Passive Acoustic Monitoring for Marine Mammals in the Jacksonville Range Complex July 2015 – November 2015

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Pilot whales, photo by Amanda J. Debich

MPL TECHNICAL MEMORANDUM # 613
January 2017

Suggested Citation:

LM Varga, KE Frasier, JS Trickey, AJ Debich, JA Hildebrand, AC Rice, BJ Thayre, M Rafter, SM Wiggins, S Baumann-Pickering, LEW Hodge, and A Read. Passive Acoustic Monitoring for Marine Mammals in the Jacksonville Range Complex July 2015 – November 2015. Final Report. Marine Physical Laboratory Technical Memorandum 613. January 2017. Submitted to Naval Facilities Engineering Command (NAVFAC) Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006 Subcontract #383-8476 (MSA2015-1176 Task Order 003) issued to HDR, Inc.

Additional information on previous HARP deployments and availability of all associated reports is available on the project profile page of the U.S. Navy's Marine Species Monitoring Program web portal.

This project is funded by US Fleet Forces Command and managed by Naval Facilities Engineering Command Atlantic as part of the US Navy's Marine Species Monitoring Program.

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Executive Summary

A High-frequency Acoustic Recording Package (HARP) was deployed from July 2015 to April 2016, with recordings made between July 2015 and November 2015, to detect marine mammal and anthropogenic sounds in the Navy's Jacksonville Range Complex. The HARP was located 83 nm off the Florida coastline on the continental slope.

The HARP recorded sound in the frequency band 10 Hz – 100 kHz, however the low frequency recording stage failed, resulting in an effective recording band of 1 – 100 kHz, with decreased sensitivity below 27 kHz. Data analysis consisted of analyst scans of long-term spectral averages (LTSAs) and spectrograms, and automated computer algorithm detection when possible. The high frequency band between 1 – 100 kHz was analyzed for marine mammal vocalizations and anthropogenic sounds.

Several known odontocete signals were detected, along with odontocete signals that cannot yet be distinguished to species. Cuvier's and Gervais' beaked whales as well as sperm whales were detected intermittently throughout the monitoring period. *Kogia* spp. echolocation clicks were also found throughout the recording period, with highest numbers of detections occurring in late September through November 2015. One acoustically identifiable delphinid species was Risso's dolphins, whose echolocation clicks were identified in high numbers between July and August 2015. Detections decreased in late September through November 2015. Odontocete signals that could not be distinguished to species were common throughout the recordings. However, two distinct click types (CT) of unknown species origin were identified and designated as CT J1 and J3. Unidentified odontocete whistles were detected and categorized as either above or below 5 kHz.

Anthropogenic sounds, namely echosounders were detected. HFA sonar was not detected in these recordings. Echosounders were detected intermittently in low numbers.

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 baleen 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 a High-frequency Acoustic Recording Package (HARP) that was deployed off Jacksonville, Florida (designated site D), within the Jacksonville Range Complex and collected data from July through November 2015 (Figure 1).

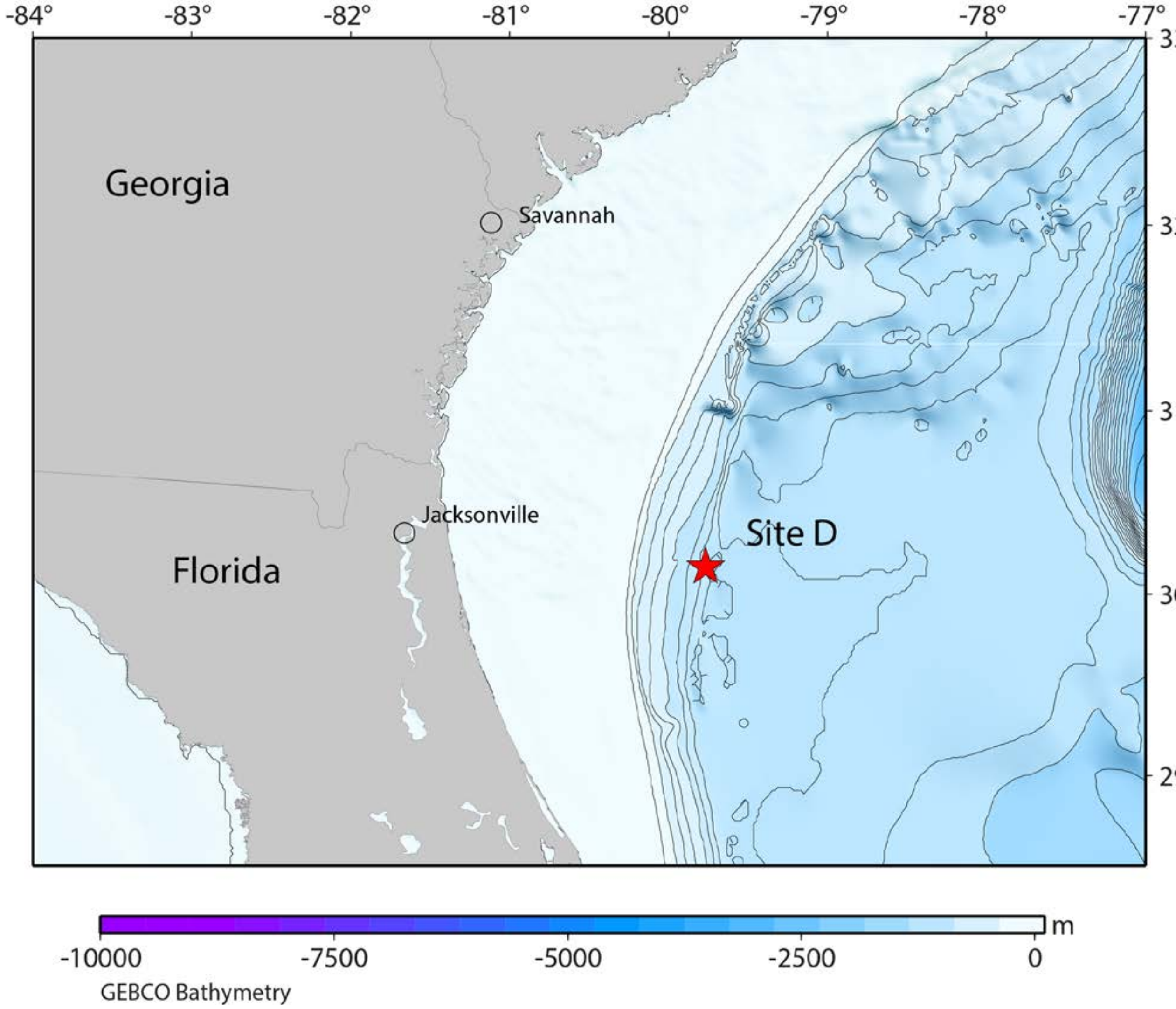

Figure 1. Location of High-frequency Acoustic Recording Package (HARP) at site D (30° 09.036 N, 79° 46.203 W, depth 800 m) deployed in the Jacksonville Range Complex study area from July to November 2015.

Methods

High-frequency Acoustic Recording Package (HARP)

HARPs are autonomous underwater acoustic recording packages that can record sounds over a bandwidth from 10 Hz up to 160 kHz and that are capable of approximately 300 days of continuous data storage. The HARP was deployed in a small mooring configuration with the hydrophone suspended approximately 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

One HARP recorded from July to November 2015 at site D (30° 09.036 N, 79° 46.203 W, depth 800 m) and sampled continuously at 200 kHz to provide 100 kHz of effective bandwidth. The instrument recorded 124.8 days from July 3rd to November 4th 2015, for a total of 2,995 hours of data analyzed. Earlier data collection in the Jacksonville Range Complex is documented in previous detailed reports (Debich *et al*., 2013; Johnson *et al*., 2014; Frasier *et al.*, 2016).

Data Quality

Approximately three days after deployment (approximately on 07/05/2015 23:58:50), the low frequency stage of the hydrophone failed. The majority of the remaining data has little to no sensitivity in the low stage (~<27 kHz), and occasional broadband masking from electronic noise. Despite the failure, the hydrophone remained sensitive to acoustic signals between approximately 1 and 100 kHz.

Data Analysis

To visualize the acoustic data, frequency spectra were calculated for all data using a time average of 5 seconds and 100 Hz frequency bins. 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 1 – 100 kHz allows detection of 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 this band in the JAX region, and the procedures used to detect them.

Due to a malfunction in the low frequency stage of the hydrophone, only the high- to mid-frequency band from 1 to 100 kHz was analyzed. This band contains odontocete and high frequency sonar sounds, which were analyzed. Acoustic signals that do not fall in that band are not discussed in this report. Despite attenuated received levels, effort was made to detect sperm whales and dolphin whistles, which are most easily detected in the mid-frequency band. Due to the decreased sensitivity in the low- to mid-frequency ranges, MFA sonar sounds were not analyzed and lower frequency dolphin whistles were most likely missed.

We summarize acoustic data collected between July and November 2015. We discuss seasonal occurrence and relative abundance of calls for different species and anthropogenic sounds that were consistently identified in the acoustic data.

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 dolphins (*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 2).

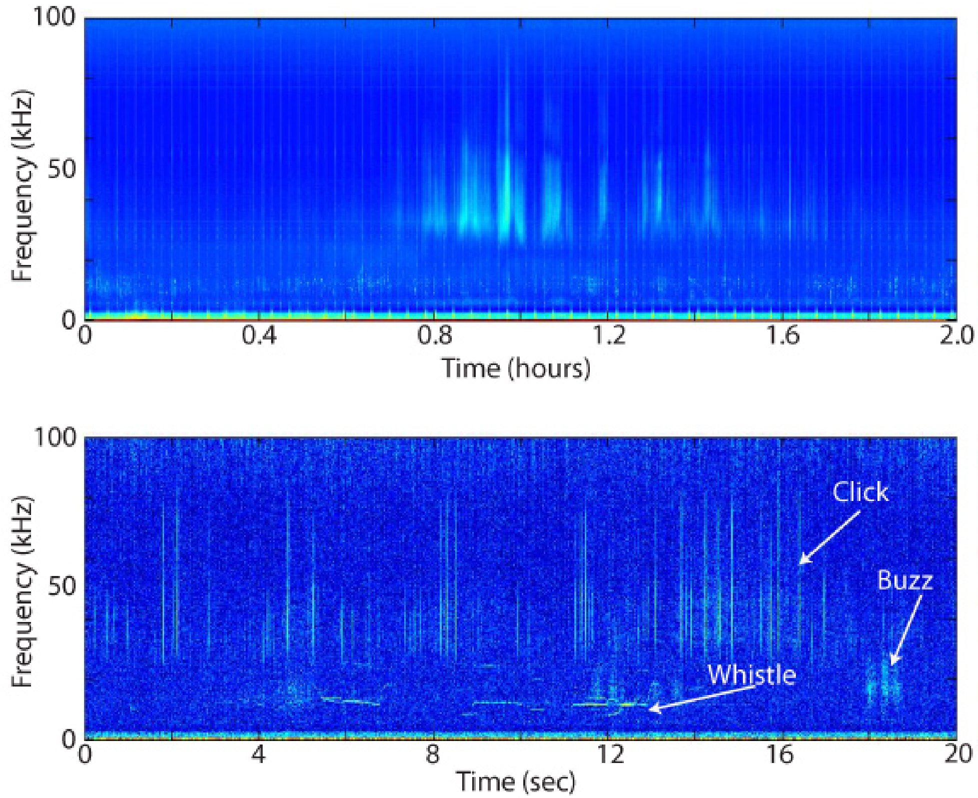

Figure 2. LTSA (top) and spectrogram (bottom) demonstrating odontocete signal types.

Beaked Whales

Beaked whales can be identified acoustically by their echolocation signals (Baumann-Pickering *et al.*, 2014). These signals are frequency-modulated (FM) upsweep pulses, which appear to be species specific and distinguishable by their spectral and temporal features. Identifiable signals are known for Gervais', Blainville's, Cuvier's, and Sowerby's beaked whales. No Sowerby's beaked whales were detected in these data or in previous JAX recordings and they are not further described below.

Beaked whale FM pulses were detected with an automated method. This automated effort was for all identifiable beaked whale signals found in the Jacksonville Range Complex. 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, was used to label the automatically detected segments to pulse type level and reject false detections (Baumann-Pickering *et al.*, 2013). The rate of missed segments is approximately 5%, varying slightly across deployments.

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 3).

