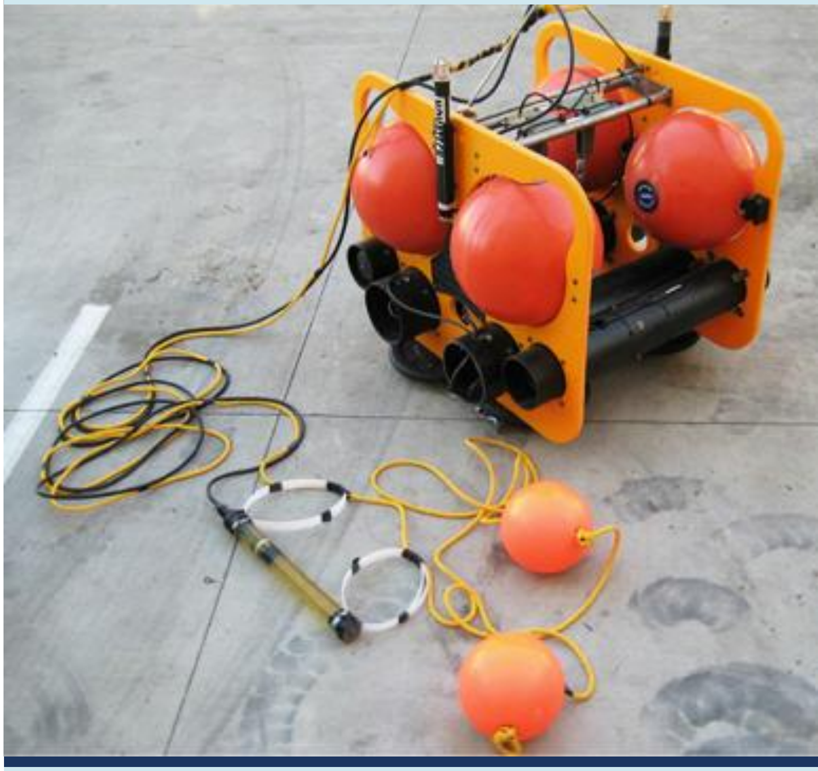
Final

Annual Report 2014: Passive Acoustic Monitoring for Marine Mammals off of Virginia, North Carolina, and Florida using High-frequency Acoustic Recording Packages



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

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High-frequency Acoustic Recording Package. Photo by Scripps Institution of Oceanography (accessed at http://www.nefsc.noaa.gov/psb/acoustics/psbAcousticsMigration.html)

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Acronyms and Abbreviations

HARP	High-frequency Acoustic Recording Package
Hz	Hertz
kHz	kilohertz
LTSA	long-term spectral average
m	meter(s)
s	second(s)
USWTR	Undersea Warfare Training Range

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1. Introduction and Background

In October 2005, the U.S. Department of the Navy proposed the installation of an Undersea Warfare Training Range (USWTR) in one of four sites along the Atlantic coast, for the purpose of anti-submarine warfare training using mid-frequency tactical sonar (1-10 kilohertz [kHz]) in shallow waters. The initial preferred site for the USWTR was Onslow Bay, North Carolina. As part of a multi-institutional monitoring plan for Onslow Bay, an acoustic monitoring effort, funded by the U.S. Atlantic Fleet, was initiated in 2007 by Duke University with assistance from Scripps Institution of Oceanography. In 2008, the preferred site was moved to Jacksonville, Florida. While acoustic monitoring continued in Onslow Bay, it also began in Jacksonville in 2009, once again led by Duke University with assistance from Scripps Institution of Oceanography. Later, acoustic monitoring expanded to Cape Hatteras, North Carolina (2012), and Norfolk Canyon, Virginia (2014), as part of the U.S. Navy's marine species monitoring program for Atlantic Fleet Training and testing (AFTT). For all locations, the primary goal of the acoustic monitoring effort has been to determine patterns of occurrence and distribution of cetacean species in the area. In order to determine which species were present, another goal was to identify species-specific characteristics of the vocalizations of marine mammal species in each area. Acoustic monitoring in each area (except for Norfolk Canyon) originally consisted of recordings made by a towed hydrophone array during vessel-based surveys and autonomous passive acoustic recorders. During 2014, passive acoustic data were collected in Jacksonville, Cape Hatteras, and Norfolk Canyon using autonomous bottom-mounted recorders.

1.1 General Methods

Bottom-mounted Recorders

To collect time-series of acoustic data in all three survey areas, autonomous High-frequency Acoustic Recording Packages (HARPs; Wiggins and Hildebrand 2007) were utilized. The HARP data-logging system includes a 16-bit A/D converter; a hydrophone suspended approximately 10-12 meters (m) (large mooring, see **Figure 1**), approximately 22 m (small mooring, see **Figure 2**), or approximately 20 m (compact small mooring, see **Figure 3**) above the seafloor; an acoustic release system; ballast weights; and flotation (**Figures 1 through 3**). The data-loggers are capable of sampling up to 200 kHz and can be set to record continuously or on a duty cycle to accommodate variable deployment durations. These instruments combine high- and low-frequency hydrophone elements to detect the vocalizations of both odontocete and mysticete cetaceans. The units sample at rates high enough to capture the clicks of many odontocetes.

HARP Data Analysis

HARP data require processing prior to analysis, including backing up data in original format, converting data to .wav format, decimating .wav data by a factor of 100 to aid in baleen whale detection, and creating long-term spectral averages (LTSAs). New compression code was implemented starting in July 2010 which allowed for greater than two terabytes of data to be collected after the raw data were decompressed. This amount of data is impractical to analyze manually, so data were compressed for visual overview by using a *MATLAB*-based acoustic

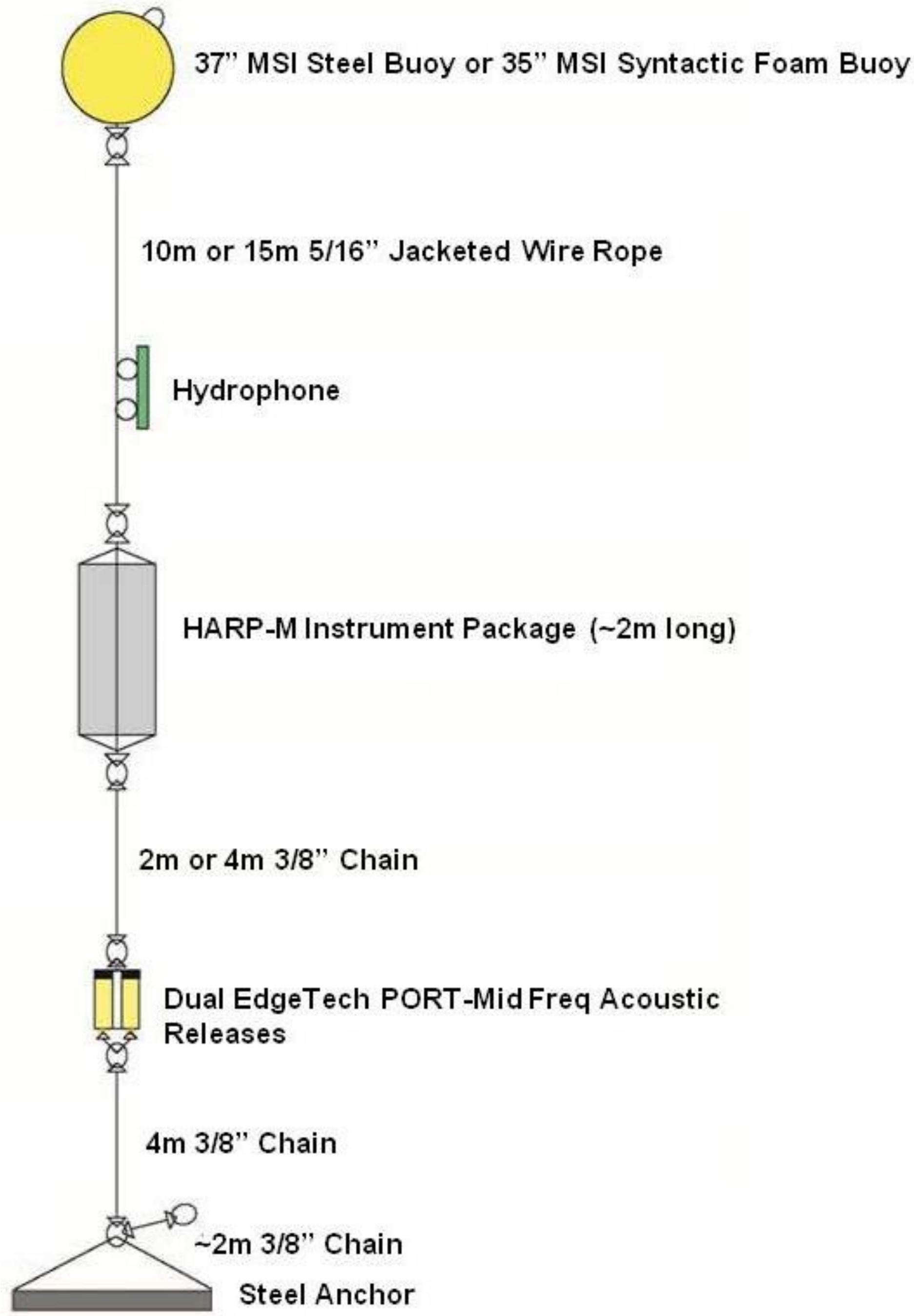

Figure 1. Schematic diagram showing details of a large mooring HARP. Note that diagram is not drawn to scale.

