Passive Acoustic Monitoring for Marine Mammals at Site A in the Cape Hatteras Survey Area, October 2012 – May 2013

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Individual technical reports of other HARP deployments are available at: http://www.navymarinespeciesmonitoring.us/reading-room/

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Abstract

A High-frequency Acoustic Recording Package (HARP; Wiggins and Hildebrand 2007) was deployed between October 2012 and May 2013 in the Cape Hatteras, NC, survey area at Site A in 970 m. This HARP sampled continuously at 200 kHz and recorded for 212 days between 9 October 2012 and 9 May 2013. The data were divided into three frequency bands (10 Hz – 1000 Hz, 500 Hz – 5000 Hz, and 1 kHz – 100 kHz) and scanned for marine mammal vocalizations using Long-Term Spectral Averages (LTSAs) and automated detectors. Vocalizations of blue whales, fin whales, minke whales, sei whales, North Atlantic right whales, humpback whales, *Kogia* spp., Risso's dolphins, sperm whales, Cuvier's beaked whales, Gervais' beaked whales, Blainville's beaked whales, and unidentified delphinids were detected in the data.

Methods

The October 2012 – May 2013 Hatteras Site A HARP (Hatteras 02A) was deployed at 35.34060° N, 74.85590° W on 9 October 2012 (recording started on 9 October 2012) and recovered on 29 May 2013 (recording ended on 9 May 2013). The instrument location is shown in Figure 1. Bottom depth at the deployment site was approximately 970 m. A schematic diagram of the Hatteras 02A HARP is shown in Figure 2.

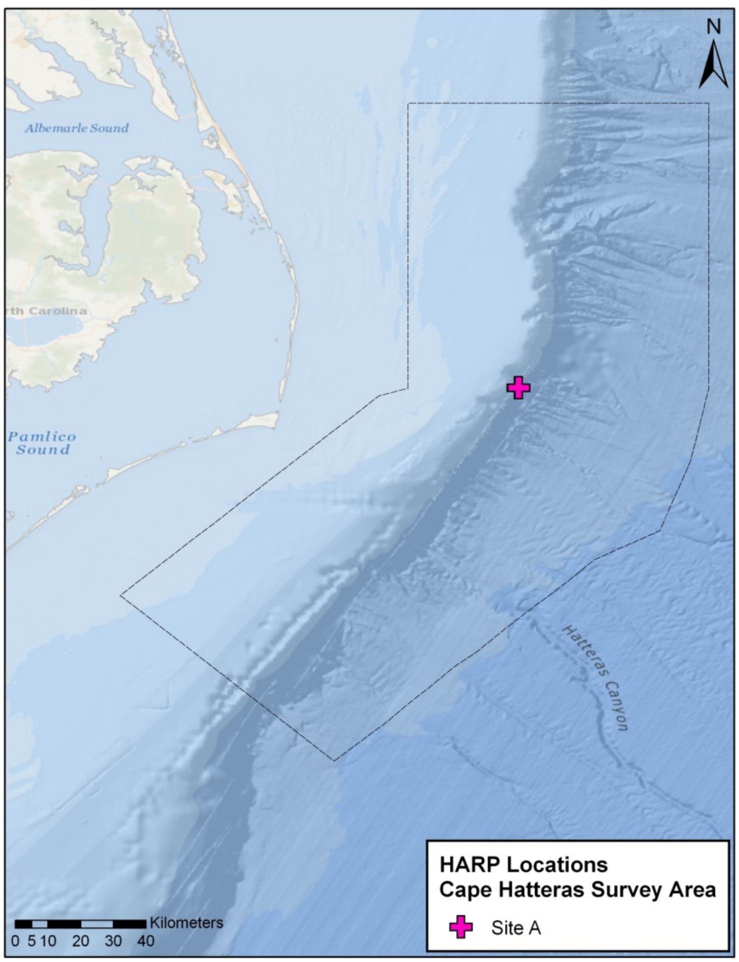

Figure 1. Location of Hatteras 02A HARP deployment in the Cape Hatteras survey area.

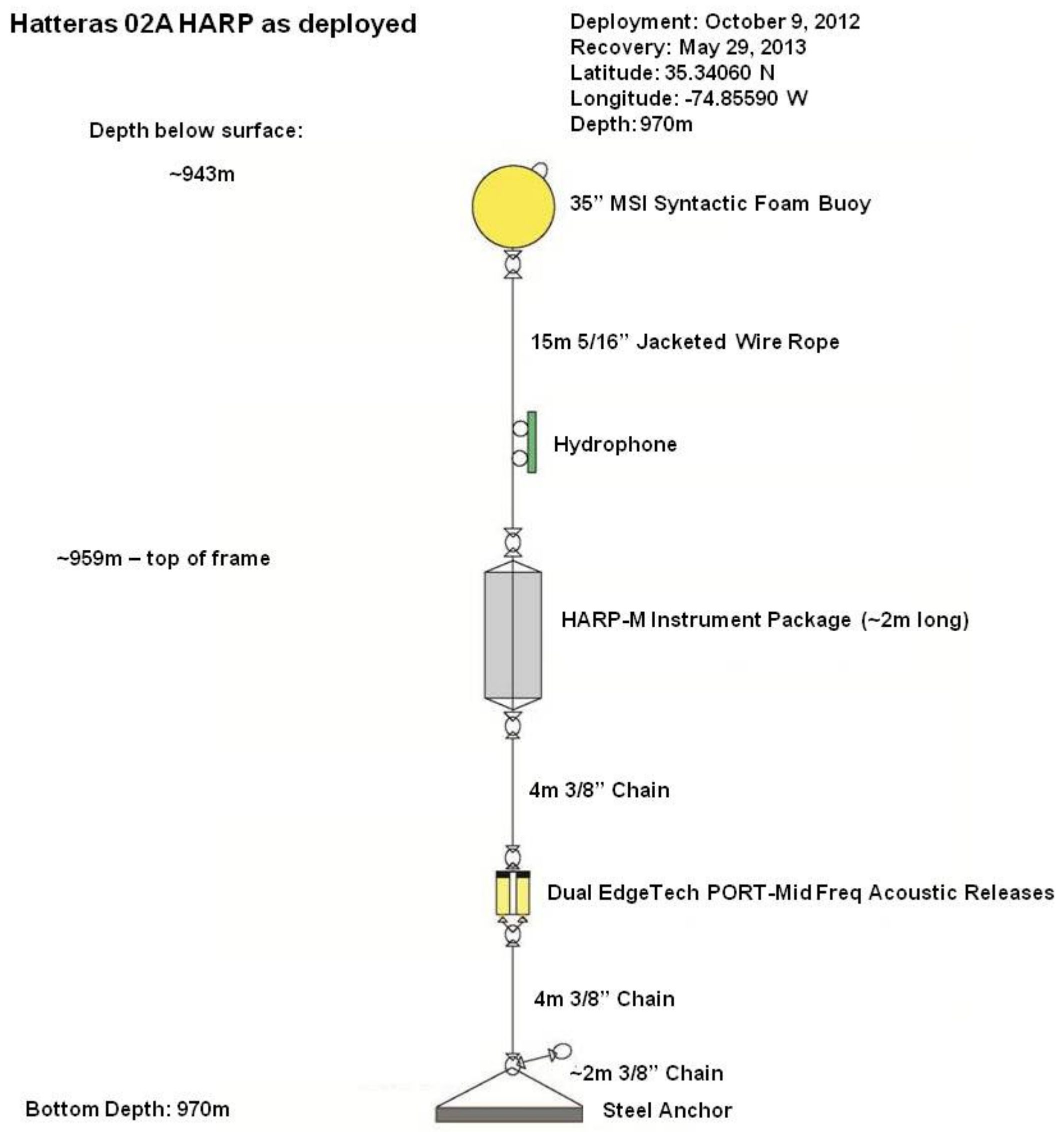

Figure 2. Schematic diagram showing details of the Hatteras 02A HARP. Note that diagram is not drawn to scale.