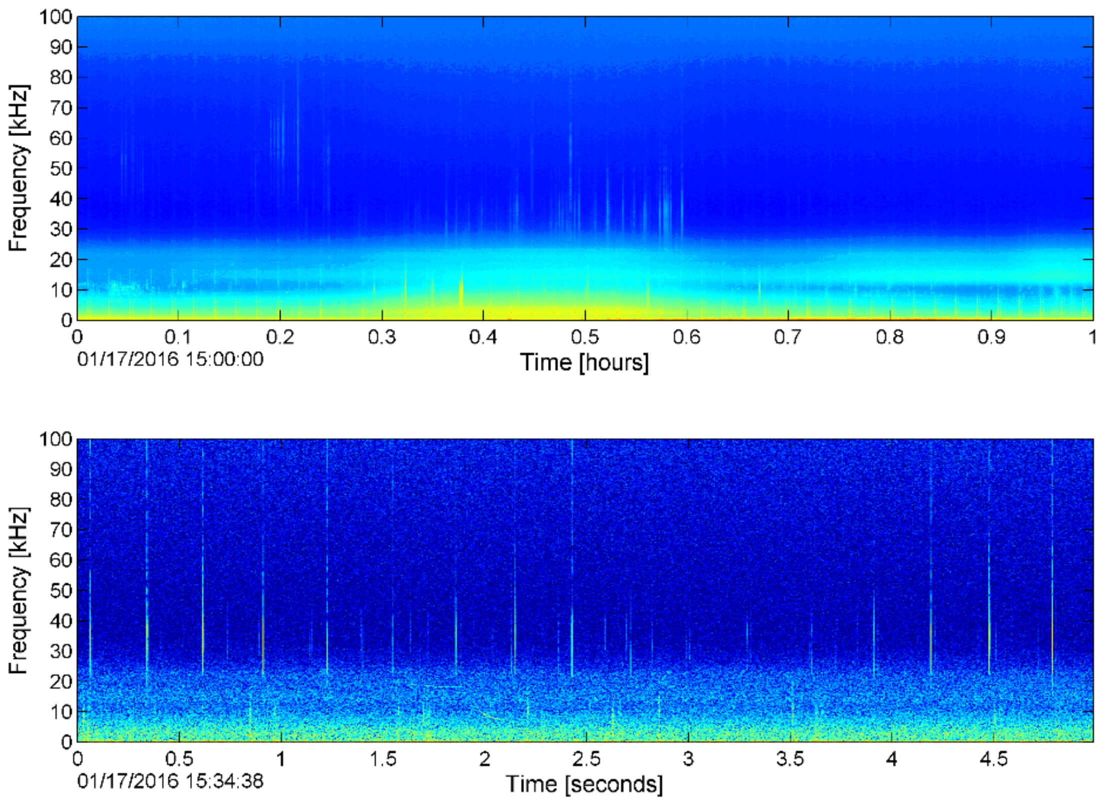

Figure 3. Blainville's beaked whale echolocation clicks in LTSA (top) and spectrogram (bottom) from the Virginia Capes range. Red arrow indicates location of LTSA expanded in the spectrogram.

Cuvier's Beaked Whales

Cuvier's echolocation signals are polycyclic, with a characteristic FM pulse upsweep, peak frequency around 40 kHz (Figure 4), 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.

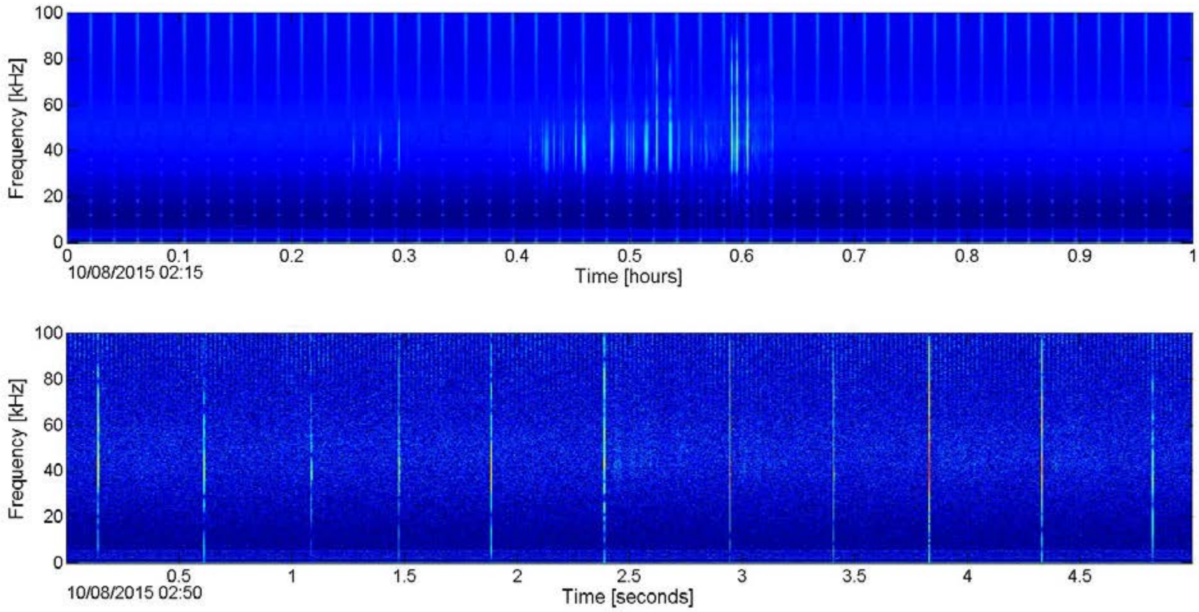

Figure 4. Cuvier's beaked whale signals in LTSA (top) and spectrogram (bottom) from HARP recording within the Jacksonville Range Complex, October 2015.

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 5). The IPI for Gervais' beaked whale signals is typically around 275 ms (Baumann-Pickering *et al.*, 2013).

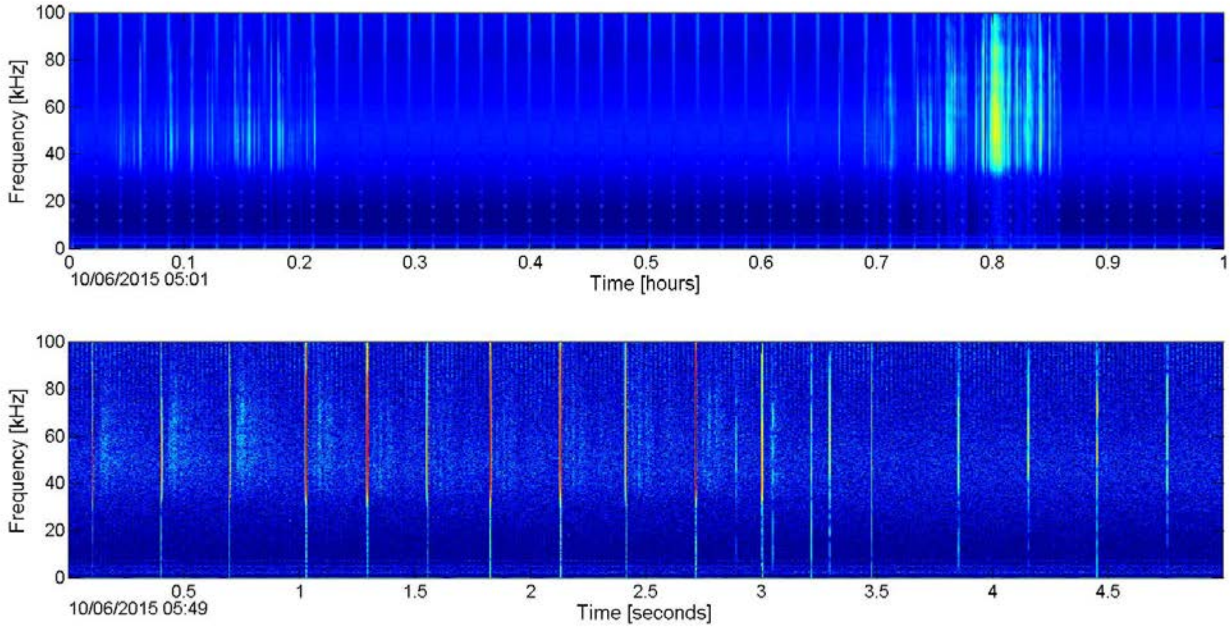

Figure 5. Gervais' beaked whale signals in LTSA (top) and spectrogram (bottom) from HARP recording within the Jacksonville Range Complex, October 2015.

Dolphins

Echolocation clicks

Delphinid echolocation clicks were detected automatically using an energy detector with a minimum received level threshold of 120 dB_{pp} re: 1 µPa (Roch *et al.*, 2011). False positives were identified and removed manually by an analyst who reviewed LTSAs and mean spectra for each detected bout. A bout was defined as a period of clicking separated before and after by at least 15 minutes without clicking.

Dominant click types at this site were identified automatically by dividing detections into successive five-minute windows and determining the dominant click type(s) in each window. An automated clustering algorithm was then used to identify recurrent types across all windows (Frasier *et al*. in prep). Recurrent types were used as templates. Templates were attributed to a specific species if known (e.g., Risso's dolphin) or assigned a number if species was unknown. Templates were compared with the click types in each five minute window for matches. Click types that matched a template were classified by the matched template. Click types that did not match a template were labeled as unknown.

Whistles

Many species of delphinids produce tonal calls known as whistles. These frequency-modulated signals are predominantly found between 1 and 20 kHz. Whistles were detected manually in LTSAs and spectrograms, and characterized based on their frequency content as unidentified odontocete whistles either above or below 5 kHz.

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 that are thus far indistinguishable from each other (Soldevilla *et al.*, 2008). Risso's dolphin clicks are distinguishable, and were identified based on known characteristics (Soldevilla *et al.*, 2008). Since delphinid signals are detectable in an LTSA as well as the spectrogram (Figure 6), they were monitored during this analysis effort, but were characterized as unidentified odontocete signals.

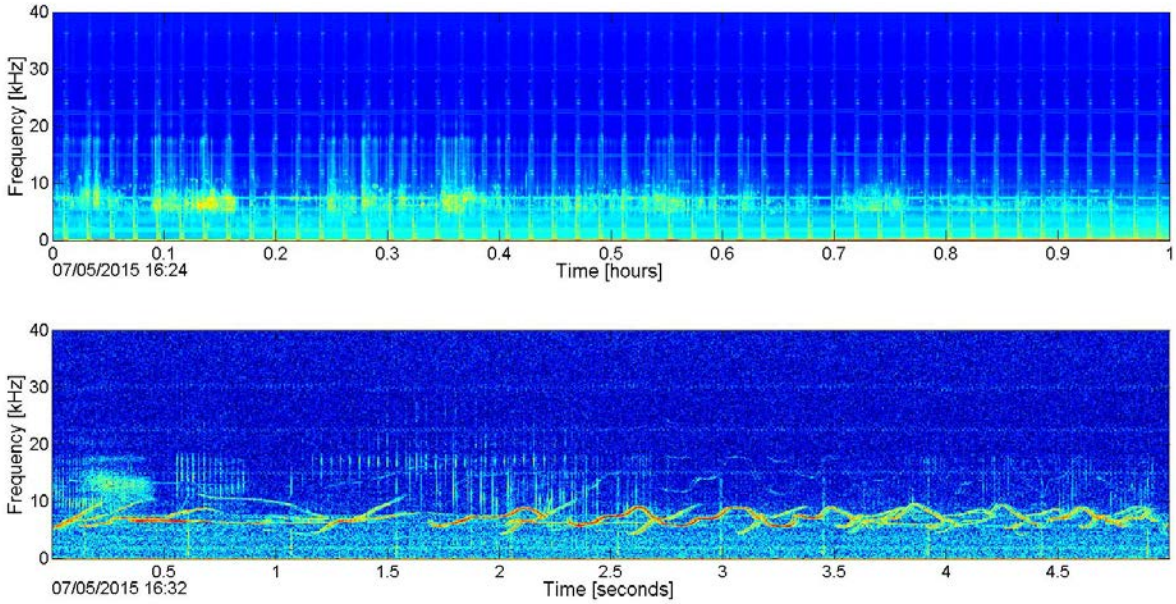

Figure 6. Unidentified odontocete signals in LTSA (top) and spectrogram (bottom) from HARP recording within the Jacksonville Range Complex, July 2015.

Risso's Dolphins

Risso's dolphin echolocation clicks can be identified to species by their distinctive banding patterns observable in the LTSA (Figure 7). Studies show that spectral properties of Risso's dolphin echolocation clicks vary based on geographic region (Soldevilla, personal communication). Risso's dolphin clicks that were detected in this recording period had peaks at 23, 26, and 33 kHz (Figure 8). Modal inter-click interval (ICI) was 170 ms, with broad variability between 100 and 200 ms across all encounters. 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).