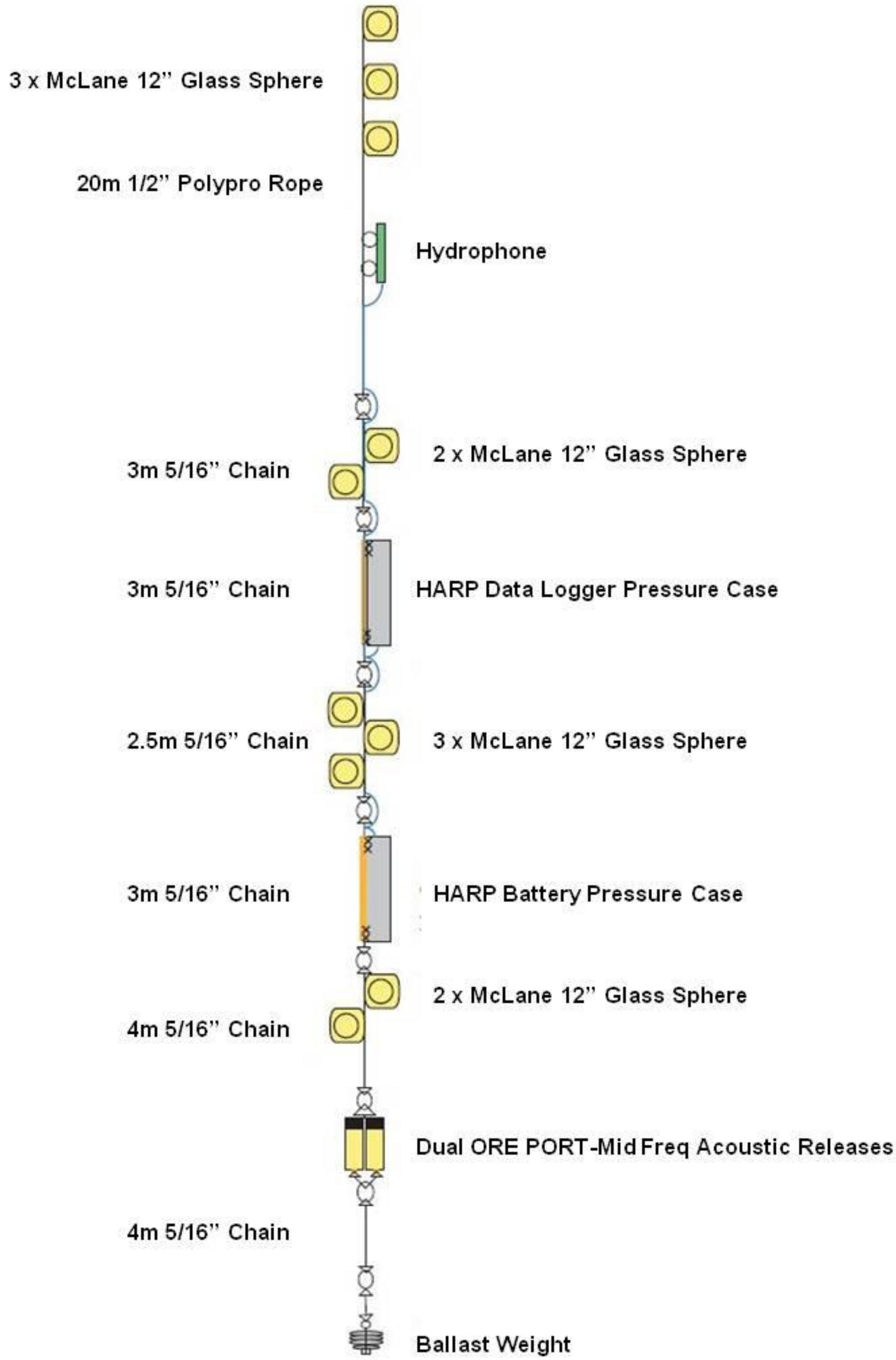

Figure 2. Schematic diagram showing details of a small mooring HARP. Note that diagram is not drawn to scale.

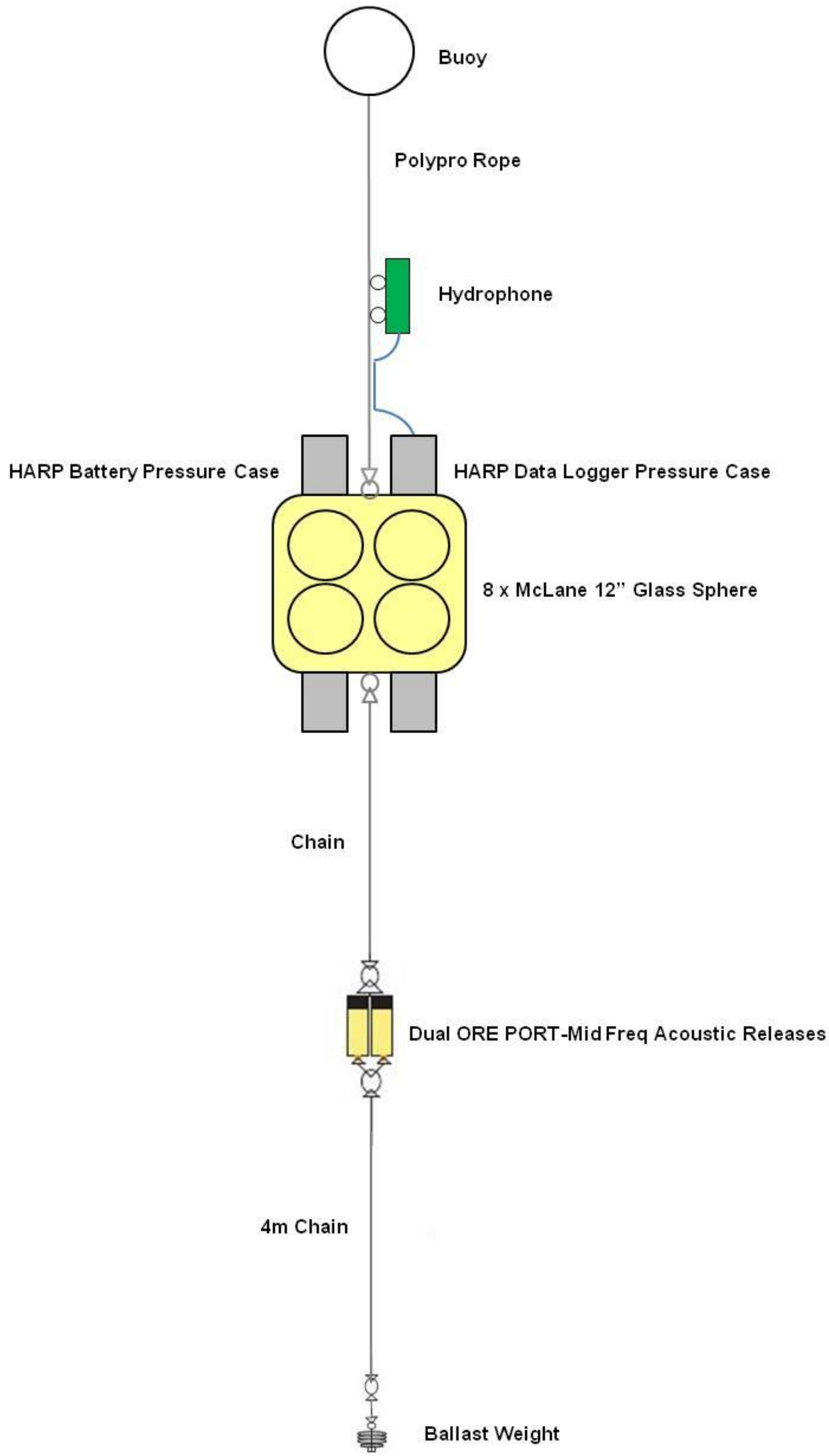

Figure 3. Schematic diagram showing details of a compact small mooring HARP. Note that diagram is not drawn to scale.

program called *Triton* (Hildebrand Lab at Scripps Institution of Oceanography, La Jolla, California) to create LTSAs from the wav files, which allowed for rapid review of the data. Long-term spectral averages are effectively compressed spectrograms created using the Welch algorithm (Welch 1967) by coherently averaging 500 spectra created from 2000-point, 0 percent-overlapped, Hann-windowed data and displaying these averaged spectra sequentially over time.