Data were acquired continuously at a 200 kHz sampling rate during the Hatteras 02A deployment. This deployment provided a total of 5093 hours of data over the 212 days of recording.

The following methods are a summary of Debich *et al.* (2016). Members of the Scripps Whale Acoustics Lab manually scanned the data from the Hatteras 02A HARP deployment for marine mammal vocalizations and anthropogenic sounds (sonar, explosions, shipping, and airguns) using LTSAs. Automated computer algorithm detectors were also used to analyze the data. Personnel at Scripps Institution of Oceanography analyzed the data for all marine mammal vocalizations except for beaked whales. J.E. Stanistreet performed the analysis for beaked whales; these methods will be discussed later.

Prior to manual review of the data, LTSAs were made for three frequency bands: (1) 10 – 1000 Hz (with resolutions of 5 s in time and 1 Hz in frequency), (2) 10 – 5000 Hz (with resolutions of 5 s in time and 10 Hz in frequency), and (3) 1 – 100 kHz (with resolutions of 5 s in time and 100 Hz in frequency). For effective analysis of marine mammal and anthropogenic sounds, analysts scanned three frequency bands: (1) low-frequency, between 10-300 Hz, (2) mid-frequency, between 10-5000 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, sei, Bryde's, minke, and North Atlantic right whales as well as the 5-pulse signal were classified as low-frequency; humpback whales, shipping, explosions, airguns, underwater communications, low-frequency active sonar greater than 500 Hz, and mid-frequency active sonar were classified as mid-frequency; and the remaining odontocete and sonar sounds were considered high-frequency. Low-frequency sounds were analyzed in hourly bins; mid- and high-frequency vocalizations were analyzed in one-minute bins. Vocalizations were assigned to species when possible. For North Atlantic right whale calls, the data were only examined for up-calls. Information on the detections of shipping, explosions, and underwater communications is not reported here but can be found in Debich *et al.* (2016).

Detections of most sounds were made by manually scanning LTSAs. However, detectors were used for some calls, including fin whale 20-Hz calls, humpback whale calls, *Kogia* spp. clicks, and echolocation clicks from the family Delphinidae. The new method of automatically detecting fin whale 20-Hz calls with an energy detection method was implemented for this dataset. This new method used a difference in acoustic energy between signal and noise, calculated from a 5 s LTSA with 1 Hz resolution. The frequency at 22 Hz was used as the signal frequency, while noise was calculated as the average energy between 10 and 34 Hz. The resulting ration is termed the fin whale acoustic index and is reported as a daily average. All calculations were preformed on a dB scale.

Humpback whale call detection effort was automated using an algorithm based on the generalized power law (Helble *et al.* 2012). After the generalized power-law algorithm was applied, a trained analyst verified the accuracy of the detected signals. No effort was made to separate song and non-song calls.

Three steps were involved in the classification of *Kogia* spp. clicks. First, clicks with energy between 70-100 Hz without energy in lower frequency bands were identified. Then, an expert system classified these clicks based on spectral characteristics and finally an analyst verified all echolocation click bouts manually as *Kogia* spp. clicks.

Echolocation clicks from the family Delphinidae were detected using a modified version of a Teager energy detector (Soldevilla *et al.* 2008, Roch *et al.* 2011). Events were reviewed manually to remove false detections. LTSAs were then manually examined to identify reoccurring echolocation click types. Clicks were manually classified into separate click types based on characteristics such as inter-click interval, spectral peaks/troughs, and peak frequency. Classification was carried out by comparison to species-specific spectral characteristics from HARP recordings in the Gulf of Mexico (Frasier 2015).

For analysis of beaked whale echolocation signals, an automated detection method customized for the Cape Hatteras HARP recordings was used. This method used the same initial automated detection steps described in detail in Debich *et al.* (2014) to find 75-second recording segments containing potential beaked whale frequency modulated pulses. A Teager Kaiser energy detector was used to find echolocation signals, and criteria based on peak and center frequency, duration, and sweep rate were used to discriminate between delphinid and beaked whale signals (Debich *et al.* 2014). Additional criteria based on the shape and duration of the signal envelope were then applied to reduce the high number of false detections of non-beaked whale clicks in the Cape Hatteras recordings. All detected signals with a signal envelope increasing after 20 sample points, and remaining above a 50 percent energy threshold for at least 19 sample points but no greater than 70 sample points were kept; signals not meeting these criteria were removed from the analysis. The remaining detections were grouped into detection events, with detections separated by no more than 5 minutes considered to be a single event. In a final computer-assisted manual classification step, each detected event was given a species label by a trained analyst, and any remaining false detections were rejected (as in Baumann-Pickering *et al.* 2013).

This method resulted in significantly more detections of beaked whales at Cape Hatteras than manual LTSA analysis for this site, due to the ability to detect faint, barely visible beaked whale clicks as well as beaked whale clicks mixed in with echolocation from other odontocete species.

Data Quality

Highly stereotyped broadband digital errors (‘glitches’) were found in this dataset. These glitches which were short in duration (between 100 microseconds and 10 milliseconds) and started in the second half of the dataset, increasing in occurrence once they appeared. To repair the glitches, the data were overwritten using a detector calibrated to the observed amplitude and duration of the glitches. This process does not overwrite any real broadband signals in the data. It is believed that neither the glitches nor the repair process significantly impacted the resulting data analysis.

Results

Table 1 summarizes the detected and identified marine mammal vocalizations for the Hatteras 02A HARP deployment. Figures 3-18 show the daily occurrence patterns for the marine mammals detected in this dataset. Figure 19 shows the occurrence of mid-frequency active sonar. Figure 20 shows the occurrence of airguns. Underwater ambient noise during this deployment is shown in Figure 21.

Mysticete detections included blue whales, fin whales, minke whales, sei whales, North Atlantic right whales, and humpback whales. Blue whales were present primarily in October and November, but continued to be detected through April (Figure 3). Fin whale 20-Hz pulses (as measured by the acoustic index) were detected throughout the deployment, with peaks in calling in December and January (Figure 4). Fin whale 40-Hz calls were detected in low numbers throughout the deployment, with a peak in hourly call detections in March (Figure 5). Minke whale pulse trains showed a strong seasonal pattern, with a peak in detections between December and February (Figure 6). Sei whale downsweeps were detected throughout the deployment (Figure 7). North Atlantic right whale up-calls were detected on two days during this deployment (Figure 8). The timing coincides with the migration of this species from the breeding grounds. Humpback whale calls were detected in low numbers during this deployment, with a peak in occurrence in March (Figure 9).

Detected odontocete vocalizations included clicks and whistles (Figures 10-18). Many of these detections were assigned to the unidentified odontocete category, with whistles divided into two categories based on frequency (Figures 10-11) and with the unidentified clicks being divided into five main groups based on spectral patterns (Figure 12). These vocalizations were present nearly continuously throughout the deployment (Figures 10-12). For more details on each of the five main groups of clicks and which species may have produced them, see Debich *et al.* (2016). Clicks produced by *Kogia* spp. were also detected during the deployment, with a peak in occurrence during the winter months (Figure 13). Risso's dolphin clicks were detected only on one day, February 16, 2013 (Figure 14). Sperm whales were detected throughout the deployment during both day and night, with peaks in click detections between January and

February (Figure 15). There were also several click detections that were assigned to beaked whales. Cuvier's beaked whale clicks occurred regularly throughout the deployment, with detections distributed fairly uniformly across both seasonal and diel time scales (Figure 16). Gervais' beaked whale clicks occurred less frequently (Figure 17). Finally, Blainville's beaked whale clicks were detected only once, on February 3, 2013 (Figure 18).

Table 1. Summary of detections of marine mammal vocalizations at the Cape Hatteras Survey Area Site A for October 2012 – May 2013 (Hatteras 02A). Fin whale 20-Hz pulses are not included as they were reported as an acoustic index and not logged with a start and end time to individual detection events.