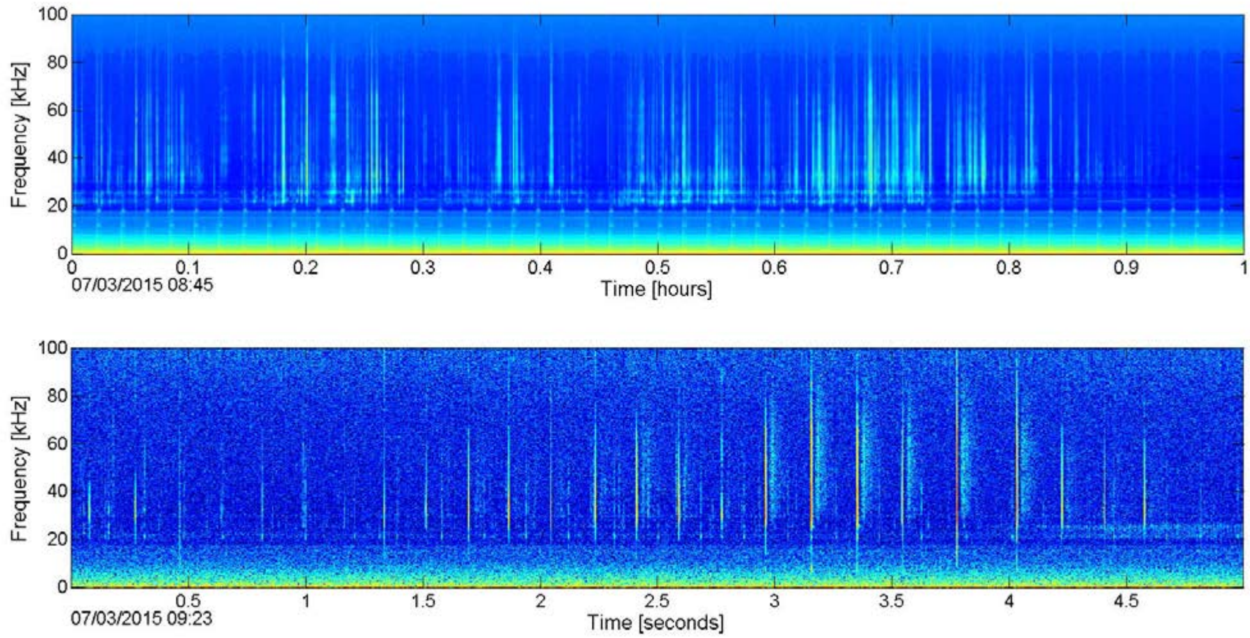

Figure 7. Risso's dolphin acoustic encounter in LTSA (top) and spectrogram (bottom) from HARP recording within the Jacksonville Range Complex, July 2015.

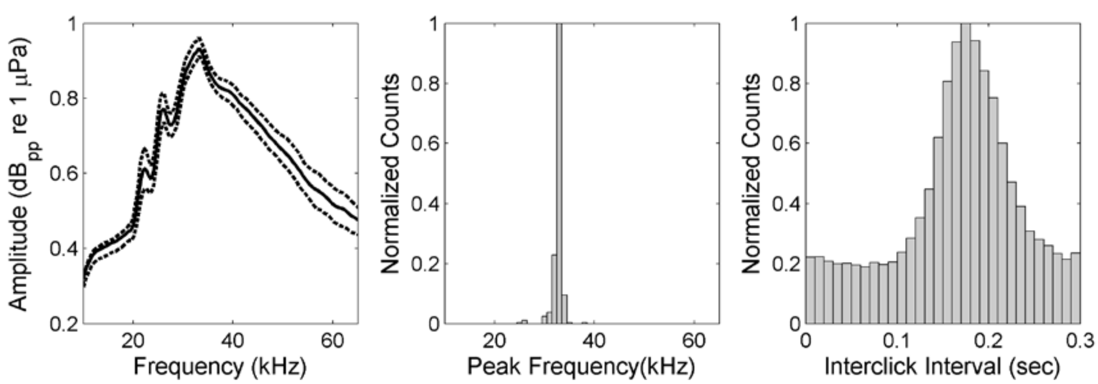

Figure 8. Risso's dolphin click type detected at site D from July to November 2015. Left: Mean frequency spectrum of click cluster (solid line) and 25th and 75th percentiles (dashed lines); Center: Distribution of click cluster peak frequencies; Right: Distribution of inter-click intervals (ICI) within cluster.

Other Echolocation Click Types

An automated clustering procedure was used to identify recurrent delphinid click types (CT) in the dataset. Two click types were identified (Figures 8-11). These click types are not currently identified to species, but have consistent spectral shapes and ICI distributions, making them candidates for future identification.

- CT J1 had a simple spectral shape with peak frequencies between 30 and 35 kHz, and a modal ICI of 75 ms (Figure 9). An example encounter is shown in Figure 10. This type has been identified in a previous deployment (Frasier *et al.*, 2016).
- CT J3 had a lower frequency distribution with a single peak near 27 kHz, and a modal ICI of 190 ms (Figure 11). An example encounter is shown in Figure 12. A similar type has been identified at continental slope sites in the northeastern Gulf of Mexico during spring and summer months (Frasier, 2015). CT J3 was identified in a previous JAX report (Frasier *et al*., 2016) with a lower peak frequency (22 kHz). Based on shape and ICI, this is likely the same click type, but the spectral peak may have shifted higher due to the reduced low frequency sensitivity.
- A third type, CT J2, found in JAX deployment 11 D, was not identified in this deployment. This is likely due to a combination of timing (J2 appears to be more common in spring), and to the loss of lower frequencies, which might mask distinguishing features of J2, including a peak at 16 kHz.

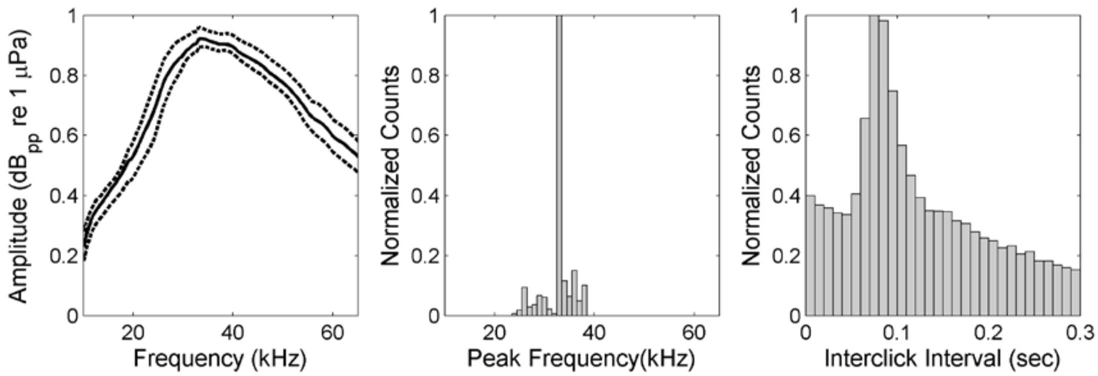

Figure 9. Click type CT J1 detected at JAX site D from July to November 2015. Left: Mean frequency spectrum of click cluster (solid line) and 25th and 75th percentiles (dashed lines); Center: Distribution of click cluster peak frequencies; Right: Distribution of inter-click intervals (ICI) within cluster.

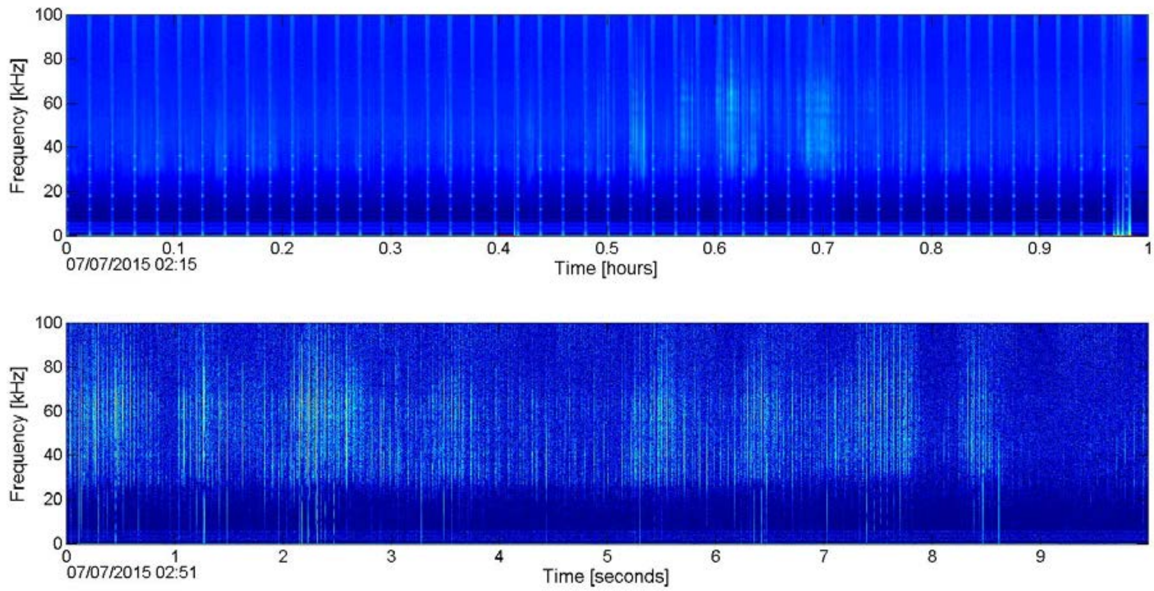

Figure 10. Click type CT J1 acoustic encounter in LTSA (top) and spectrogram (bottom) recorded at JAX site D in July 2015.

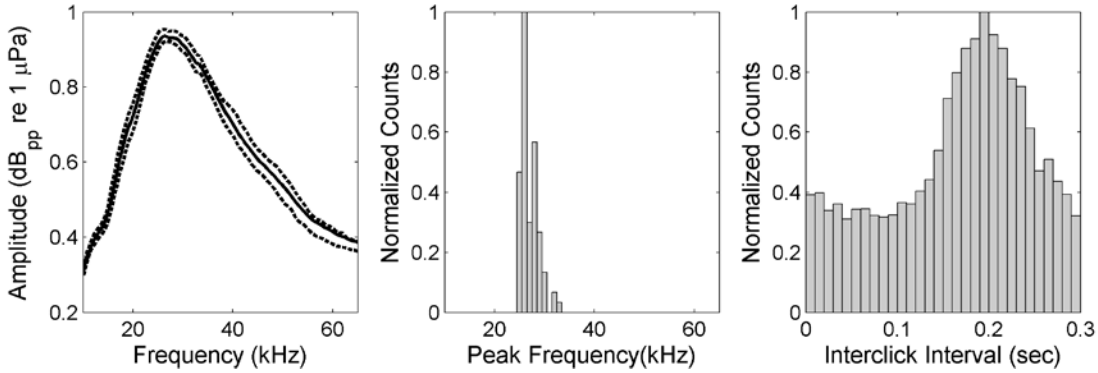

Figure 11. Click type CT J3 detected at JAX site D from July to November 2015. Left: Mean frequency spectrum of click cluster (solid line) and 25th and 75th percentiles (dashed lines); Center: Distribution of click cluster peak frequencies; Right: Distribution of inter-click intervals (ICI) within cluster.

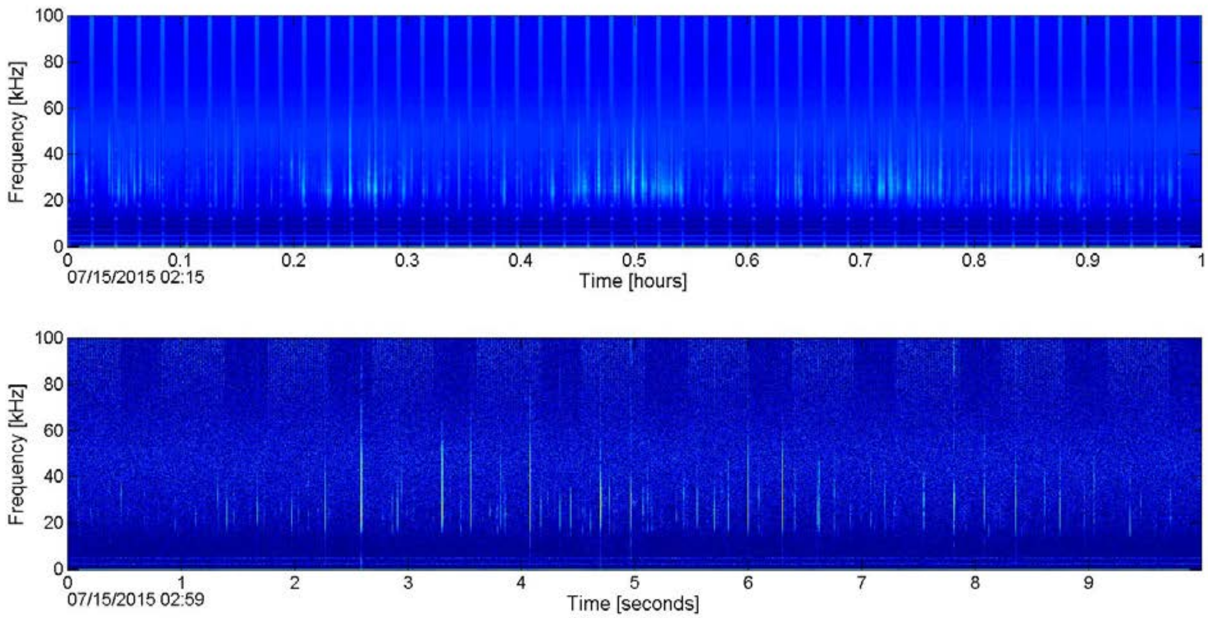

Figure 12. Click type CT J3 acoustic encounter in LTSA (top) and spectrogram (bottom) recorded at JAX site D in July 2015.