2. Summary of Deployments

Table 1 shows all HARP deployments in Norfolk Canyon, Cape Hatteras, Onslow Bay, and Jacksonville to date. The table includes location, depth, deployment and retrieval dates, recording dates, information on duty cycle, mooring type, status of analysis, and type of reports written, if any. All HARPs sampled at 200 kHz.

1 **Table 1. Details of all HARP deployments in Jacksonville, Onslow Bay, Hatteras, and Norfolk Canyon.**

Location	Deployment ID	Latitude	Longitude	Depth (m)	Deployment Date	Retrieval Date	Recording Start Date	Recording End Date	Duty Cycle (min on/off)	Mooring Type	Status of Analysis	Reports
JAX												
JAX A	JAX01A	30.2771	-80.1258	82	30MAR09	16SEP09	02APR09	25MAY09	5/10	large	HF	N/A
JAX B	JAX01B	30.2582	-80.4282	37	30MAR09	16SEP09	02APR09	05SEP09	5/10	large	HF, M	T
JAX A	JAX02A	30.28052	-80.21603	83	16SEP09	21FEB10	16SEP09	15DEC09	5/10	large	HF, M	T
JAX B	JAX02B	30.25820	-80.42800	39	23SEP09	21FEB10	No data	No data	5/10	large	N/A	No – no data
JAX A	JAX03A	30.28111	-80.21530	89	21FEB10	26AUG10	22FEB10	30JUL10	5/10	large	HF, M	T
JAX B	JAX04B	30.25919	-80.42566	38	09MAR10	26AUG10	09MAR10	19AUG10	5/10	large	HF, LF	T, D
JAX A	JAX05A	30.26819	-80.20894	91	26AUG10	01FEB11	26AUG10	25JAN11	5/10	large	HF, LF	T, D
JAX B	JAX05B	30.25708	-80.43269	37	26AUG10	01FEB11	27AUG10	01FEB11	5/10	large	HF, LF	T, D
JAX A	JAX06A	30.27818	-80.22085	91	01FEB11	14JUL11	01FEB11	14JUL11	5/10	large	HF, LF	T, D
JAX B	JAX06B	30.25768	-80.42781	37	02FEB11	14JUL11	02FEB11	14JUL11	5/10	large	HF, LF	T, D
JAX A	JAX08A	30.28501	-80.22141	91	24JAN12	abandoned	27JAN12	unknown	continuous	large	abandoned	No – no data
JAX C	JAX09C	30.33287	-80.20071	94	12MAY13	17FEB14	13MAY13	20JUN13	continuous	large	HF, LF	T, D
JAX C	JAX10C	30.32643	-80.20493	88	17FEB14	23AUG14	17FEB14	23AUG14	continuous	small	HF, LF	T, D
JAX D	JAX11D	30.15060	-79.77005	806	23AUG14	N/A	23AUG14	N/A	continuous	small	N/A	N/A
ONSLOW												
Onslow Bay A	USWTR01A	33.79138	-76.52382	162	09OCT07	27MAY08	10OCT07	16JAN08	5/5*	large	HF, LF	T
Onslow Bay B	USWTR02B	33.81107	-76.42829	232	30MAY08	24NOV08	30MAY08	10SEP08	5/5	large	HF, LF	T
Onslow Bay A	USWTR03A	33.78951	-76.51920	174	24APR09	16SEP09	24APR09	09AUG09	5/5	large	HF, LF	T
Onslow Bay A	USWTR04A	33.78733	-76.52409	171	08NOV09	19JUN10	08NOV09	24FEB10	5/10	large	HF, LF	T
Onslow Bay C	USWTR04C	33.67784	-76.47689	335	08NOV09	19JUN10	08NOV09	20APR10	5/10	large	HF, LF	T
Onslow Bay A	USWTR05A	33.79316	-76.51620	171	29JUL10	10JUN11	30JUL10	03MAR11	5/5	large	HF, LF	T
Onslow Bay D	USWTR05D	33.58065	-76.55015	338	29JUL10	10JUN11	30JUL10	24FEB11	5/5	large	HF, LF	T
Onslow Bay E	USWTR06E	33.77794	-75.92641	952	18AUG11	13JUL12	19AUG11	01DEC11	5/5	large	HF, LF	T, D
Onslow Bay E	USWTR07E	33.78666	-75.92915	914	13JUL12	24OCT12	14JUL12	02OCT12	5/5	large	HF, LF	T, D
Onslow Bay E	USWTR08E	33.78696	-75.92801	853	24OCT12	08AUG13	24OCT12	30JUN13	5/5	large	HF, LF	T
CAPE HATTERAS												
Cape Hatteras A	HAT01A	35.34054	-74.85761	950	15MAR12	09OCT12	15MAR12	11APR12	continuous	large	HF, LF	T

Location	Deployment ID	Latitude	Longitude	Depth (m)	Deployment Date	Retrieval Date	Recording Start Date	Recording End Date	Duty Cycle (min on/off)	Mooring Type	Status of Analysis	Reports
Cape Hatteras A	HAT02A	35.3406	-74.85590	970	09OCT12	29MAY13	09OCT12	09MAY13	continuous	large	In progress	N/A
Cape Hatteras A	HAT03A	35.34445	-74.8521	970	29MAY13	8MAY14	29MAY13	15MAR14	continuous	large	In progress	N/A
Cape Hatteras A	HAT04A	35.34677	-74.84805	850	08MAY14	N/A	09MAY14	N/A	continuous	large	In progress	N/A
NORFOLK CANYON												
Norfolk Canyon A	NFC01A	37.16623	-74.46692	982	19JUN14	N/A	19JUN14	N/A	continuous	compact	N/A	N/A

Notes: All HARPs sampled at 200 kHz. For Status of Analysis: HF = high-frequency (odontocete, > 1 kHz) analysis completed; LF = low-frequency (mysticete, < 1 kHz) analysis completed; M = low-frequency analysis completed only for minke whale pulse trains; N/A = not applicable, because data are not yet available for analysis. For Reports: T = technical report; D = detailed report; N/A = not applicable because HARP is still in the field or data analysis is in progress. Key: JAX = Jacksonville Range Complex; m = meter(s); USWTR=Undersea Warfare Training Range. * = represents the initial duty cycle, but instrument recorded continuously starting 01 January 2008.

3. Norfolk Canyon, Virginia

3.1 Methods

Data Collection

A compact small mooring design HARP was deployed in Norfolk Canyon at a depth of 982 m at 37.16623^{o} N, 74.46692^{o} W (Site A) on June 19, 2014 (**Table 2**, **Figure 4**); the deployment period will be approximately 10 months. A schematic diagram of the HARP mooring for this deployment is shown in **Figure 5**. This instrument is still in the field and is expected to be recovered during early April 2015. The HARP was programmed to sample continuously at 200 kHz. This HARP was also equipped with a SPOT-293A tag as a safety precaution in case the instrument breaks free of its mooring earlier than expected.

Table 2. Norfolk Canyon, Virginia, HARP data set detailed in this report.

Site	Deployment Date	Retrieval Date	Recording Start Date	Recording End Date	Latitude	Longitude	Depth (m)	Sampling Rate	Duty Cycle
01A	19-Jun-14	N/A	19-Jun-14	N/A	37.16623	-74.46692	982	200 kHz	continuous