Species	**Call type**	**Total duration of vocalizations (hours)**	**Percent of recording duration**	**Days with vocalizations**	**Percent of recording days**
Blue whale[a]	A and B calls	157	3.08	42	19.72
Fin whale[a]	40 Hz	37	0.73	16	7.51
Minke whale[a]	pulse train (slow-down, speed-up, regular)	1880	36.91	128	60.09
Sei whale[a]	downsweep	214	4.20	57	26.76
North Atlantic right whale[a]	up-call	7	0.14	2	0.94
Humpback whale	variable	17.85	0.35	25	11.74
Unidentified odontocete	whistles	2567.68	50.42	212	99.53
Unidentified odontocete	clicks	3072.78	60.33	213	100
Kogia spp.	clicks	2.57	0.05	37	17.37
Risso's dolphin	clicks	0.02	0.0003	1	0.47
Sperm whale	clicks	818.25	16.07	150	70.42
Cuvier's beaked whale	clicks	334.90	6.58	206	96.71
Gervais' beaked whale	clicks	13.02	0.26	42	19.72
Blainville's beaked whale	clicks	0.07	0.001	1	0.47

[a]Analyzed in hourly bins versus one-minute bins.

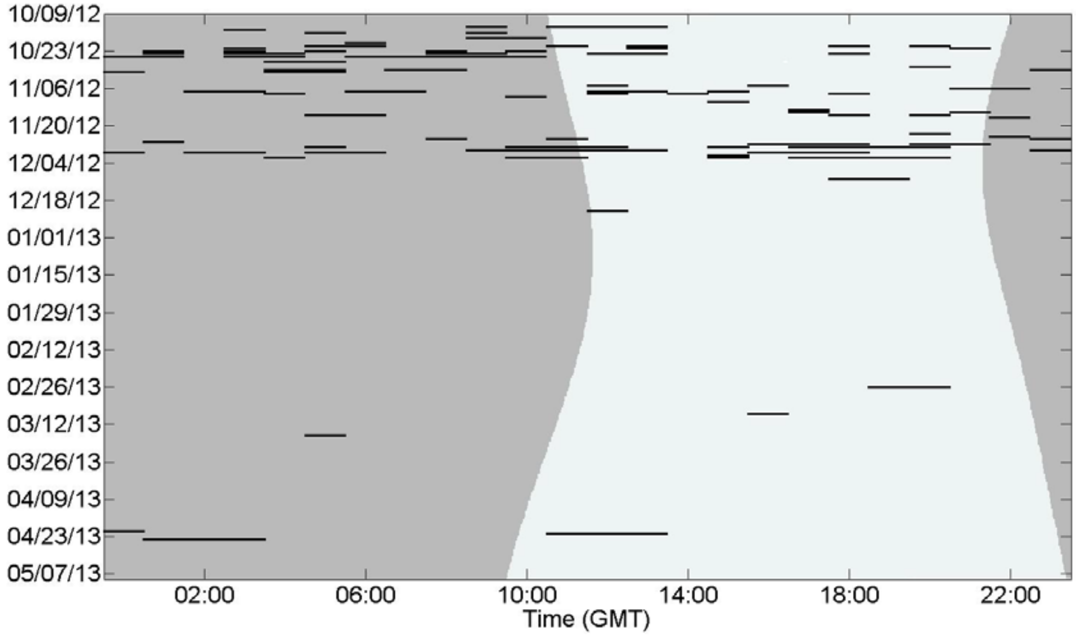

Figure 3. Blue whale call detections (black bars) in hourly bins for the Hatteras 02A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

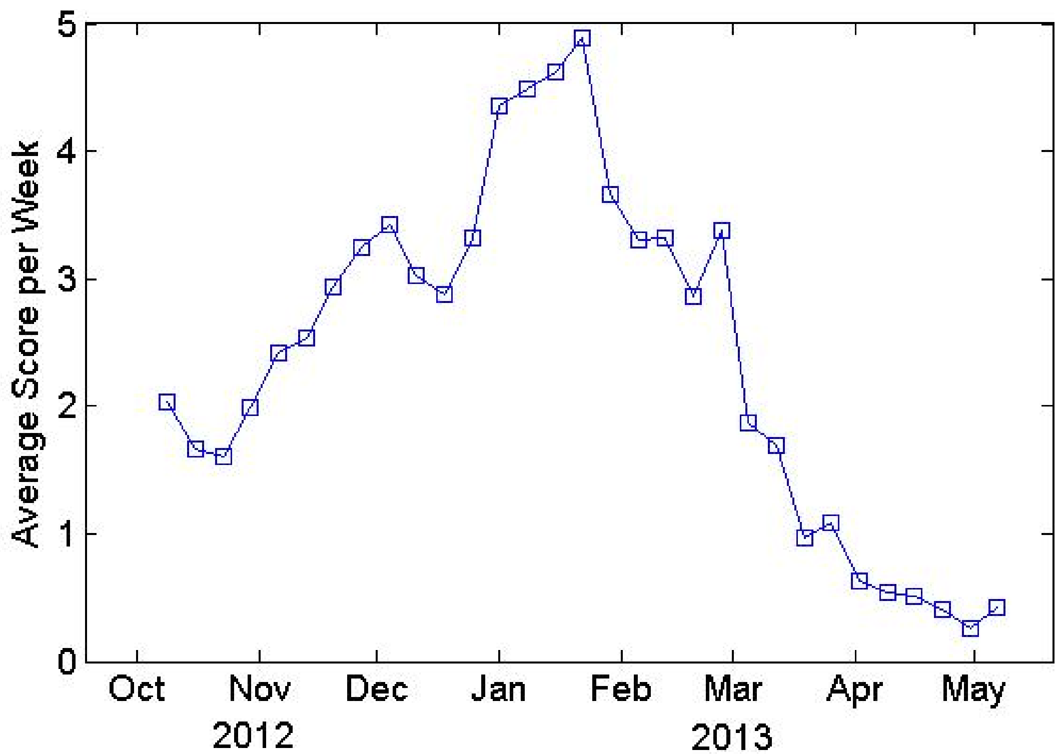

Figure 4. Weekly value of fin whale 20-Hz call acoustic index for the Hatteras 02A deployment.

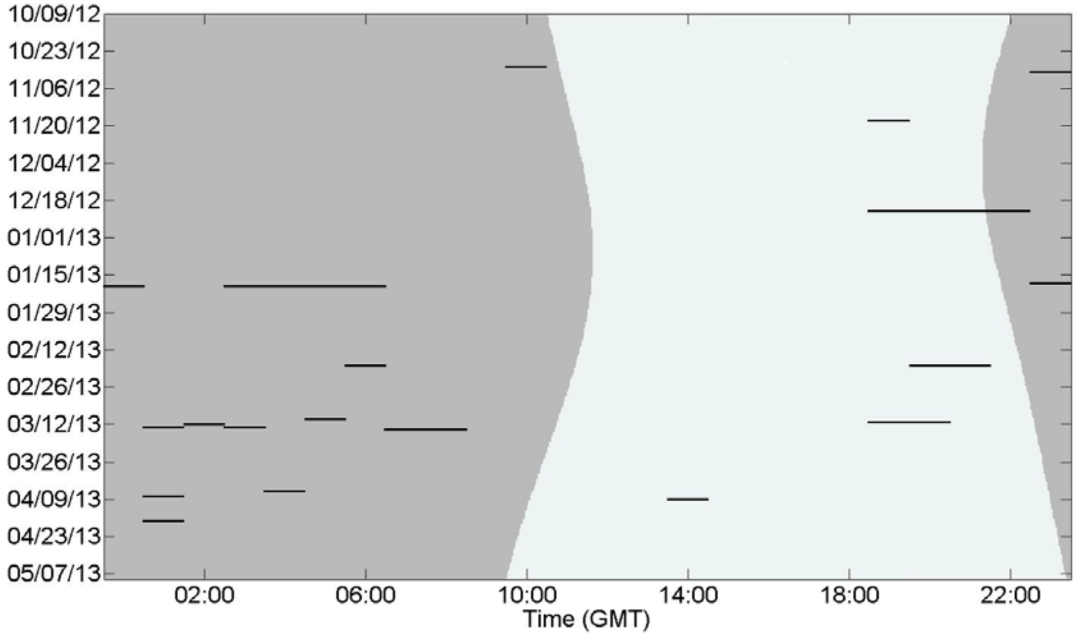

Figure 5. Fin whale 40-Hz call detections (black bars) in hourly bins for the Hatteras 02A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