Sperm Whales

Sperm whale clicks contain energy from 2-20 kHz, with most energy between 10-15 kHz (Møhl *et al.*, 2003) (Figure 13). Regular clicks, observed during foraging dives, demonstrate an ICI from 0.25-1 s (Goold and Jones, 1995; Madsen *et al.*, 2002a). Short bursts of closely spaced clicks called creaks are observed during foraging dives and are believed to indicate a predation attempt (Wysocki *et al.*, 2006). Slow clicks (> 1 sec ICI) are used only by males and are more intense than regular clicks with long inter-click intervals (Madsen *et al.*, 2002b). Codas are stereotyped sequences of clicks which are less intense and contain lower peak frequencies than regular clicks (Watkins and Schevill, 1977). There was no effort to divide sperm whale clicks by type.

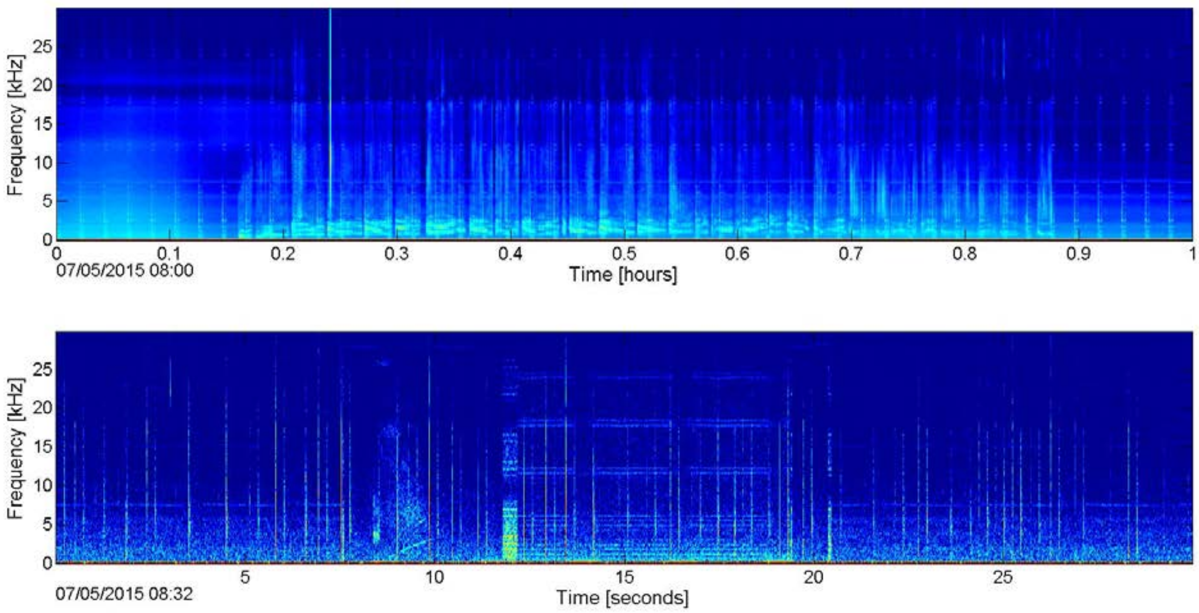

Figure 13. Sperm whale echolocation clicks in LTSA (top) and spectrogram (bottom) recorded at JAX site D in July 2015.

***Kogia* spp.**

Dwarf and pygmy sperm whales emit echolocation signals that have peak energy at frequencies near 130 kHz (Au, 1993). While this is above the frequency band recorded by the HARP, the lower portion of the *Kogia* energy spectrum is within the 100 kHz HARP bandwidth (Figure 14). The observed signal may result both from the low-frequency tail of the *Kogia* echolocation click spectra, and from aliasing of energy from above the Nyquist frequency of 100 kHz (Figure 15). *Kogia* echolocation clicks were analyzed using a multi-step detector. The first step was to identify clicks with energy in the 70-100 kHz band that simultaneously lacked energy in lower frequency bands. An expert system then classified these clicks based on spectral characteristics, and finally an analyst verified all echolocation click bouts manually.

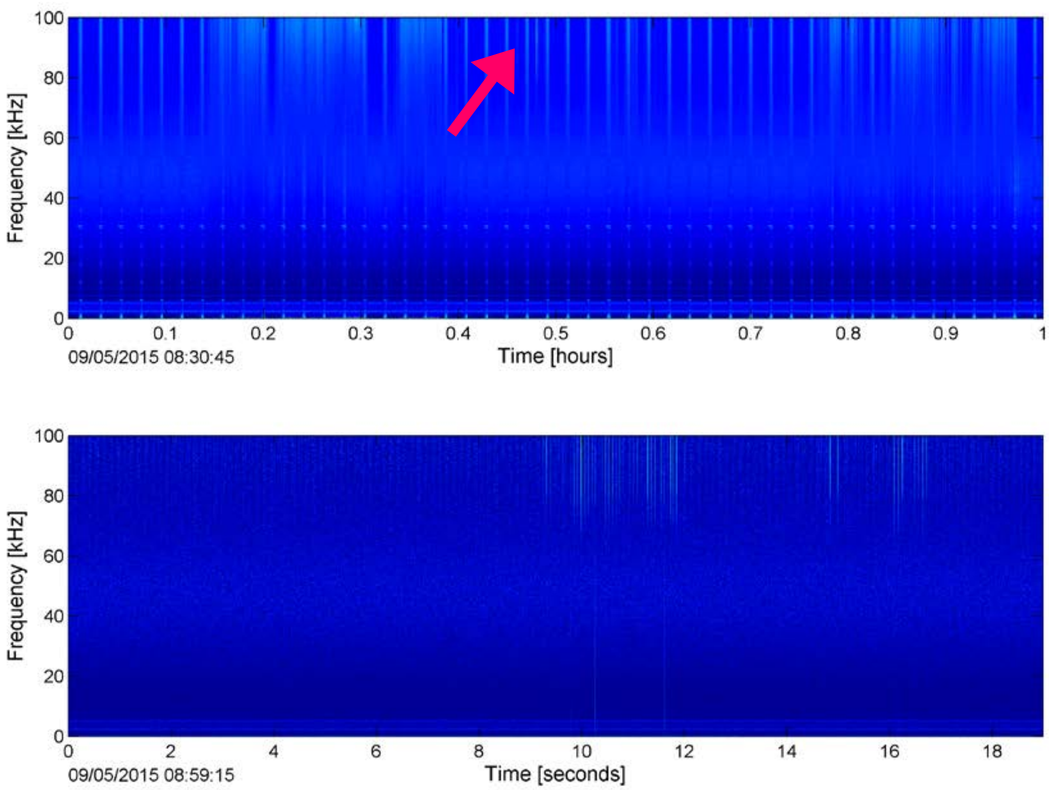

Figure 14. *Kogia* spp. echolocation clicks in LTSA (top) and spectrogram (bottom) recorded at JAX site D in September 2015. Red arrow indicates the location of the *Kogia* spp. clicks.

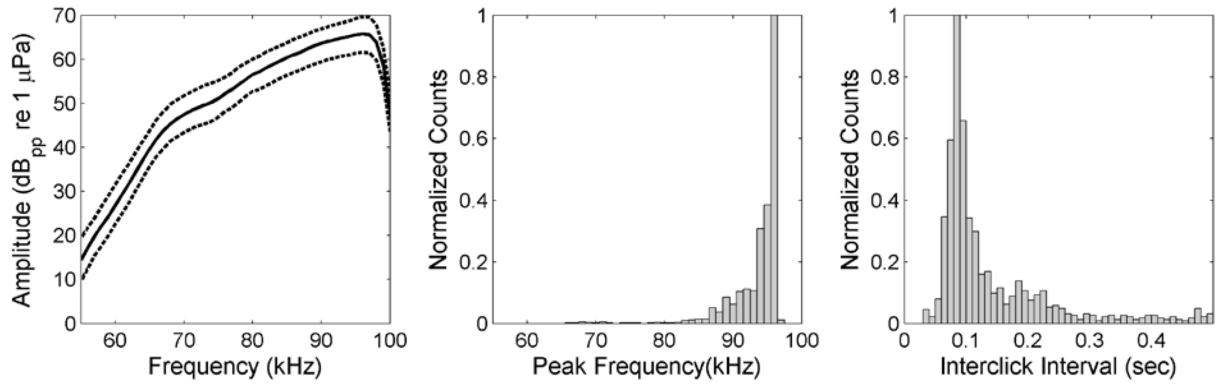

Figure 15. *Kogia* spp. detected at JAX site D from July to November 2015. Left: Mean frequency spectrum of click cluster (solid line) and 25th and 75th percentiles (dashed lines); Center: Distribution of click cluster peak frequencies; Right: Distribution of inter-click intervals (ICI) within cluster.

Anthropogenic Sounds

Anthropogenic sounds including High Frequency Active (HFA) sonar and echosounders, were monitored for this report. The LTSA search parameters used to detect these sounds 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. Anthropogenic sound data manual effort analysis parameters.

Sound Type	LTSA Search Parameters	
	Plot Length (hr)	Display Frequency Range (Hz)
HFA Sonar	1	10,000 – 100,000
Echosounder	1	5,000 – 100,000

High-Frequency Active Sonar

HFA sonar is used for specialty military and commercial applications including high-resolution seafloor mapping, short-range communications, such as with Autonomous Underwater Vehicles (AUVs), multi-beam fathometers, and submarine navigation (Cox, 2004). HFA sonar upsweeps between 10 and 100 kHz were manually detected by analysts in LTSA plots (Figure 16) in JAX deployment 11 D, but were not identified in this deployment.

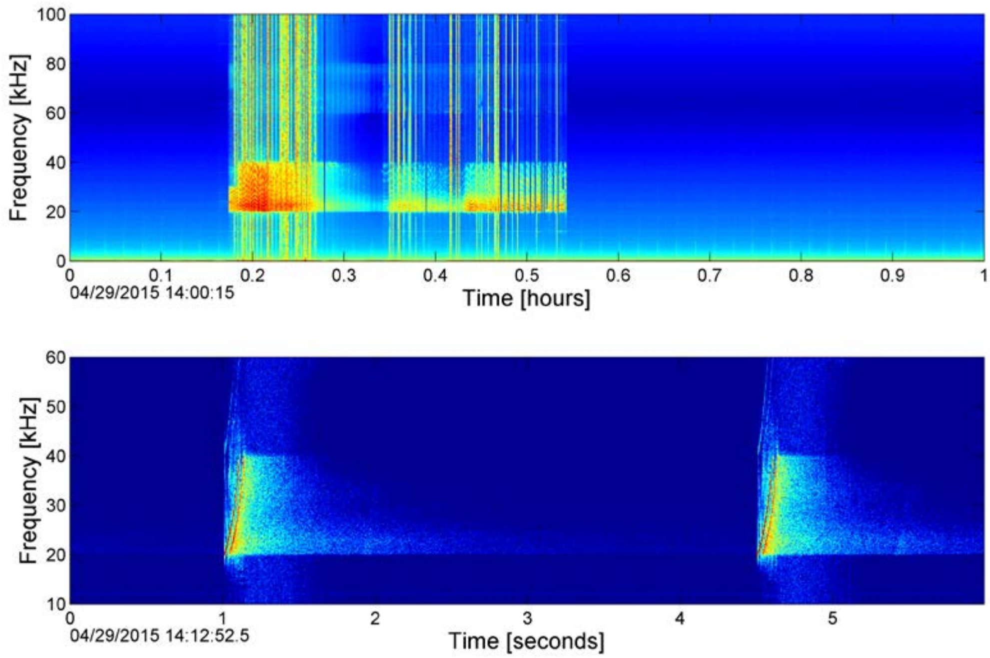

Figure 16. HFA sonar in LTSA (top) and spectrogram (bottom) in JAX deployment 11 D in April 2015.