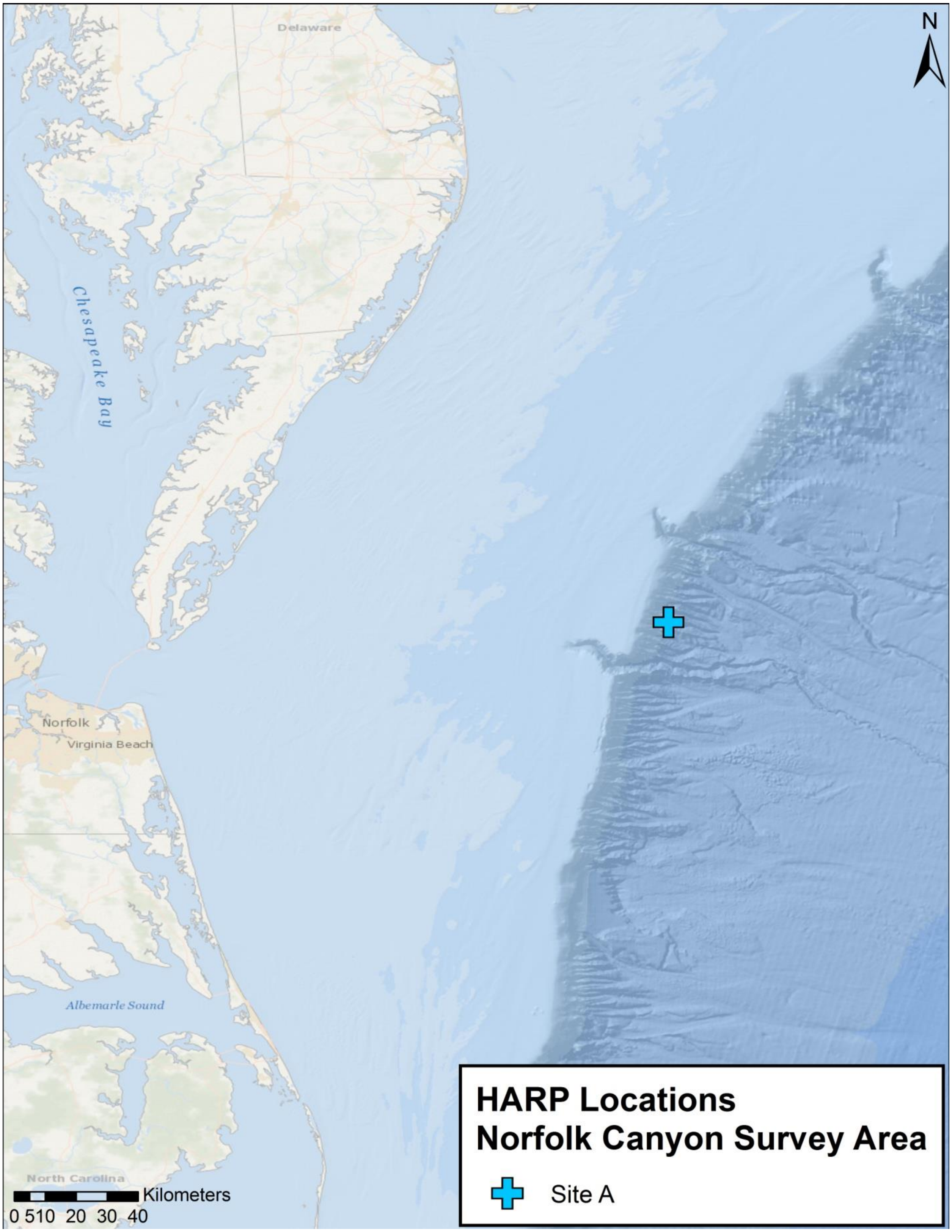

Figure 4. Location of the HARP deployment site in Norfolk Canyon.

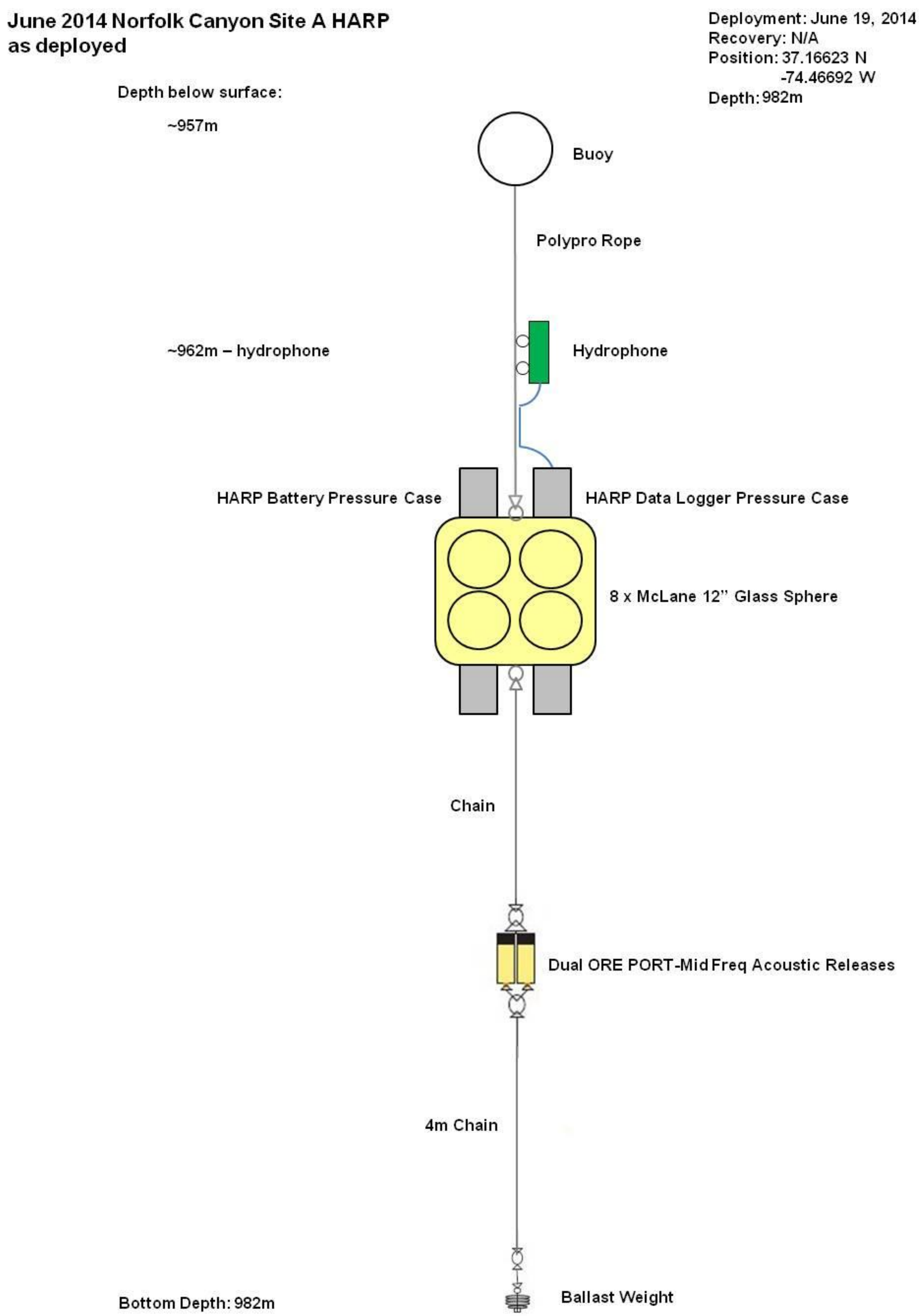

Figure 5. Schematic diagram showing details of 2014 Norfolk Canyon Site A HARP deployment. Note that diagram is not drawn to scale.

4. Cape Hatteras, North Carolina

4.1 Methods

Data Collection

The HARP initially deployed on May 29, 2013 was recovered and redeployed at a depth of approximately 835 m at 35.34445^{o} N, 74.84805^{o} W (Site A) on May 8, 2014 (**Table 3, Figure 6**), yielding a deployment period of 345 days. A schematic diagram of the HARP mooring for these deployments is shown in **Figure 7**. This instrument is still in the field and is expected to be recovered during early April 2015. The HARP was programmed to sample continuously at 200 kHz for both deployments. The May 2013–May 2014 deployment provided data during 291 days (May 29, 2013 – March 15, 2014).

Table 3. Cape Hatteras, North Carolina, HARP data sets analyzed and detailed in this report.

Site	Deployment Date	Retrieval Date	Recording Start Date	Recording End Date	Latitude	Longitude	Depth (m)	Sampling Rate	Duty Cycle
01A	15-Mar-12	9-Oct-12	15-Mar-12	11-Apr-12	35.34054	-74.85761	950	100 kHz	continuous
02A	9-Oct-12	29-May-13	9-Oct-12	9-May-13	35.34060	-74.85590	970	200 kHz	continuous
03A	29-May-13	8-May-14	29-May13	15-Mar-14	35.34445	-74.85210	970	200 kHz	continuous
04A	8-May-14	N/A	9-May-14	N/A	35.34677	-74.84805	~835	200 kHz	continuous