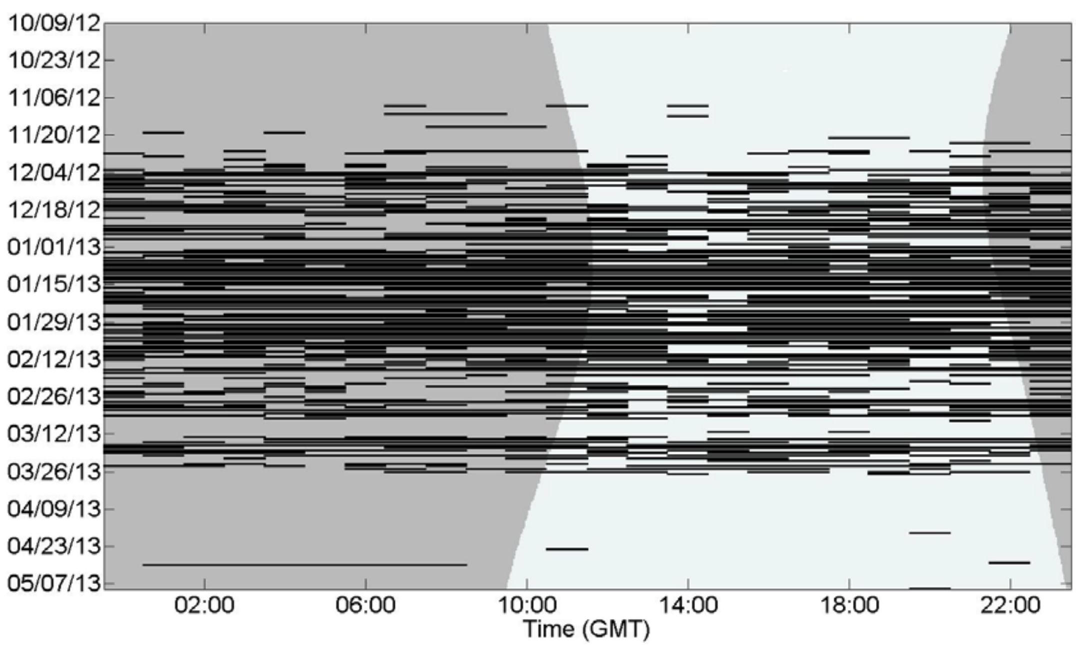

Figure 6. Minke whale pulse train detections (black bars) in hourly bins for the Hatteras 02A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

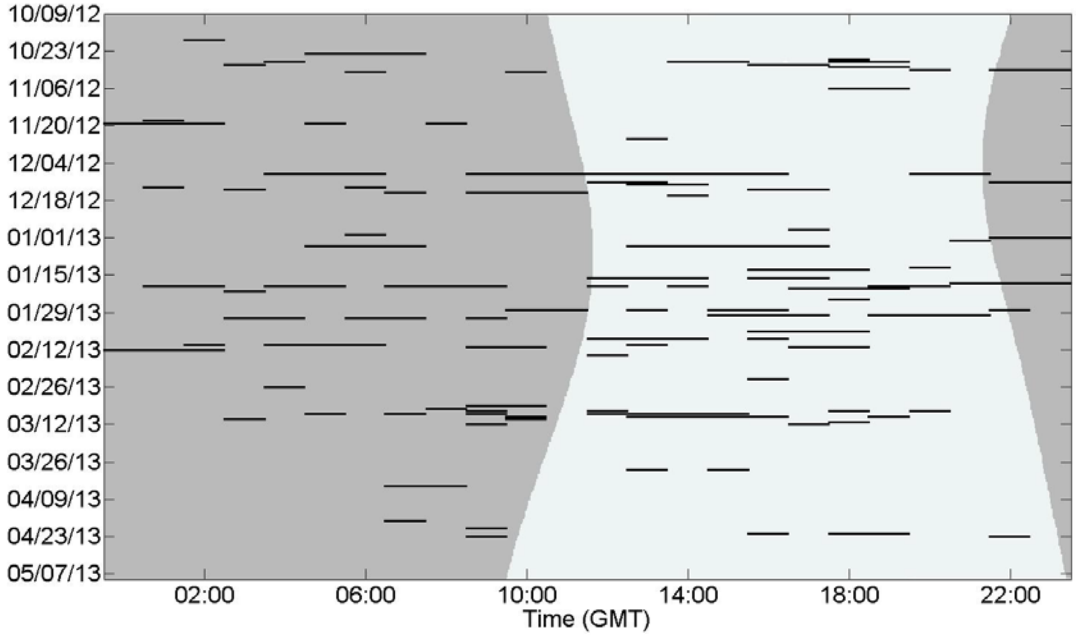

Figure 7. Sei whale downsweep detections (black bars) in hourly bins for the Hatteras 02A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

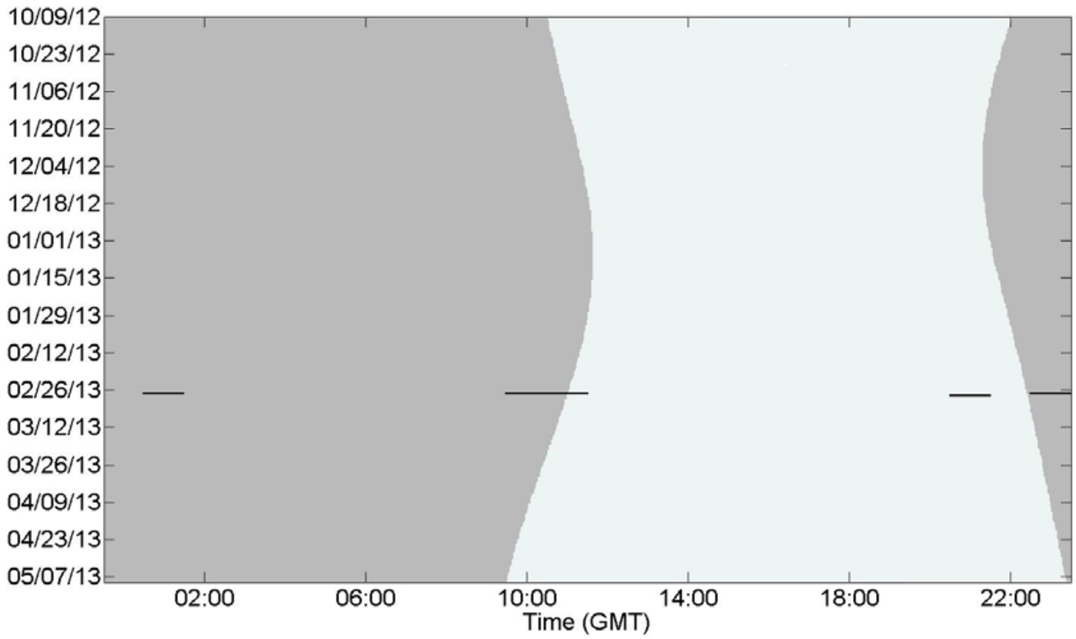

Figure 8. North Atlantic right whale up-call detections (black bars) in hourly bins for the Hatteras 02A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