Echosounders

Echosounding sonars transmit short pulses or frequency sweeps, typically in the high-frequency (above 5 kHz) band (Figure 17), 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. High-frequency echosounders were manually detected by analysts reviewing LTSA plots.

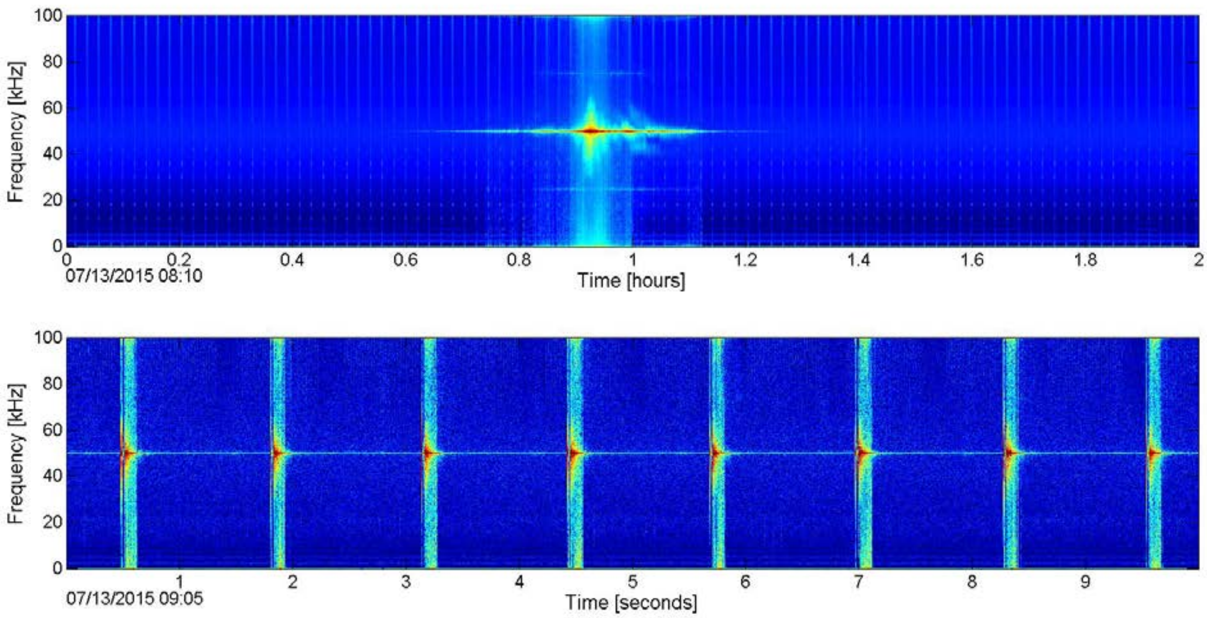

Figure 17. Echosounders in LTSA (top) and spectrogram (bottom) recorded at JAX site D in July 2015.

Results

The results of acoustic data analysis at site D from July to November 2015 are summarized, and the seasonal occurrence and relative abundance of marine mammal acoustic signals and anthropogenic sounds are documented.

Odontocetes

Clicks from Cuvier's beaked whale, Gervais' beaked whale, Risso's dolphins, *Kogia* spp., sperm whales, clicks of two types that are not yet assigned to a species, and clicks of unidentified odontocetes were discriminated. Whistles from unidentified odontocete species were detected both above and below 5 kHz. Details of each species' presence at these sites are given below.

Cuvier's beaked whale

- Cuvier's beaked whale echolocation clicks were detected during one week in October 2015 (Figure 18).
- There were not enough encounters to discern a diel pattern (Figure 19).

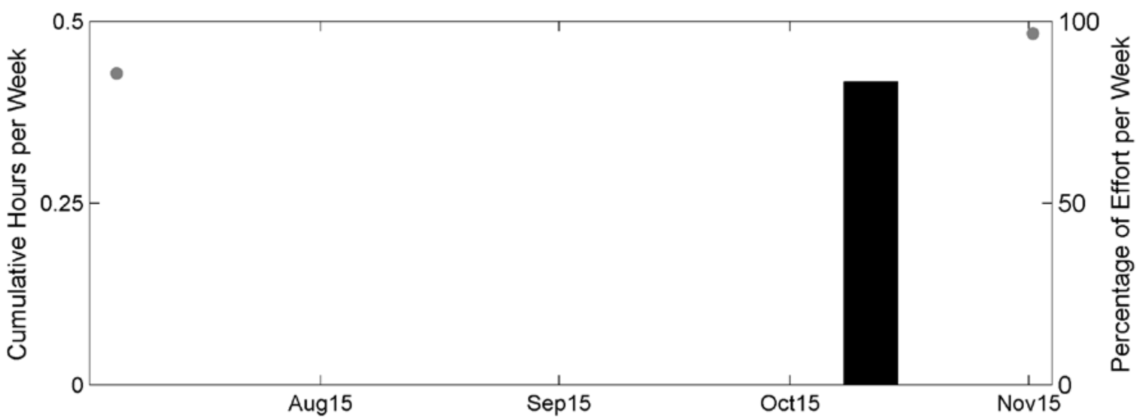

Figure 18. Weekly presence of Cuvier's beaked whale echolocation clicks between July and November 2015 at site D. Gray dots represent percent of effort per week in weeks with less than 100% recording effort. Where gray dots are absent, full recording effort occurred for the entire week. X-axis labels refer to month and year of recording.

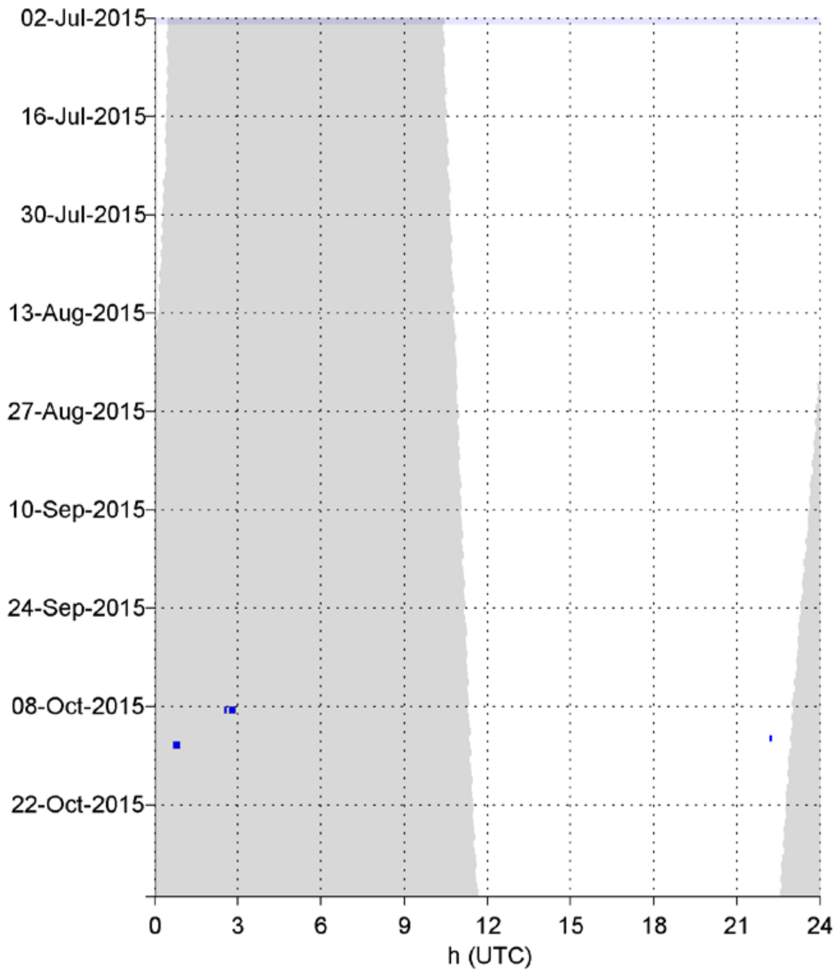

Figure 19. Cuvier's beaked whale echolocation clicks in one-minute bins between July and November 2015 at site D. Gray vertical shading denotes nighttime.

Gervais' beaked whale

- Gervais' beaked whale echolocation clicks were detected occasionally (Figure 20).
- Although the number of detections was small, clicks were primarily detected at night (Figure 21).

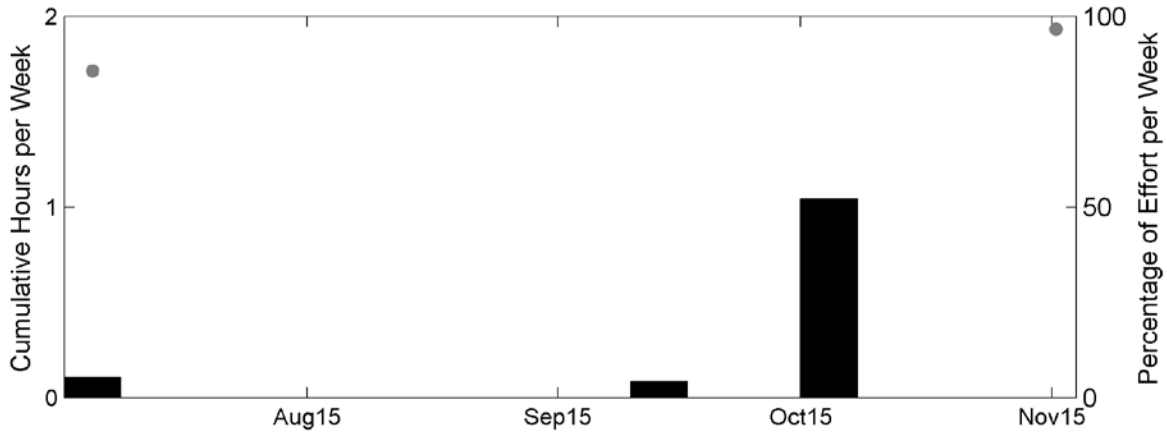

Figure 20. Weekly presence of Gervais' beaked whale echolocation clicks between July and November 2015 at site D. Effort markings are described in Figure 18.

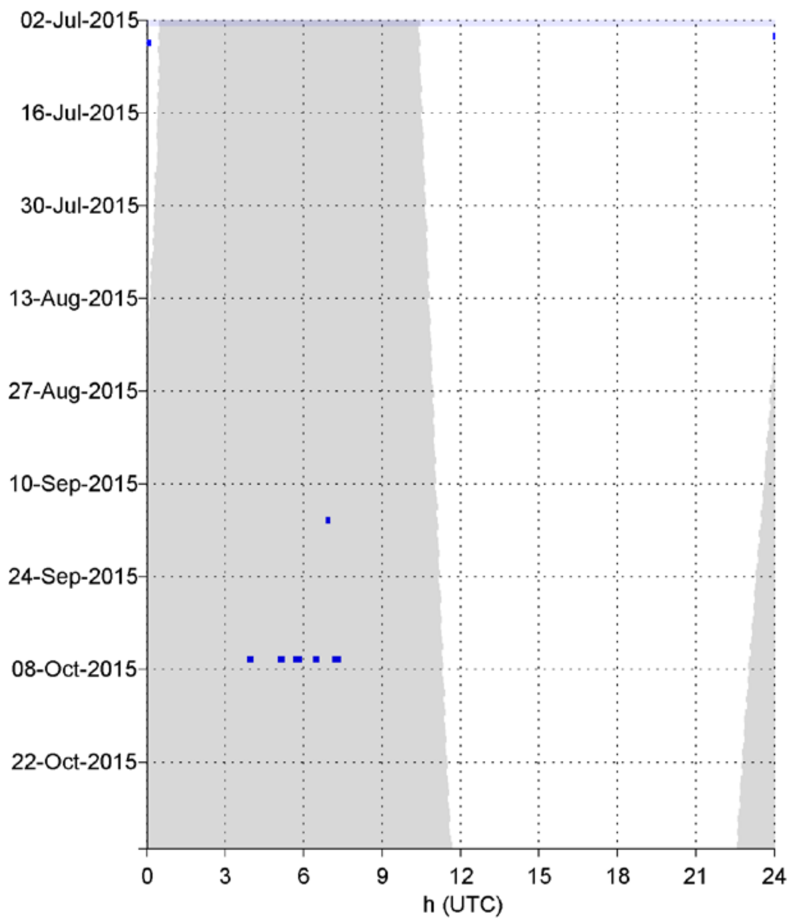

Figure 21. Gervais' beaked whale echolocation clicks in one-minute bins between July and November 2015 at site D. Effort markings as in Figure 19.

Risso's Dolphins

- Risso's dolphin echolocation clicks were detected in high numbers between July and August 2015, and in September 2015. Detections decreased in late September through November 2015 (Figure 22).
- Clicks were primarily detected during nighttime (Figure 23).