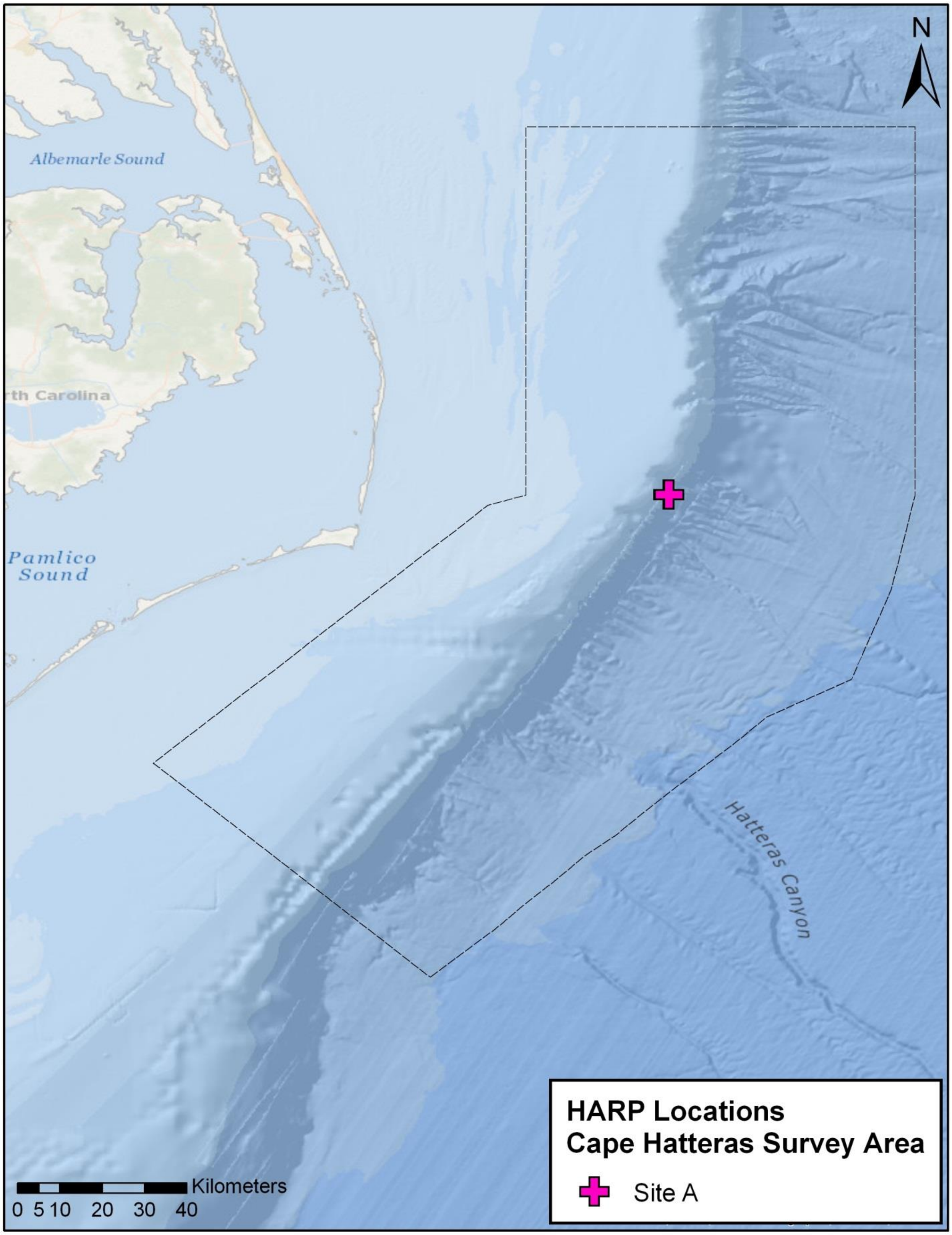

Figure 6. Location of the HARP deployment site in the Cape Hatteras survey area.

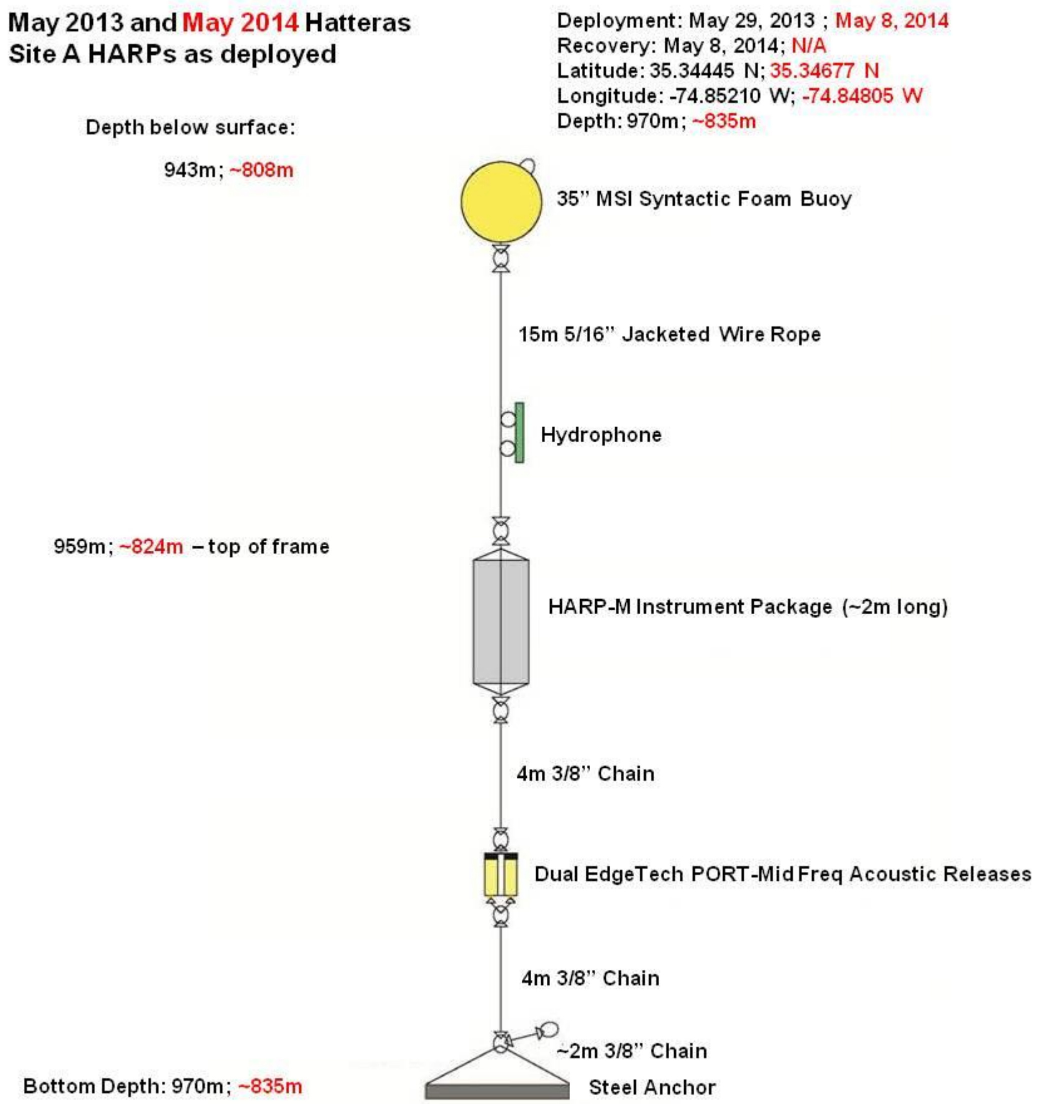

Figure 7. Schematic diagram showing details of the May 2013 and May 2014 Cape Hatteras Site A HARP deployments. Note that diagram is not drawn to scale.

Data Analysis

Data from the most recent Cape Hatteras HARP deployment (May 2013–March 2014) are still being analyzed and results are not presented here. As in the previous Cape Hatteras deployment, short-duration (0.005 second [s]) skips in the recording occurred with increasing frequency during the second half of this deployment. A post-processing solution was applied to minimize the appearance of these skips in the LTSAs during analysis, and analysis of the full dataset is currently underway.

Data from the 2012–2013 HARP deployment (October 9, 2012–May 9, 2013; 4901.6 hours of recording time) were re-processed to reduce the appearance of the recording skips in the LTSAs toward the end of the deployment, allowing these data to be re-analyzed for marine mammal vocalizations. Previously, this dataset was only analyzed through March 31, 2013. Re-processed data from April 1, 2013–May 1, 2013 were analyzed for sperm whale (*Physeter macrocephalus*) vocalizations, and sperm whale occurrence is reported here for the first 205 days of this dataset (October 9, 2012–May 1, 2013). The remaining 8 days (May 2, 2013–May 9, 2013) had only intermittent recordings due to low battery voltage, and were not included in the updated analyses. Recordings were manually scanned for sperm whale clicks using the "logger" version of *Triton* (v1.81.20121030) to view LTSAs with a frequency range of 1–30 kHz and a resolution of 5 s in time and 100 hertz (Hz) in frequency. The presence of vocalizations was determined in 1-minute bins.

All re-processed data from the 2012–2013 HARP deployment (October 9, 2012–May 1, 2013; 4901.6 hours of recording time) as well as original data from the March–April 2012 HARP deployment (March 15, 2012–April 11, 2012; 636.75 hours of recording time) were re-analyzed for beaked whale echolocation signals using a new automated detection method customized for the Cape Hatteras HARP recordings. 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 previously reported using manual LTSA analysis, 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.

4.2 Results

Table 4 summarizes the updated occurrence of detected and identified sperm whale and beaked whale clicks for the 2012–2013 Site A HARP deployment. **Figures 8 through 11** show the temporal occurrence patterns for sperm whales, Cuvier's beaked whales (*Ziphius cavirostris*), Gervais' beaked whales (*Mesoplodon europaeus*), and Blainville's beaked whales (*Mesoplodon densirostris*). As previously reported, sperm whales were present throughout much of the deployment, with detections on 70.7 percent of days analyzed, and no apparent diel pattern (**Figure 8**). Sperm whales were detected most frequently January through March. Cuvier's beaked whale clicks occurred regularly throughout the deployment, with detections on 96.6 percent of days analyzed (**Figure 9**). These click events were distributed fairly uniformly across both seasonal and diel time scales. Gervais' beaked whale clicks occurred less frequently, with detections on 20.5 percent of days analyzed (**Figure 10**). Blainville's beaked whale clicks were detected only once, on February 3, 2013 (**Figure 11**).

