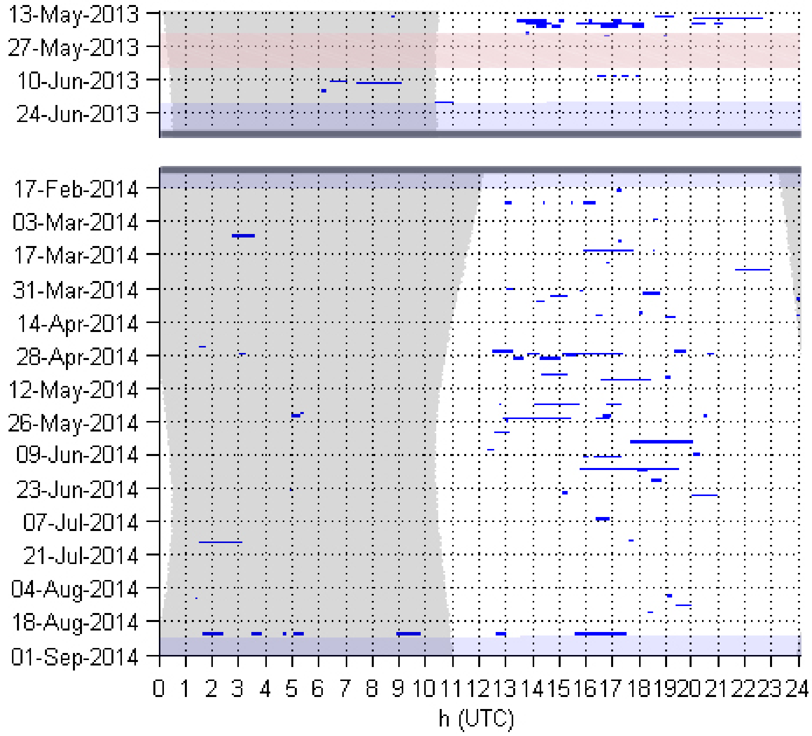


Figure 87. Echosounder detections in one-minute bins at site C. Effort markings as in Figure 50.

References

Baumann-Pickering, S., McDonald, M. A., Simonis, A. E., Solsona Berga, A., Merkens, K. P. B., Oleson, E. M., Roch, M. A., Wiggins, S. M., Rankin, S., Yack, T. M., and Hildebrand, J. A. (**2013**). "Species-specific beaked whale echolocation signals," Journal of the Acoustical Society of America **134**, 2293-2301.

Baumgartner, M. F., and Fratantoni, D. M. (**2008**). "Diel periodicity in both sei whale vocalization rates and the vertical migration of their copepod prey observed from ocean gliders," Limnology and Oceanography **53**, 2197-2209.

Baumgartner, M. F., Van Parijs, S. M., Wenzel, F. W., Tremblay, C. J., Esch, H. C., and Warde, A. M. (**2008**). "Low frequency vocalizations attributed to sei whales (*Balaenoptera borealis*)," Journal of the Acoustical Society of America **124**, 1339-1349.

Debich, A. J., Baumann-Pickering, S., Širović, A., Buccowich, J. S., Gentes, Z. E., Gottlieb, R. S., Johnson, S. C., Kerosky, S. M., Roche, L. K., Thayre, B. J., Trickey, J. S., Wiggins, S. M., Hildebrand, J. A., Hodge, L. E. W., and Read, A. J. (**2014**). "Passive Acoustic Monitoring for Marine Mammals in the Cherry Point OPAREA 2011-2012," (Scripps Institution of Oceanography, Marine Physical Laboratory, La Jolla, CA), p. 83.

Debich, A. J., Baumann-Pickering, S., Širović, A., Kerosky, S. M., Roche, L. K., Johnson, S. C., Gottlieb, R. S., Gentes, Z. E., Wiggins, S. M., and Hildebrand, J. A. (**2013**). "Passive Acoustic Monitoring for Marine Mammals in the Jacksonville Range Complex 2010-2011," (Scripps Institution of Oceanography, Marine Physical Laboratory, La Jolla, CA), p. 57.

Ford, J. B. (**1989**). "Acoustic behaviour of resident killer whales (*Orcinus orca*) off Vancouver Island, British Columbia," Canadian Journal of Zoology **67**, 727-745.

Ford, J. K. B., and Fisher, D. (**1983**). *Group-specific dialects of killer whales (Orcinus orca) in British Columbia* (Westview Press, Boulder, CO).

Gillespie, D., Caillat, M., Gordon, J., and White, P. (**2013**). "Automatic detection and classification of odontocete whistles," Journal of the Acoustical Society of America **134**, 2427-2437.

Gillespie, D., Dunn, C., Gordon, J., Claridge, D., Embling, C., and Boyd, I. (**2009**). "Field recordings of Gervais' beaked whales *Mesoplodon europaeus* from the Bahamas," Journal of the Acoustical Society of America **125**, 3428-3433.

Helble, T. A., Ierley, G. R., D'Spain, G. L., Roch, M. A., and Hildebrand, J. A. (**2012**). "A generalized power-law detection algorithm for humpback whale vocalizations," Journal of the Acoustical Society of America **131**, 2682-2699.