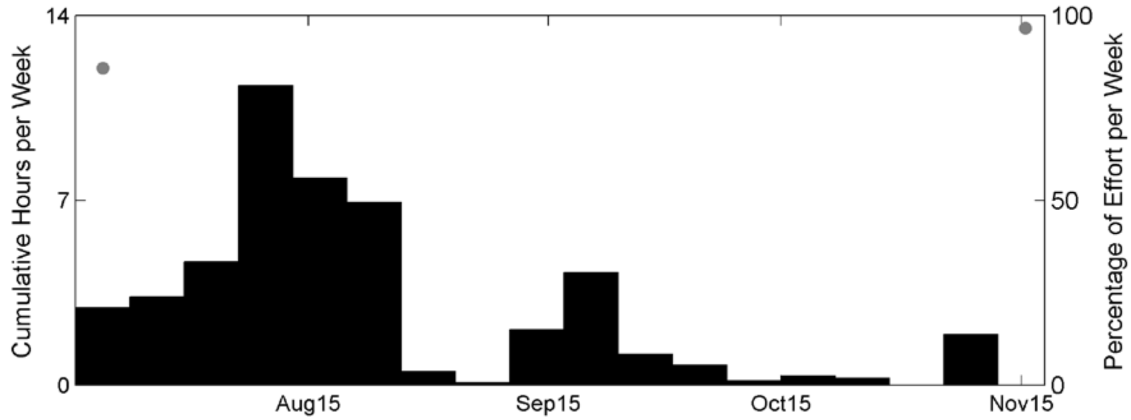

Figure 22. Weekly presence of Risso's dolphin echolocation clicks between July and November 2015 at site D. Effort markings are described in Figure 18.

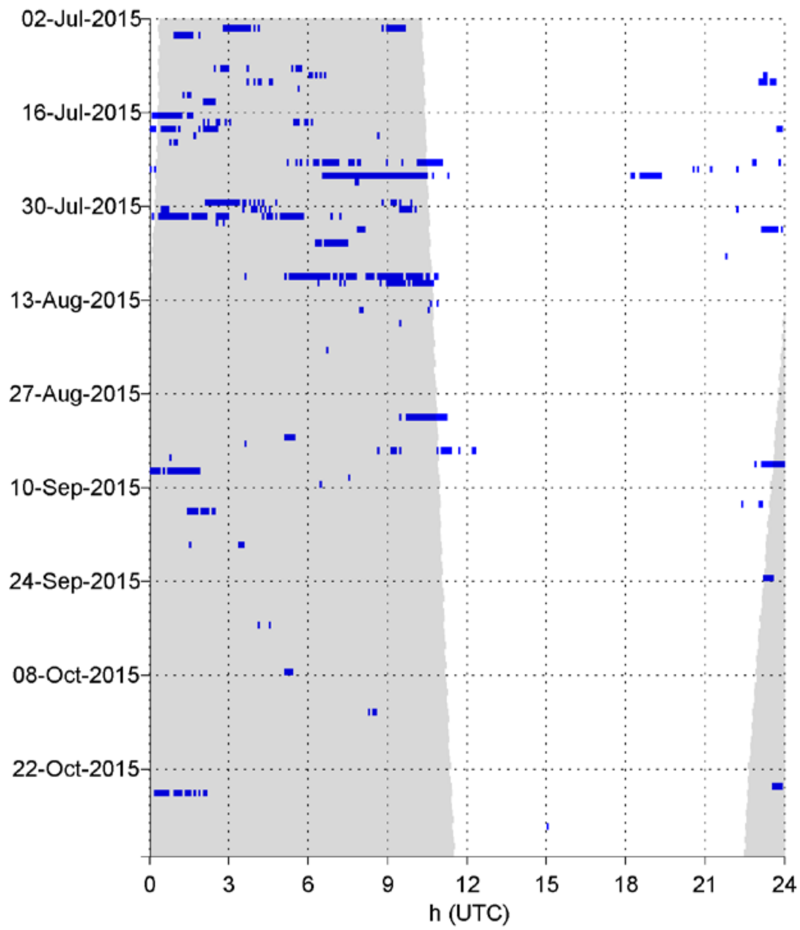

Figure 23. Risso's dolphin echolocation clicks in one-minute bins between July and November 2015 at site D. Effort markings as in Figure 19.

Unidentified Odontocetes

Signals that had characteristics of odontocete sounds (both whistles and clicks), but could not be classified to species were labeled as unidentified odontocetes.

- Clicks were left unidentified if too few clicks were detected in a time bin, or if detected clicks were of poor quality (e.g. low amplitude or masked).
- Unidentified odontocete clicks were detected throughout the recording period in low numbers. Unidentified detections decreased in October and November 2015 (Figure 24).
- Unidentified clicks were detected primarily during nighttime (Figure 25).

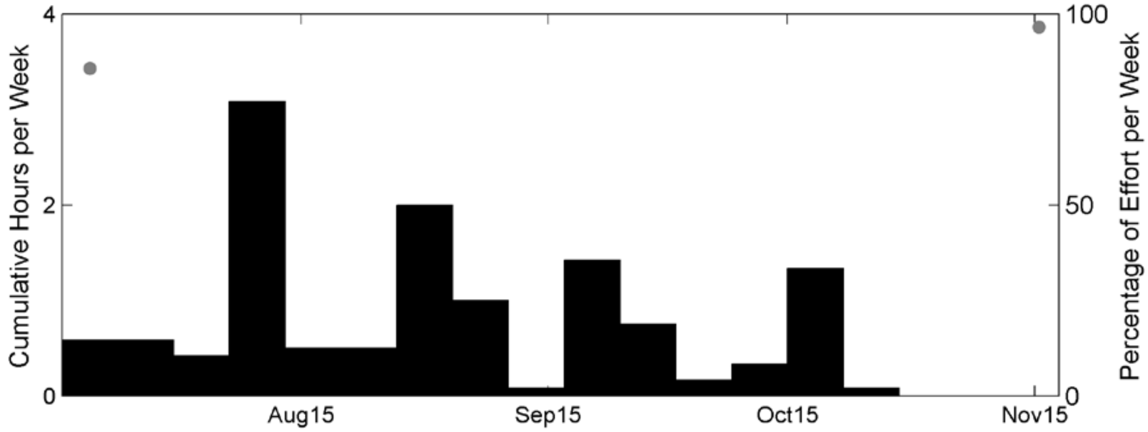

Figure 24. Weekly presence of unidentified odontocete clicks between July and November 2015 at site D. Effort markings are described in Figure 18.

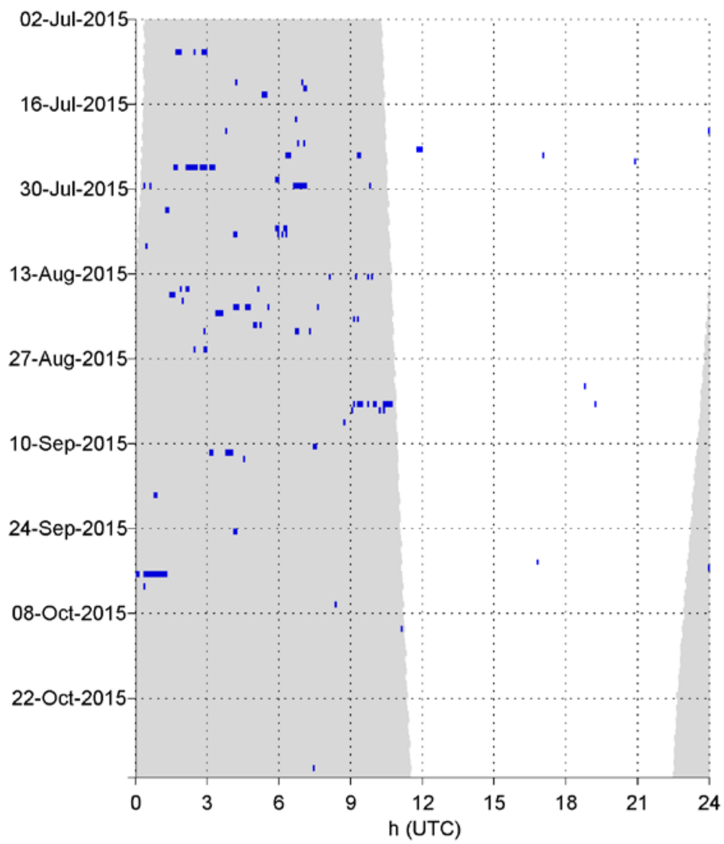

Figure 25. Unidentified odontocete clicks in one-minute bins between July and November 2015 at site D. Effort as in Figure 19.

Click Type J1

- CT J1 was detected between July and November 2015 with presence decreasing in October and early November (Figure 26).
- CT J1 was more often detected during nighttime (Figure 27).

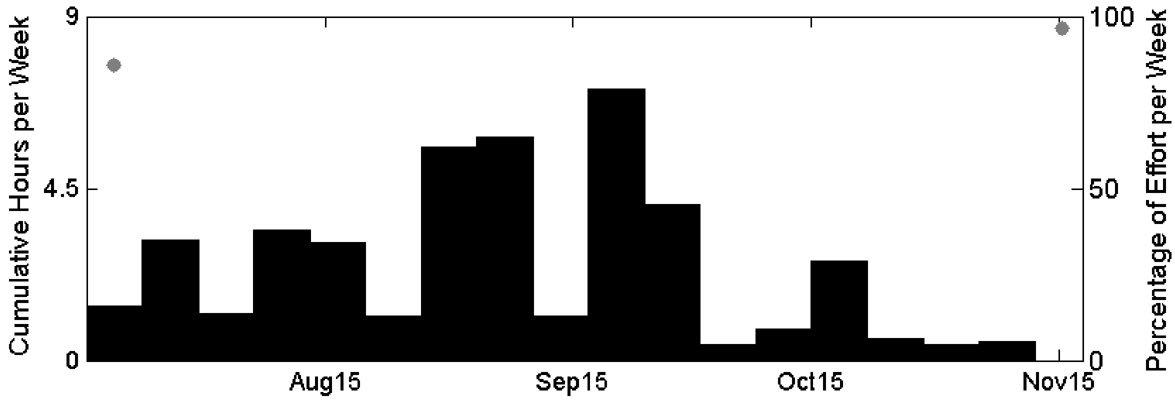

Figure 26. Weekly presence of CT J1 between July and November 2015 at site D. Effort markings are described in Figure 18.

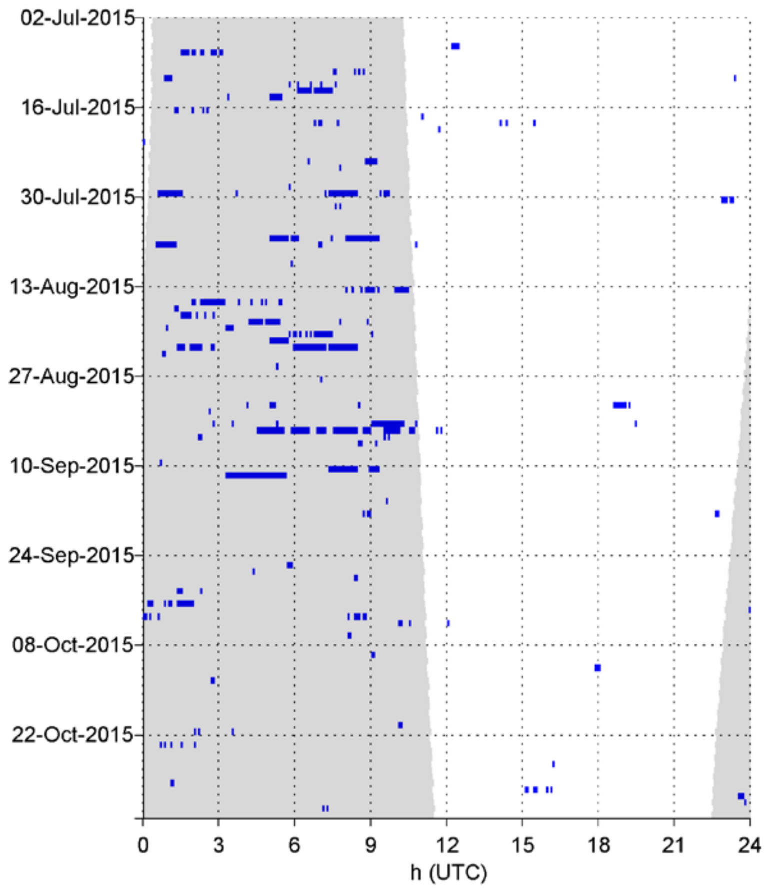

Figure 27. CT J1 in one-minute bins between July and November 2015 at site D. Effort markings as in Figure 19.