Table 4. Updated summary of detections of sperm whales and beaked whales at Site A for October 9, 2012–May 1, 2013.

Species	Call type	Hours with vocalizations	Percent of total recording hours	Days with vocalizations	Percent of total recording days
Sperm whale	clicks	1157	23.6	145	70.7
Cuvier's beaked whale	clicks	1485	30.3	198	96.6
Gervais' beaked whale	clicks	86	1.75	42	20.5
Blainville's beaked whale	clicks	1	0.02	1	0.49

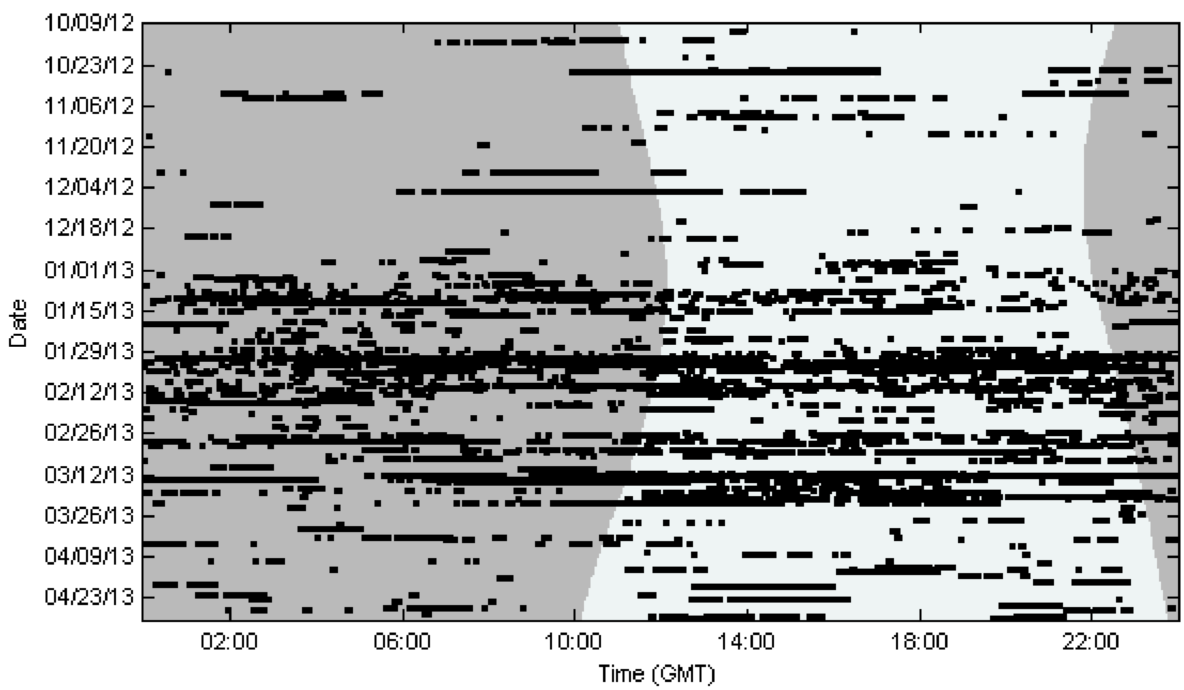

Figure 8. Sperm whale click detections (black bars) within the 2012-2013 Site A dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

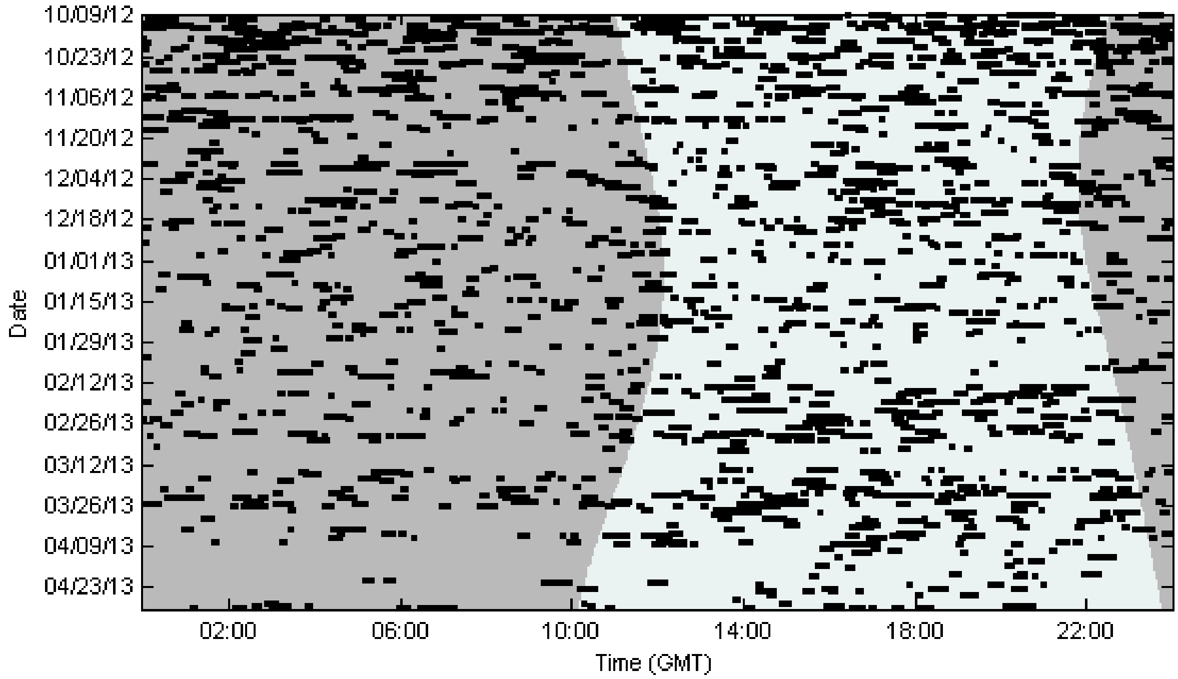

Figure 9. Cuvier's beaked whale click detections (black bars) within the 2012-2013 Site A dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

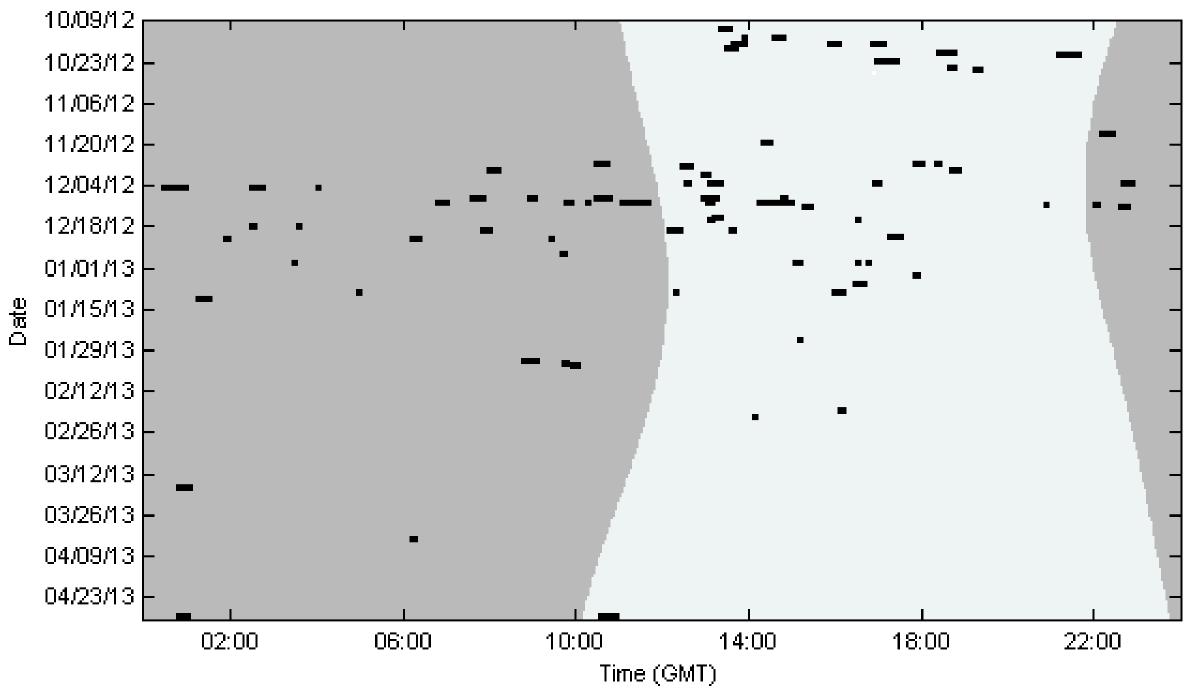

Figure 10. Gervais' beaked whale click detections (black bars) within the 2012-2013 Site A dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