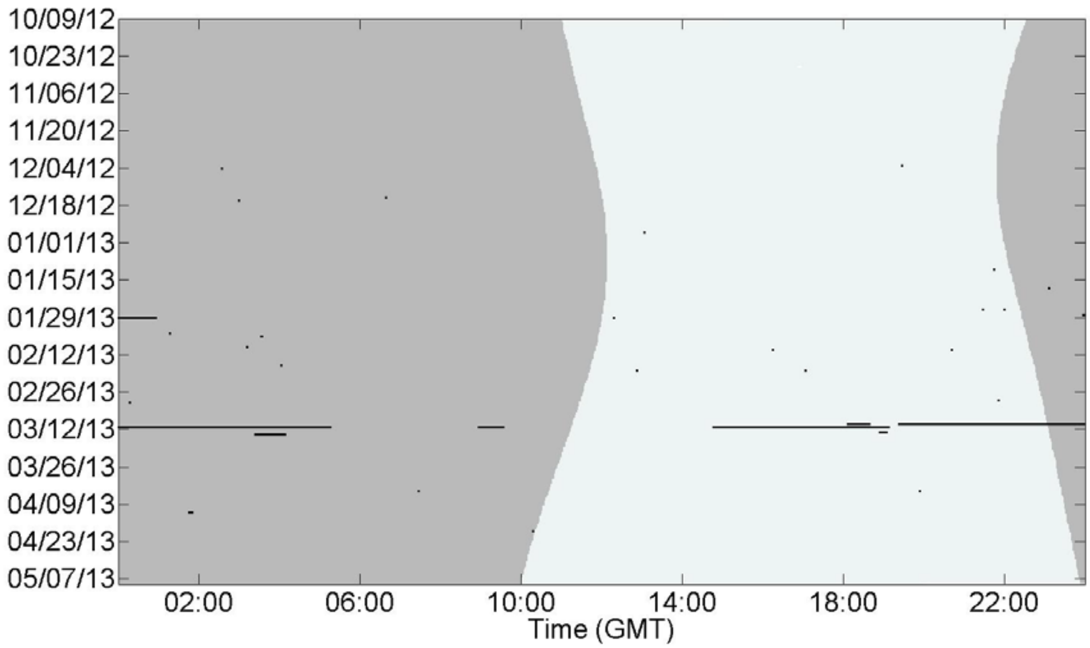

Figure 9. Humpback whale call detections (black bars) in one-minute bins for the Hatteras 02A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

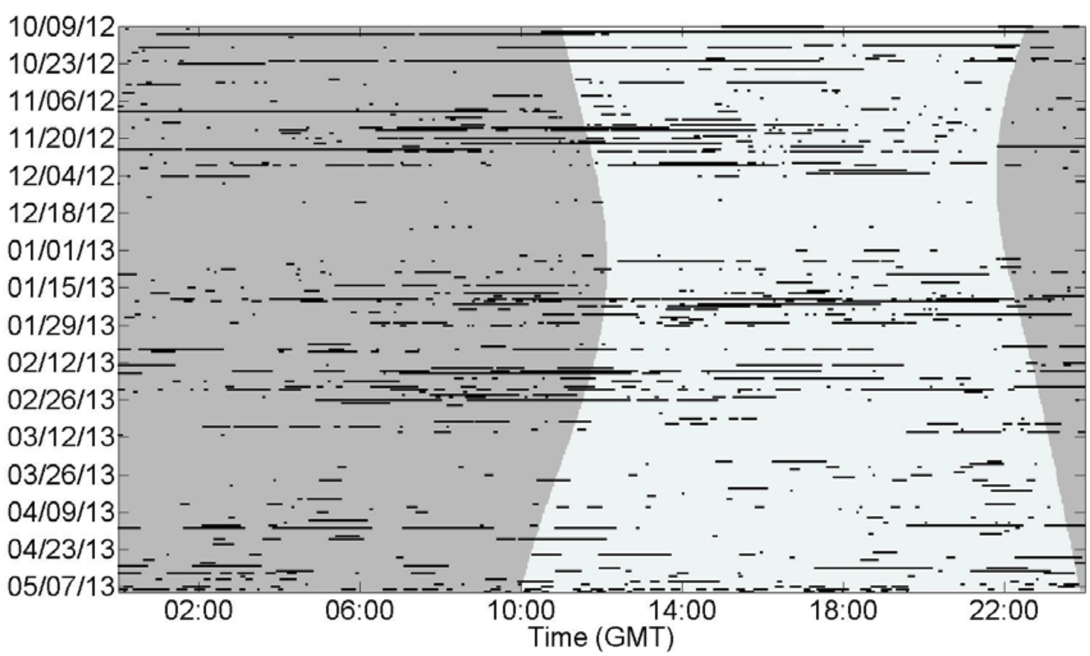

Figure 10. Unidentified odontocete whistle detections that were less than 5 kHz (black bars) in one-minute bins for the Hatteras 02A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

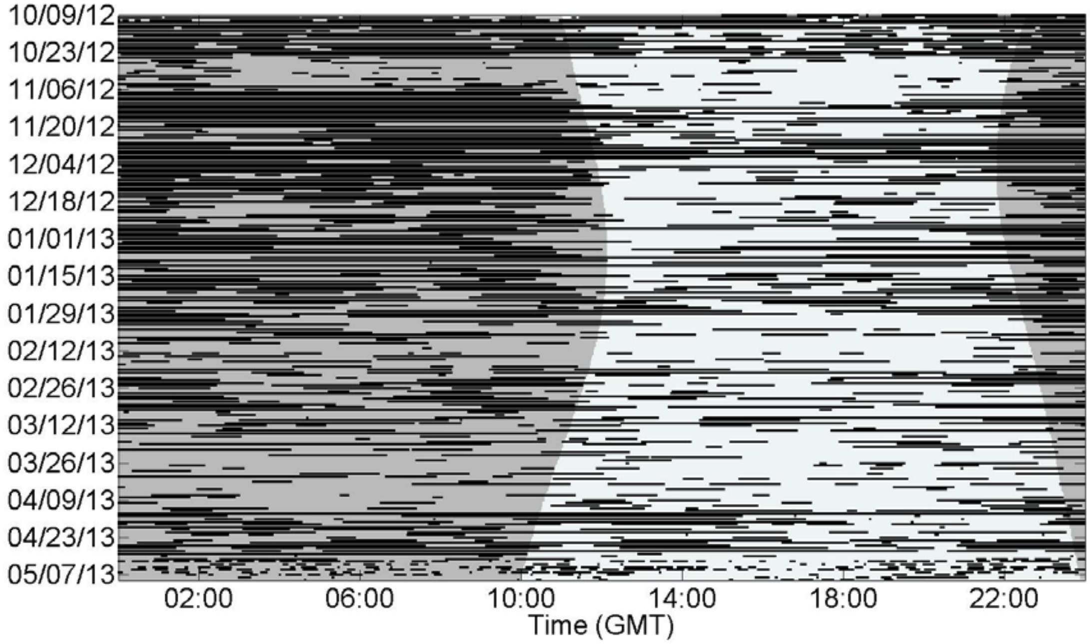

Figure 11. Unidentified odontocete whistle detections that were greater than 5 kHz (black bars) in one-minute bins for the Hatteras 02A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