Click Type J3

- CT J3 was detected from July to November 2015, with fewer detections in October and November (Figure 28).
- CT J3 was detected predominantly during nighttime (Figure 29).

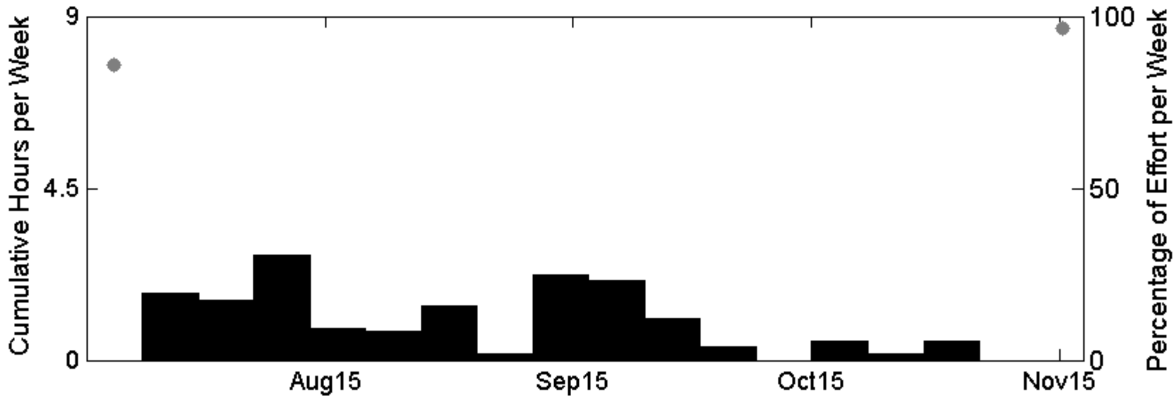

Figure 28. Weekly presence of CT J3 between July and November 2015 at site D. Effort markings are described in Figure 18.

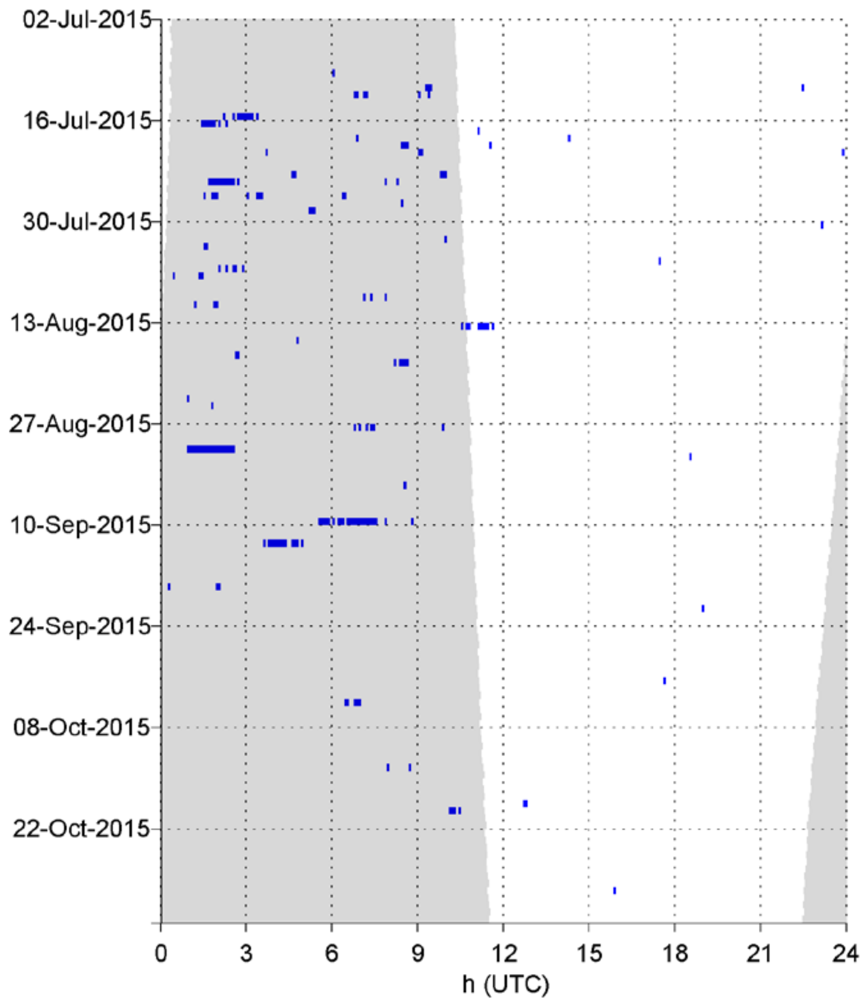

Figure 29. CT J3 in one-minute bins between July and November 2015 at site D. Effort markings as in Figure 19.

Unidentified Odontocete Whistles Greater Than 5 kHz

- Unidentified whistles greater than 5 kHz were detected intermittently between July and November 2015. Detections were highest in July 2015 (Figure 30).
- There was no diel pattern for whistles greater than 5 kHz (Figure 31).

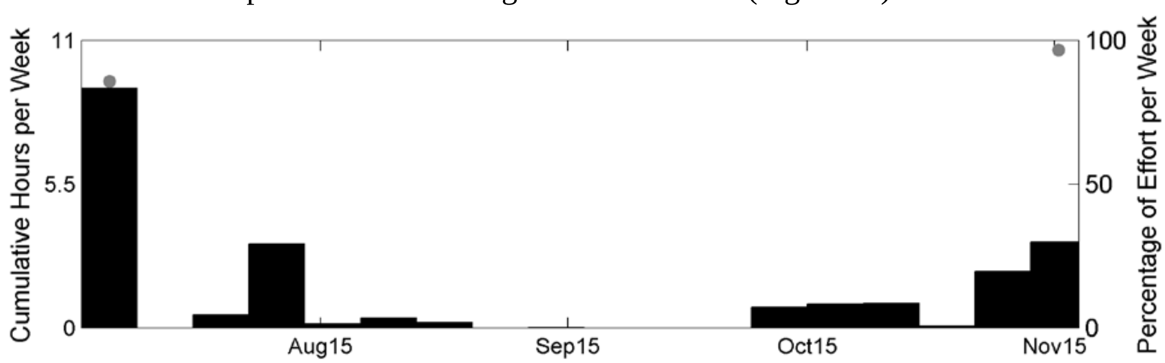

Figure 30. Weekly presence of unidentified odontocete whistles greater than 5 kHz between July and November 2015 at site D. Effort markings as in Figure 18.

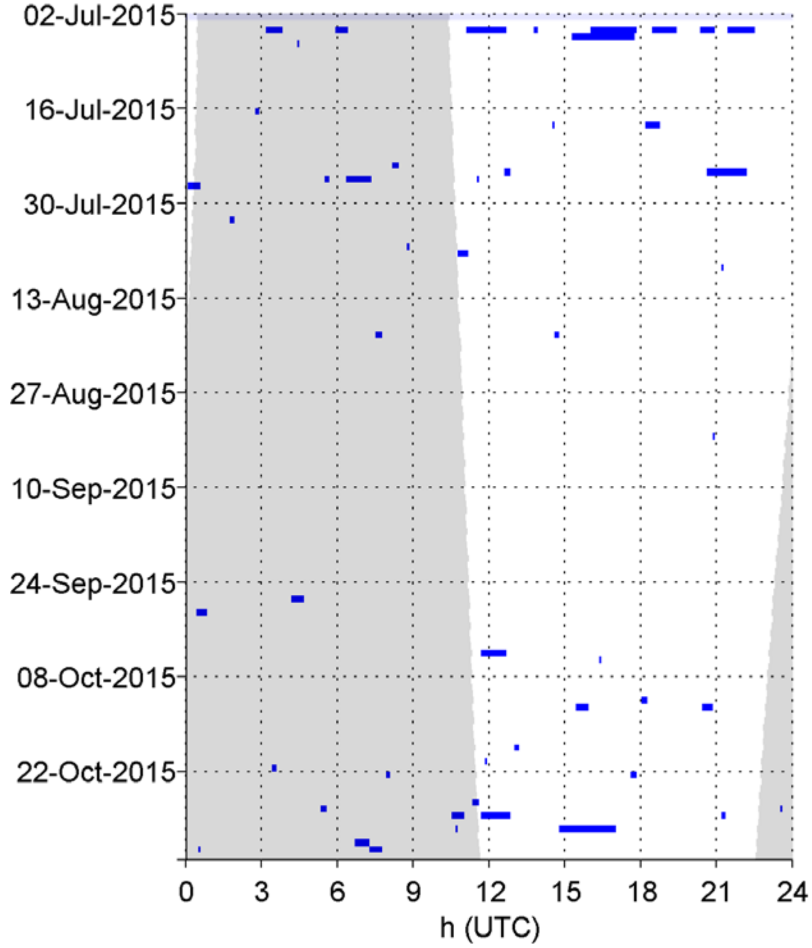

Figure 31. Unidentified odontocete whistles greater than 5 kHz in one-minute bins between July and November 2015 at site D. Effort markings as in Figure 19.

Unidentified Odontocete Whistles Less Than 5 kHz

- Unidentified odontocete whistles less than 5 kHz were detected in low numbers between July and November 2015. Most detections were in July 2015 (Figure 32).
- There was no apparent diel pattern (Figure 33).
- Due to the decreased sensitivity in the low- to mid-frequency ranges, some whistles less than 5 kHz may have been missed.
- Pilot whales most likely produced these whistles, though it is possible they are from other blackfish species that have overlapping distributions.

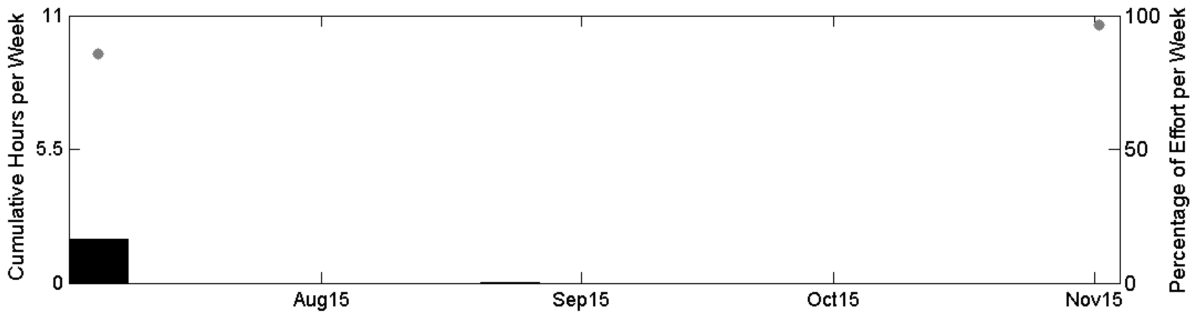

Figure 32. Weekly presence of unidentified odontocete whistles less than 5 kHz between July and November 2015 at site D. Effort markings are described in Figure 18.

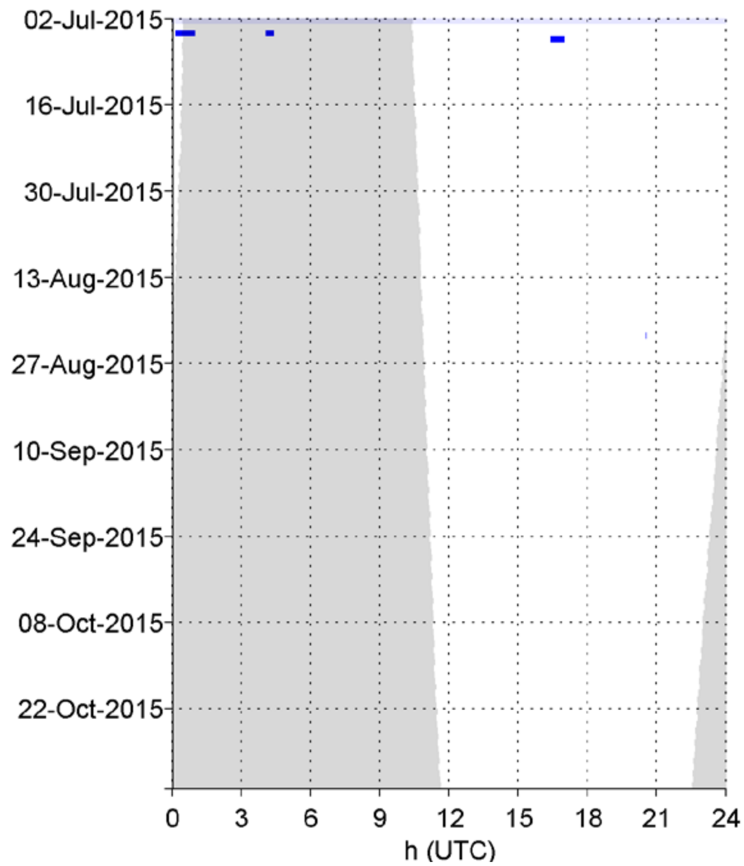

Figure 33. Unidentified odontocete whistles less than 5 kHz in one-minute bins between July and November 2015 at site D. Effort markings as in Figure 19.