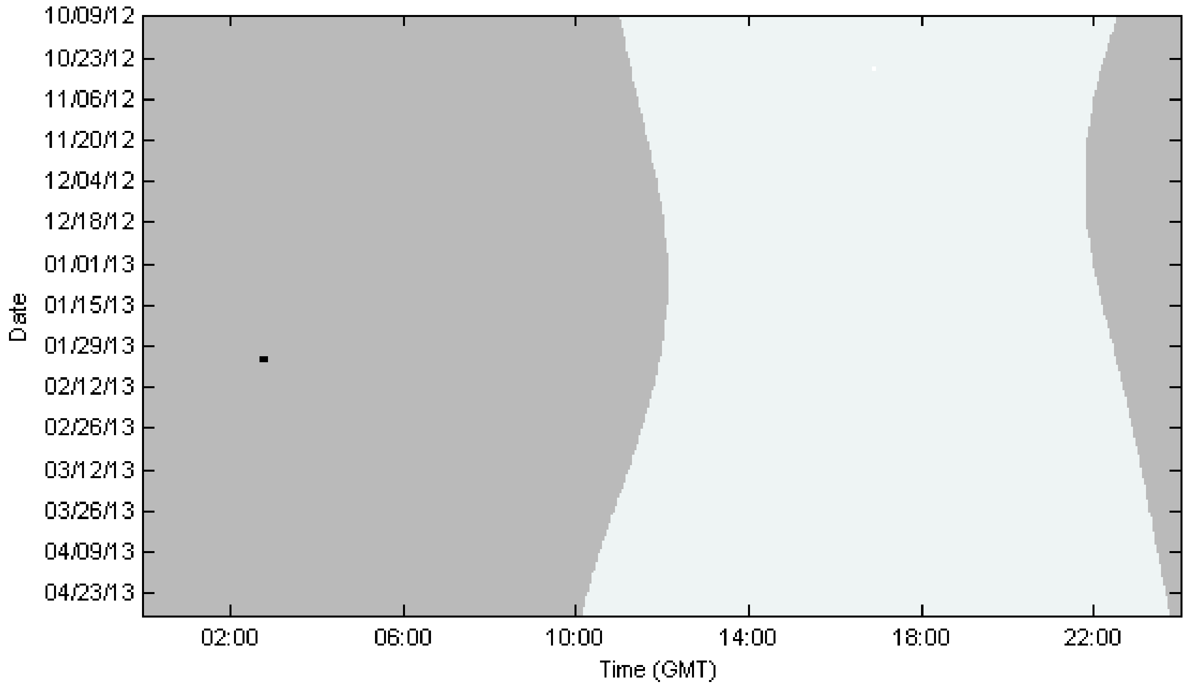

Figure 11. Blainville's beaked whale click detections (black bars) within the 2012-2013 Site A dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

Table 5 summarizes the updated occurrence of beaked whale clicks detected in the March-April 2012 Site A HARP deployment. **Figures 12 through 13** show the temporal occurrence patterns for Cuvier's beaked whales and Gervais' beaked whales. Cuvier's beaked whales were detected every day except the last recording day (April 11, 2012), which had less than 5 hours of available recording time (**Figure 12**). Gervais' beaked whales were detected less frequently, on 35.7 percent of recording days (**Figure 13**).

Table 5. Updated summary of detections of beaked whales at Site A for March 15, 2012–April 11, 2012.

Species	Call type	Hours with vocalizations	Percent of total recording hours	Days with vocalizations	Percent of total recording days
Cuvier's beaked whale	clicks	257	40.4	27	96.4
Gervais' beaked whale	clicks	22	3.40	10	35.7

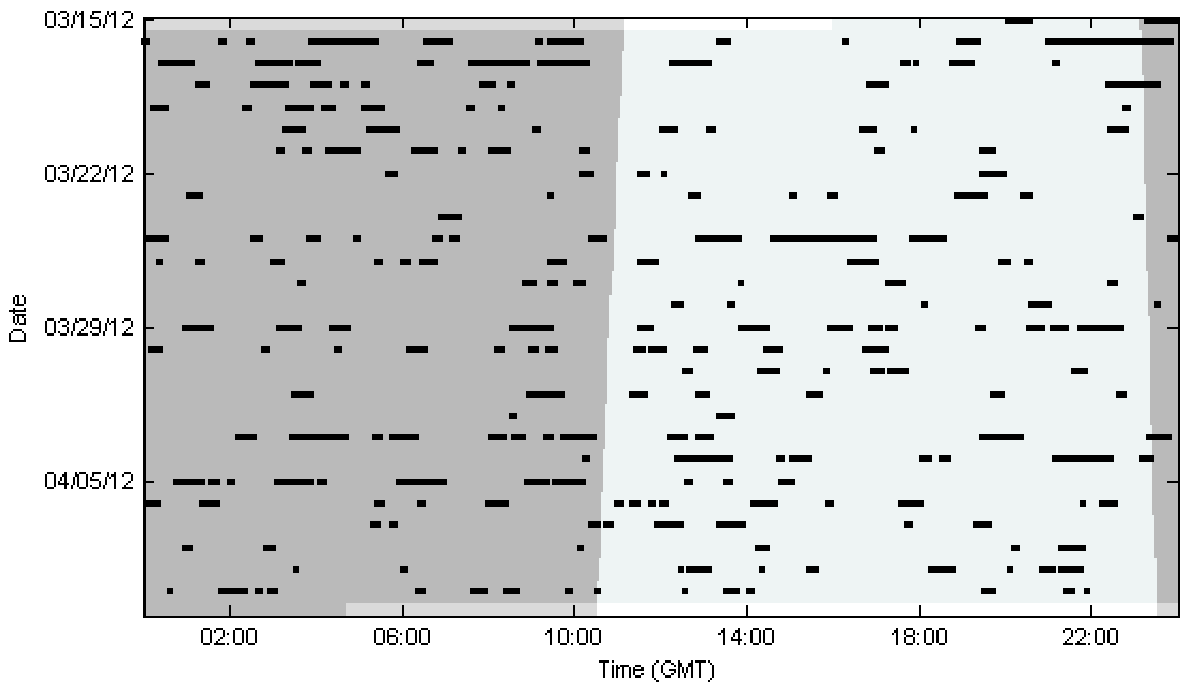

Figure 12. Updated Cuvier's beaked whale click detections (black bars) within the March 2012 – April 2012 Site A dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Lighter shading indicates recording/analysis effort.

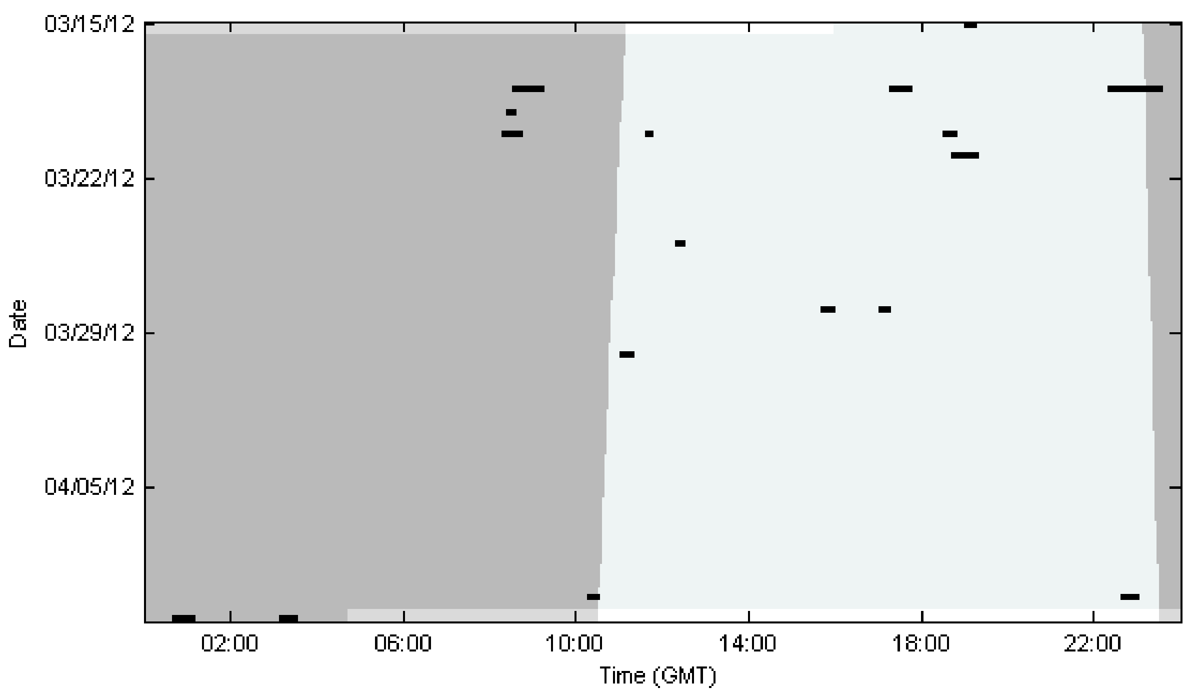

Figure 13. Updated Gervais' beaked whale click detections (black bars) within the March 2012 – April 2012 Site A dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Lighter shading indicates recording/analysis effort.