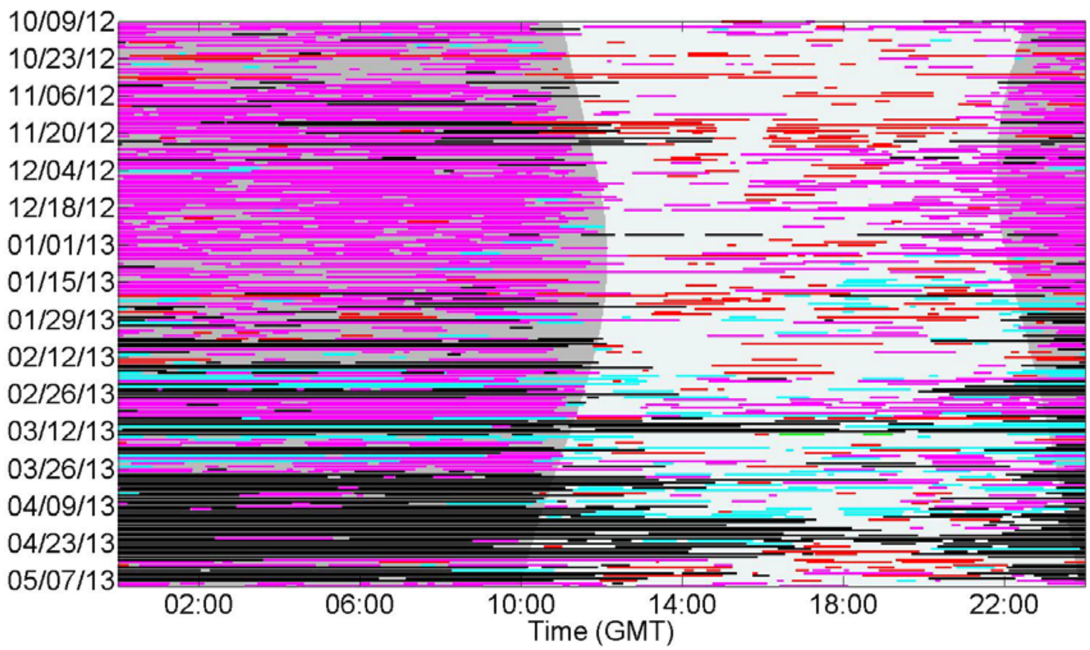

Figure 12. Unidentified odontocete click detections (different colored horizontal bars represent the different groups clicks were divided into for this report) in one-minute bins for the Hatteras 02A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

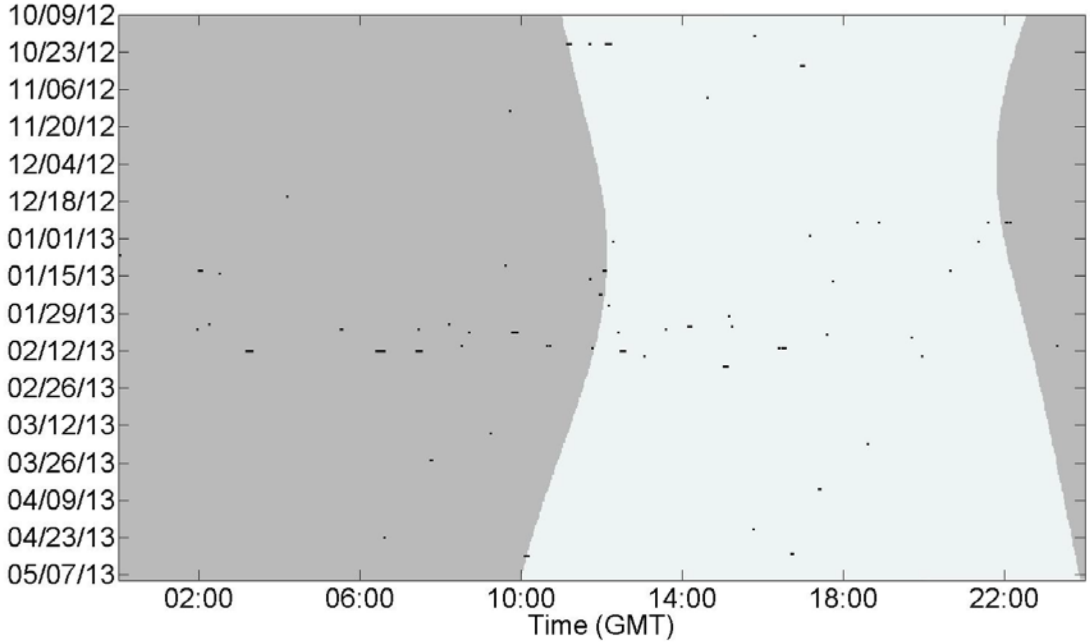

Figure 13. *Kogia* spp. click detections (black bars) in one-minute bins for the Hatteras 02A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

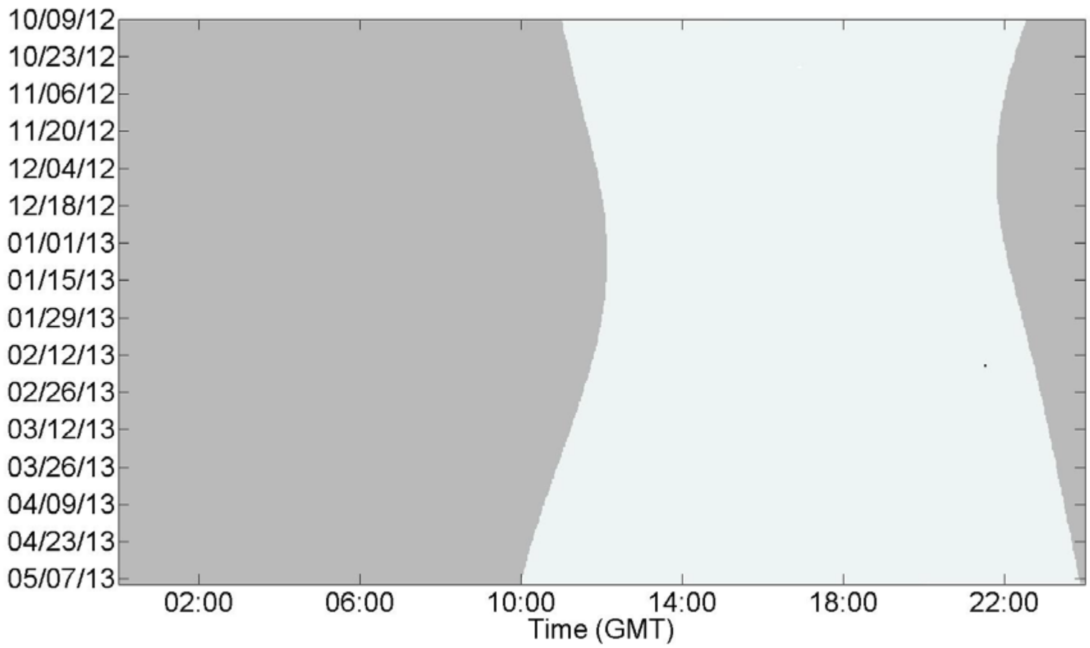

Figure 14. Risso's dolphin click detections (black bars) in one-minute bins for the Hatteras 02A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

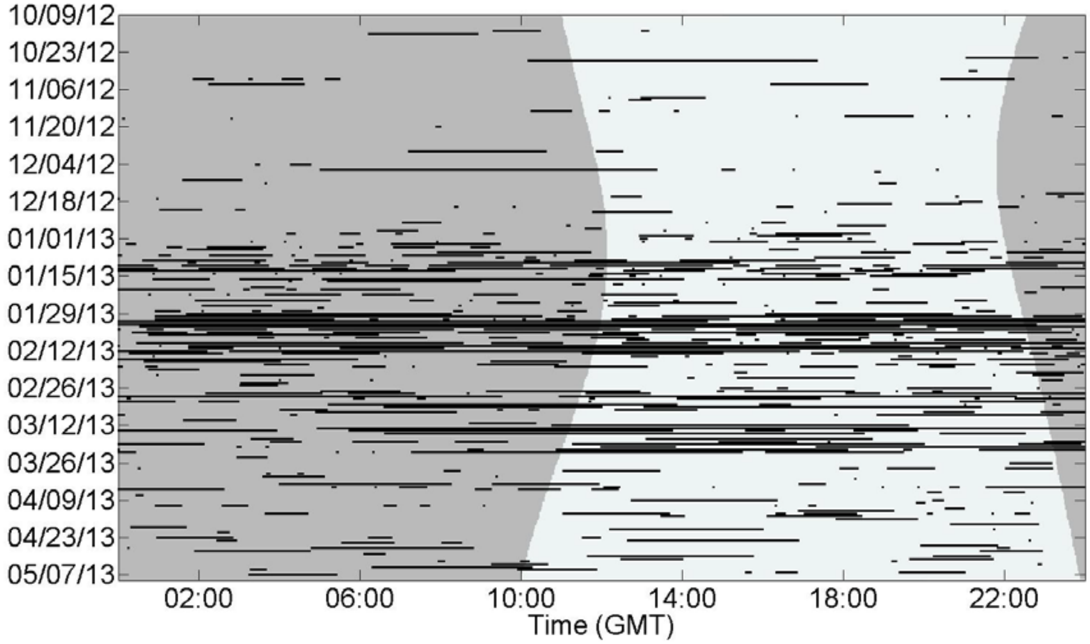

Figure 15. Sperm whale click detections (black bars) in one-minute bins for the Hatteras 02A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