Sperm Whales

- Sperm whale clicks were detected intermittently between July and November 2015 (Figure 34).
- There was no discernible diel pattern for sperm whale clicks (Figure 35).

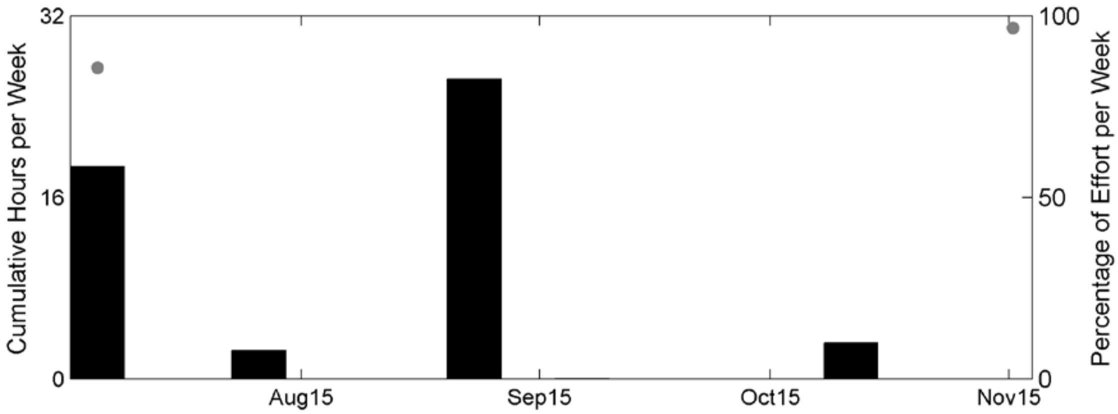

Figure 34. Weekly presence of sperm whale clicks between July and November 2015 at site D. Effort markings as in Figure 18.

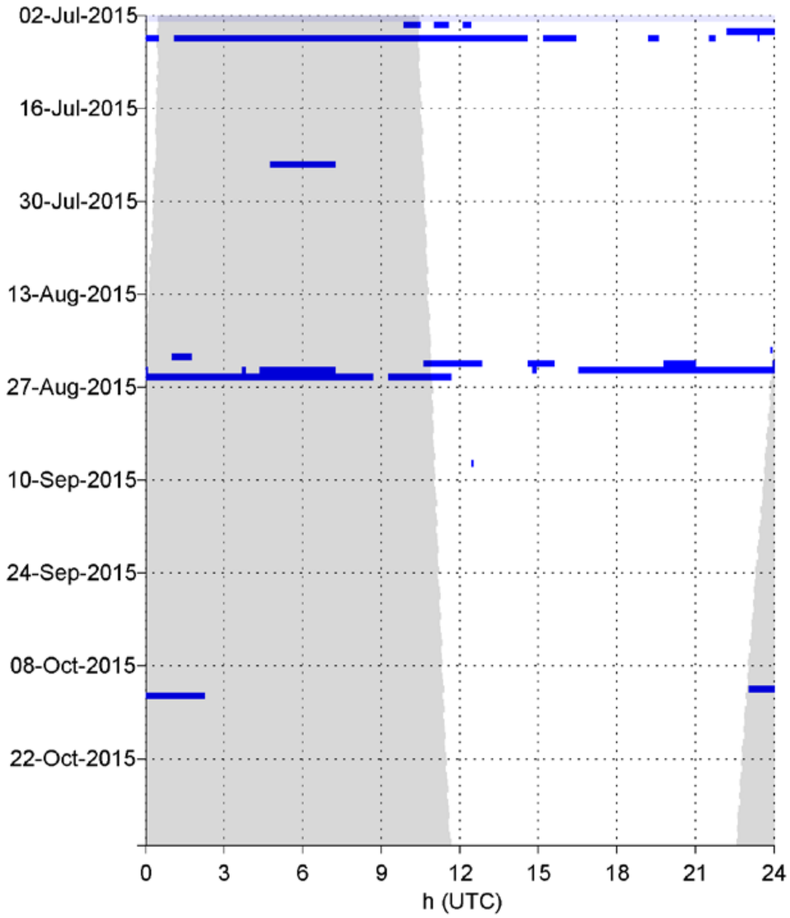

Figure 35. Sperm whale clicks in one-minute bins between July and November 2015 at site D. Effort markings as in Figure 19.

***Kogia* spp.**

- *Kogia* spp. echolocation clicks were detected intermittently, with most of the detections in late September through November 2015 (Figure 36).
- There was no discernible diel pattern for *Kogia* echolocation clicks (Figure 37).

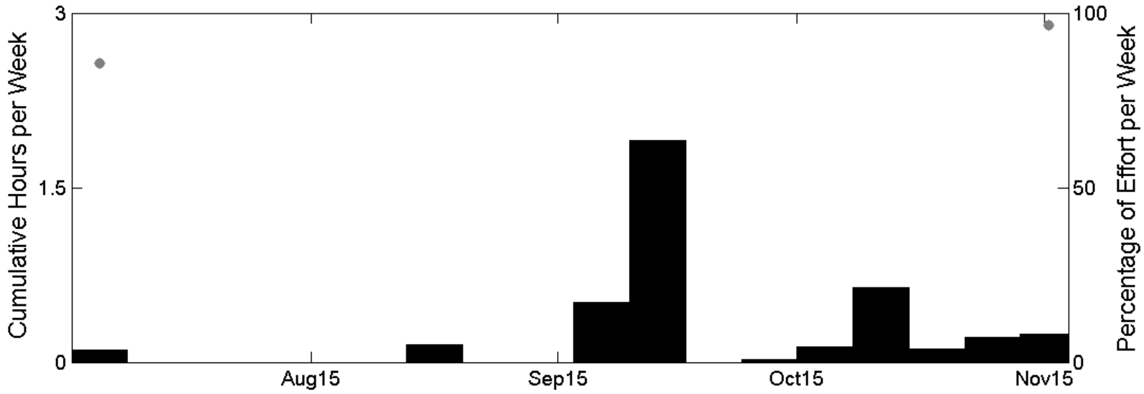

Figure 36. Weekly presence of *Kogia* clicks between July and November at site D. Effort markings as in Figure 18.

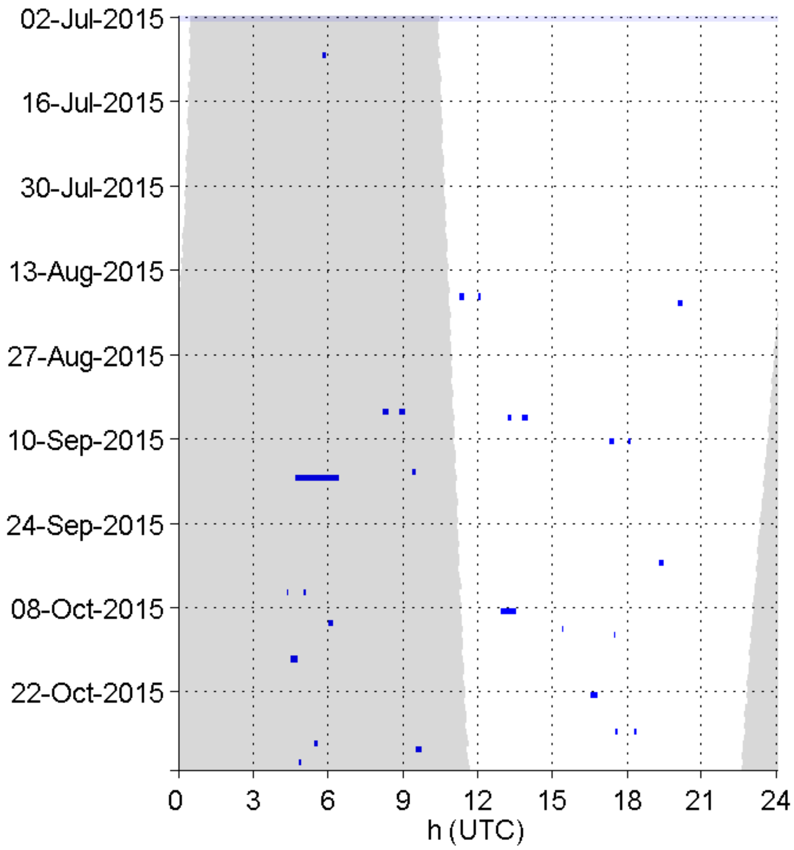

Figure 37. *Kogia* spp. clicks in one-minute bins between July and November 2015 at site D. Effort markings as in Figure 19.

Anthropogenic Sounds

Echosounders were the only type of anthropogenic sound detected between July and November 2015 at site D in the available frequency range.

Echosounders

- Echosounders greater than 5 kHz were detected in low numbers throughout the monitoring period (Figure 38).
- There was no apparent diel pattern for echosounder detections (Figure 39).

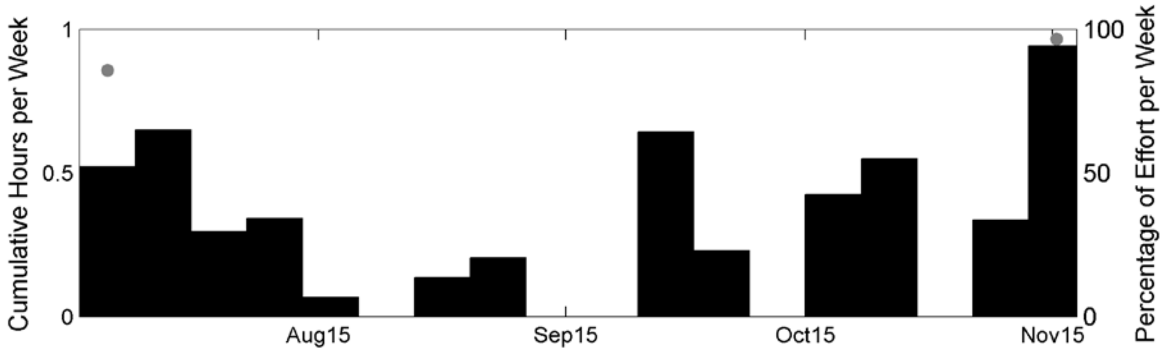

Figure 38. Weekly presence of echosounders greater than 5 kHz between July and November 2015 at site D. Effort markings are described in Figure 18.

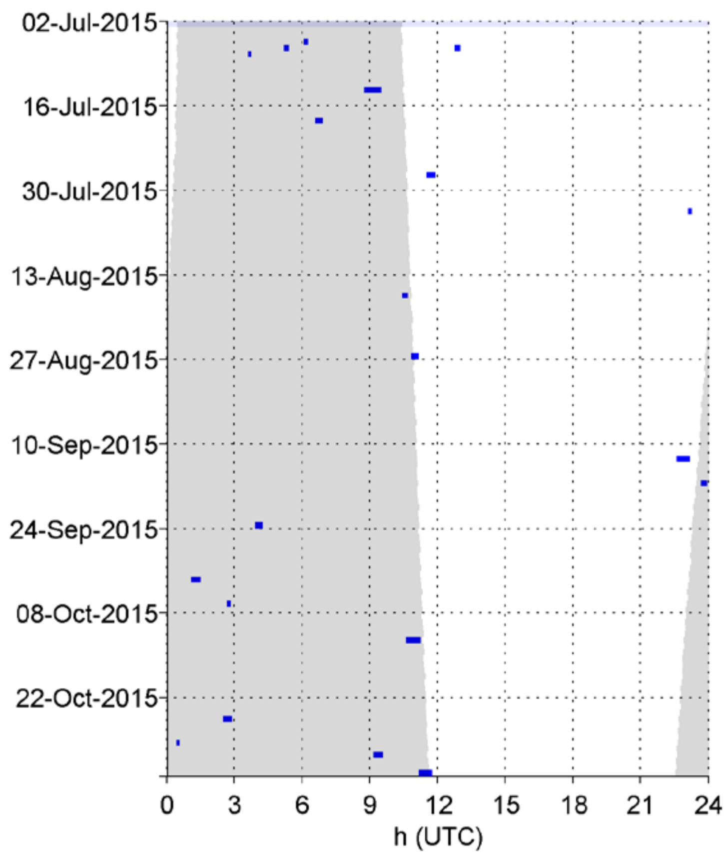

Figure 39. Echosounders greater than 5 kHz in one-minute bins between July and November 2015 at site D. Effort markings as in Figure 19.

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