Johnson, M., Madsen, P. T., Zimmer, W. M. X., Aguilar de Soto, N., and Tyack, P. L. (**2004**). "Beaked whales echolocate on prey," Proceedings of the Royal Society B: Biological Sciences **271**, S383-S386.

Johnson, S. C., Širović, A., Buccowich, J. S., Debich, A. J., Roche, L. K., Thayre, B. J., Wiggins, S. M., Hildebrand, J. A., Hodge, L. E. W., and Read, A. J. (**2014**). "Passive Acoustic Monitoring for Marine Mammals in the Jacksonville Range Complex 2010," (Scripps Institution of Oceanography, Marine Physical Laboratory, La Jolla, CA), p. 26.

McDonald, M. A., Hildebrand, J. A., and Webb, S. C. (**1995**). "Blue and fin whales observed on a seafloor array in the Northeast Pacific," J. Acoust. Soc. Am. **98**, 712-721.

McDonald, M. A., Messnick, S. L., and Hildebrand, J. A. (**2006**). "Biogeographic characterisation of blue whale song worldwide: using song to identify populations," Journal of Cetacean Research and Management **8**, 55-65.

McKenna, M. F., Ross, D., Wiggins, S. M., and Hildebrand, J. A. (**2012**). "Underwater radiated noise from modern commercial ships," Journal of the Acoustical Society of America **131**, 92-103.

Mellinger, D. K., Carson, C. D., and Clark, C. W. (**2000**). "Characteristics of minke whale (*Balaenoptera acutorostrata*) pulse trains recorded near Puerto Rico," Marine Mammal Sciene **16**, 739-756.

Mellinger, D. K., and Clark, C. W. (**2003**). "Blue whale (*Balaenoptera musculus*) sounds from the North Atlantic," Journal of the Acoustical Society of America **114**, 1108-1119.
Mizroch, S. A., Rice, D. W., and Breiwick, J. M. (**1984**). "The sei whale, *Balaenoptera borealis*," Marine Fisheries Review **46**, 25-29.
Oleson, E. M., Barlow, J., Gordon, J., Rankin, S., and Hildebrand, J. A. (**2003**). "Low frequency calls of Bryde's whales," Marine Mammal Science **19**, 160-172.
Omura, H. (**1959**). "Bryde's whale from the coast of Japan," Scientific Reports of the Whales Research Institute, Tokyo **14**, 1-33.
Parks, S. E., and Tyack, P. L. (**2005**). "Sound production by North Atlantic right whales (*Eubalaena glacialis*) in surface active groups," Journal of the Acoustical Society of America **117**, 3297-3306.
Payne, R., and McVay, S. (**1971**). "Songs of humpback whales," Science **173**, 585-597.
Perry, S. L., DeMaster, D. P., and Silber, G. K. (**1999**). "The great whales: History and status of six species listed as endangered under the US Endangered Species Act of 1973," Marine Fisheries Review **61**, 1-74.
Risch, D., Clark, C. W., Dugan, P. J., Popescu, M., Siebert, U., and Van Parijs, S. M. (**2013**). "Minke whale acoustic behavior and multi-year seasonal and diel vocalization patterns in Massachusetts Bay, USA," Mar Ecol Prog Ser **489**, 279-295.
Roch, M. A., Klinch, H., Baumann-Pickering, S., Mellinger, D. K., Qui, S., Soldevilla, M. S., and Hildebrand, J. A. (**2011**). "Classification of echolocation clicks from odontocetes in the Southern California Bight," Journal of the Acoustical Society of America **129**, 467-475.
Širović, A., Bassett, H. R., Johnson, S. C., Wiggins, S. M., and Hildebrand, J. A. (**2014**). "Bryde's whale calls recorded in the Gulf of Mexico," Marine Mammal Science **30**, 399-409.
Soldevilla, M. S., Henderson, E. E., Campbell, G. S., Wiggins, S. M., Hildebrand, J. A., and Roch, M. (**2008**). "Classification of Risso's and Pacific white-sided dolphins using spectral properties of echolocation clicks," Journal of the Acoustical Society of America **124**, 609-624.
Thompson, P. O., Findley, L. T., and 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**, 3051-3057.
Trygonis, V., Gerstein, E., Moir, J., and McCulloch, S. (**2013**). "Vocalization characteristics of North Atlantic right whale surface active groups in the calving habitat, southeastern United States," Journal of the Acoustical Society of America **134**, 4518-4521.
Wade, P. W., and Gerrodette, T. (**1993**). "Estimates of cetacean abundance and distribution in the Eastern Tropical Pacific," Report of the International Whaling Commission **43**, 477-494.
Watkins, W. A. (**1981**). "Activities and underwater sounds of fin whales," Scientific Reports of the Whale Research Institute **33**, 83-117.
Wiggins, S. M., and Hildebrand, J. A. (**2007**). "High-frequency Acoustic Recording Package (HARP) for broadband, long-term marine mammal monitoring," International Symposium on Underwater Technology 2007 and International Workshop on Scientific Use of Submarine Cables and Related Technologies 2007, 551-557.
Zimmer, W. M. X., Johnson, M. P., Madsen, P. T., and Tyack, P. L. (**2005**). "Echolocation clicks of free-ranging Cuvier's beaked whales (*Ziphius cavirostris*)," Journal of the Acoustical Society of America **117**, 3919-3927.