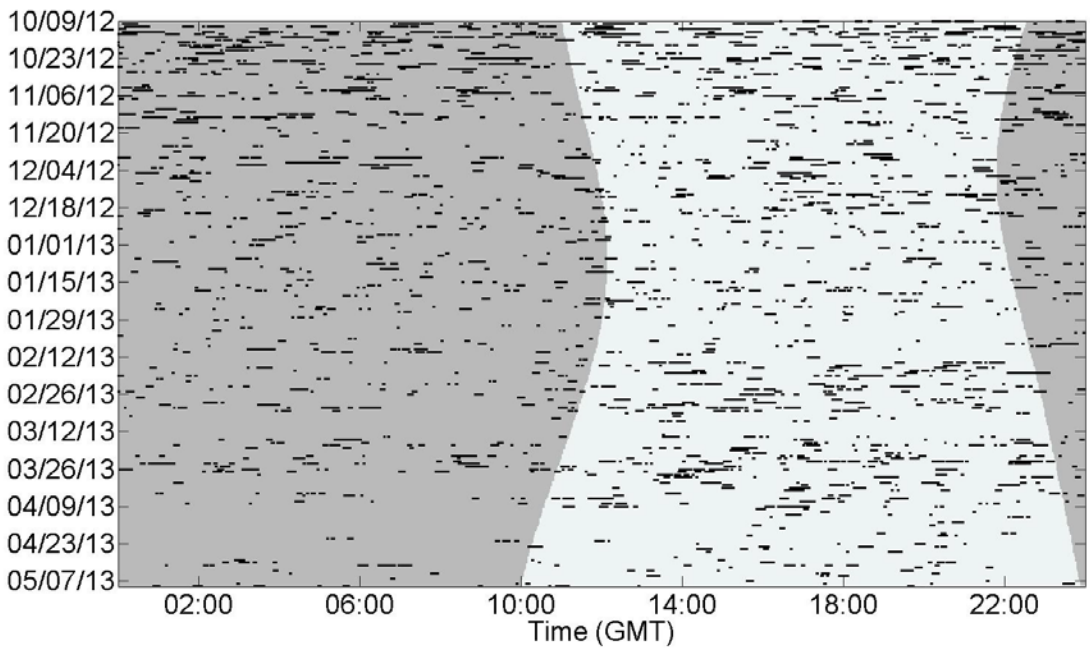

Figure 16. Cuvier's beaked whale click detections (black bars) in one-minute bins for the Hatteras 02A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

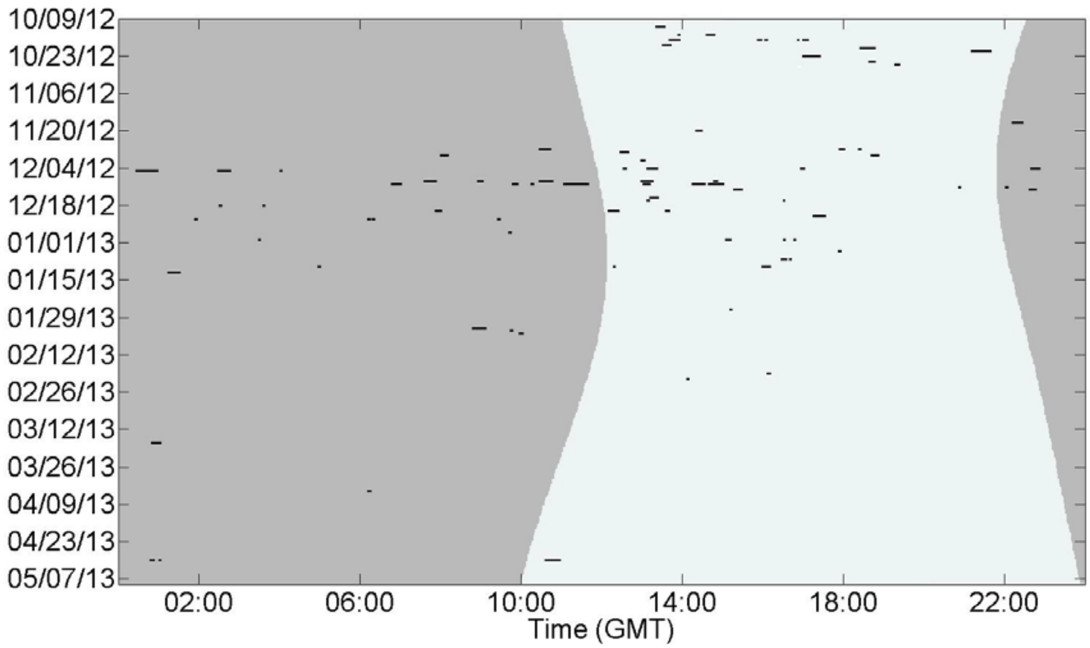

Figure 17. Gervais' beaked whale click detections (black bars) in one-minute bins for the Hatteras 02A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

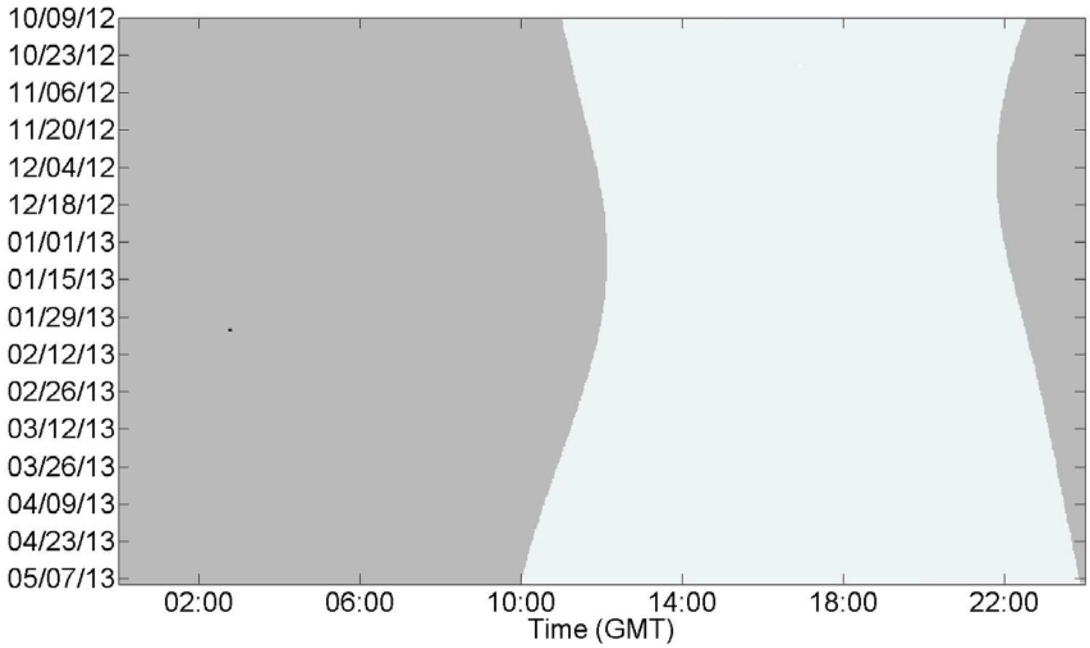

Figure 18. Blainville's beaked whale click detections (black bars) in one-minute bins for the Hatteras 02A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

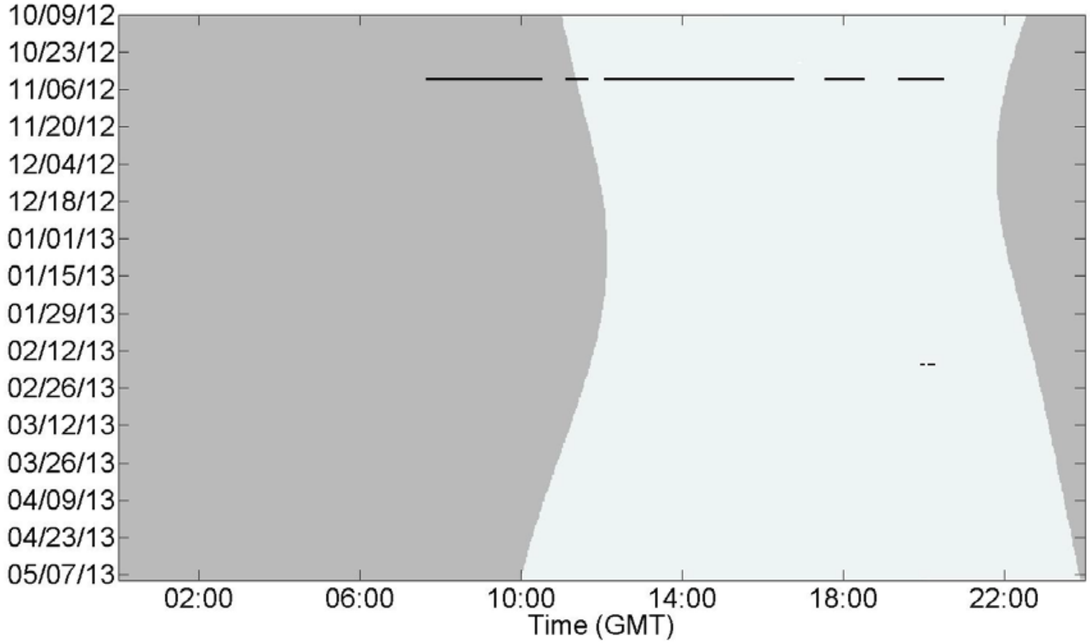

Figure 19. Mid-frequency active sonar (black bars) detected during the Hatteras 02A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

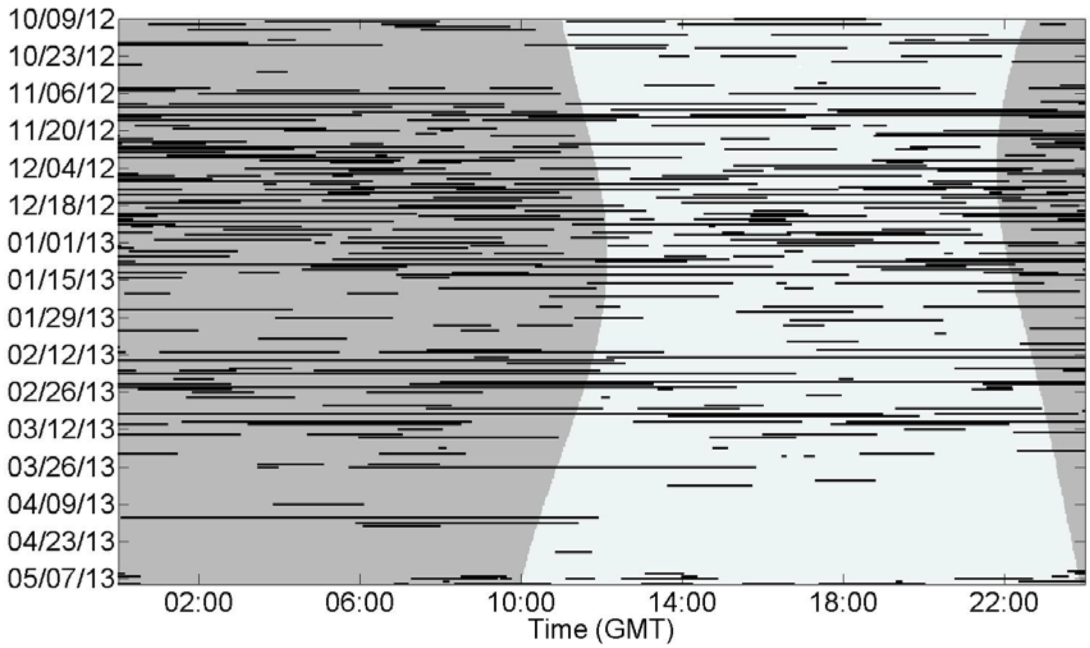

Figure 20. Airgun detecions (black bars) within the Hatteras 02A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

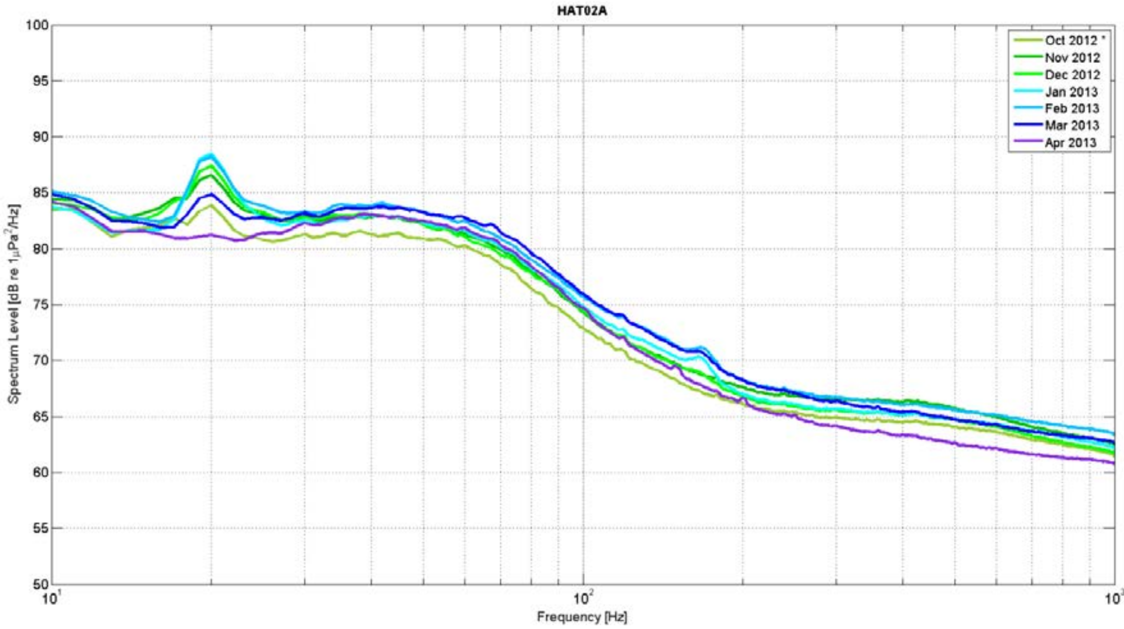

Figure 21. Monthly averages of ambient noise at Cape Hatteras, NC, Site A for October 2012 – May 2013. Months with an asterisk (*) are partial recording periods. Figure from Debich *et al.* (2016).

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