5. Onslow Bay, North Carolina

5.1 Methods

Data Collection

No HARPs have been deployed in Onslow Bay since August 2013. There are no current plans to redeploy in this area. **Figure 14** shows the locations of all HARP deployments that have occurred in this area.

Data Analysis

All datasets from Onslow Bay deployments have now been analyzed for marine mammal sounds and mid-frequency active sonar. **Table 6** gives details on the datasets analyzed during this reporting period. For both datasets analyzed here (the July 2010–June 2011 Site D deployment with 2733.9 hours of recording time over 210 days and the October 2012–August 2013 Site E deployment with 3436.1 hours of recording time over 250 days), recordings were manually scanned for marine mammal vocalizations using the "logger" version of *Triton* (v1.81.20121030; Hildebrand Lab at Scripps Institution of Oceanography, La Jolla, California). The effective frequency range of the HARP data (10 Hz–100 kHz) was divided into three parts for this manual review: 10–1,000 Hz, 500–5,000 Hz, and 1–100 kHz. The resulting LTSAs had resolutions of 5 s in time and 1 Hz in frequency (for the data decimated by a factor of 100: 10–1,000 Hz band), 5 s in time and 10 Hz in frequency (for the data decimated by a factor of 20: 500–5,000 Hz band), and 5 s in time and 100 Hz in frequency (for the data not decimated: 1-100 kHz). Long-term spectral averages decimated by a factor of 100 were inspected for sounds produced by mysticetes. Long-term spectral averages decimated by a factor of 20 were inspected for a new sound type, a 2-kHz trill, detected when looking through non-decimated data. Non-decimated LTSAs were inspected for odontocete whistles, clicks, and burst-pulses as well as mid-frequency active sonar. The presence of vocalizations and mid-frequency active sonar was determined in 1-minute bins, and vocalizations were assigned to species when possible.

Table 6. Onslow Bay, North Carolina, HARP data sets analyzed and detailed in this report.

Site	Deployment Date	Retrieval Date	Recording Start Date	Recording End Date	Latitude	Longitude	Depth (m)	Sampling Rate	Duty Cycle
05D	29-Jul-10	10-Jun-11	30-Jul-10	24-Feb-11	33.58065	-76.55015	338	200 kHz	5 min on / 5 min off
08E	24-Oct-12	8-Aug-13	24-Oct-12	30-Jun-13	33.78696	-75.92801	853	200 kHz	5 min on / 5 min off

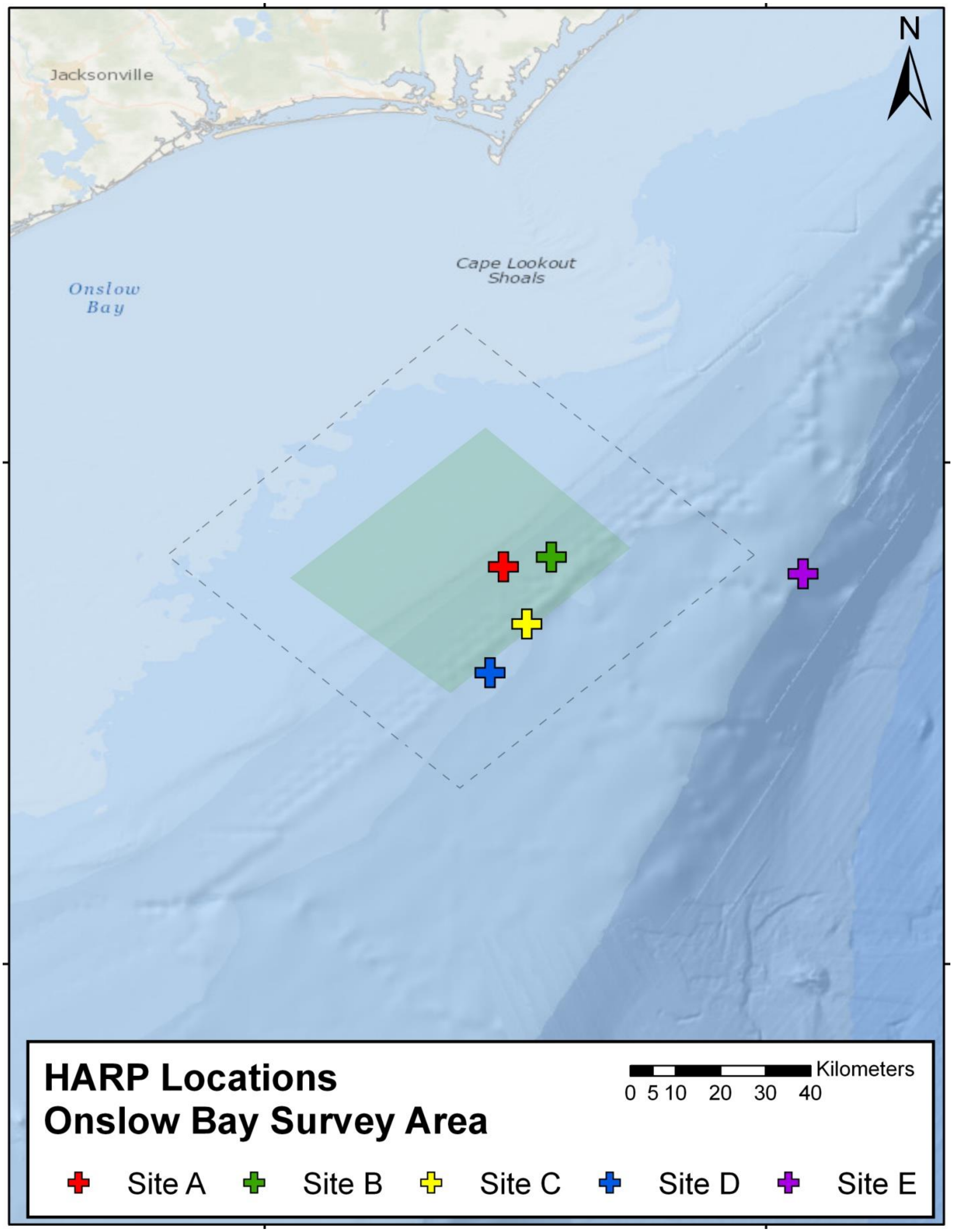

Figure 14. Location of HARP deployment sites in the Onslow Bay survey area.

Detections of most sounds were made by manually scanning LTSAs. However, beaked whale echolocation signals were detected with an automated method and then assigned to species by a trained analyst, as detailed in Debich et al. (2014). 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. In a second computer-assisted manual classification step, each detected event containing potential beaked whale signals was given a species label by a trained analyst, and any remaining false detections were rejected (as in Baumann-Pickering et al. 2013).

For both the 2010–2011 Site D dataset and the 2012–2013 Site E dataset, there were a few 5-minute segments of data that were not analyzed due to hard drive issues. These segments were not analyzed either because they were missing (skipped during the recording process) or the hard drive recorded the sound incorrectly. These segments were removed from the analysis effort. In addition, for the 2012–2013 Site E dataset, there were 16 days that had periods of high ambient noise levels that decreased the detection ability for low-frequency sounds. These segments were identified and removed from analysis for low-frequency sounds.

5.2 Results

July 2010–June 2011 Site D Deployment

Underwater ambient noise during the July 2010–June 2011 Site D deployment is shown in **Figure 15**. **Table 7** summarizes the detected and identified marine mammal vocalizations during this deployment. **Figures 16 through 23** show the daily occurrence patterns for the different marine mammal groups (classified to species when possible). **Figure 24** shows the occurrence of mid-frequency active sonar.

Mysticete detections included calls from blue whales (*Balaenoptera musculus*), fin whales (*Balaenoptera physalus*), minke whales (*Balaenoptera acutorostrata*), and possible sei whales (*Balaenoptera borealis*). Blue whales were present primarily from August 2010 to mid-February 2011 (**Figure 16**), although most detections occurred before the end of December. Fin whale 20-Hz pulses were present between the end of August and mid-September 2010 and between the end of October 2010 and February 2011 (**Figure 17**). Peaks in detections occurred between December and February, which is similar to previous findings in Onslow Bay of peaks between January and March. Minke whale pulse trains (mainly slow-down pulse trains) were detected between mid-November 2010 and the last day of the recording period, February 24, 2011 **(Figure 18**). Peaks in pulse train calls occurred from the end of December through the end of February, similar to the previous findings in Onslow Bay of peaks between January and March for earlier deployments. Downsweeps similar to those ascribed to sei whales by Baumgartner et al. (2008) were detected on October 16–17, 2010 and between November 13, 2010 and February 17, 2011 (**Figure 19**). The general occurrence of this call type is similar to previous findings in Onslow Bay.

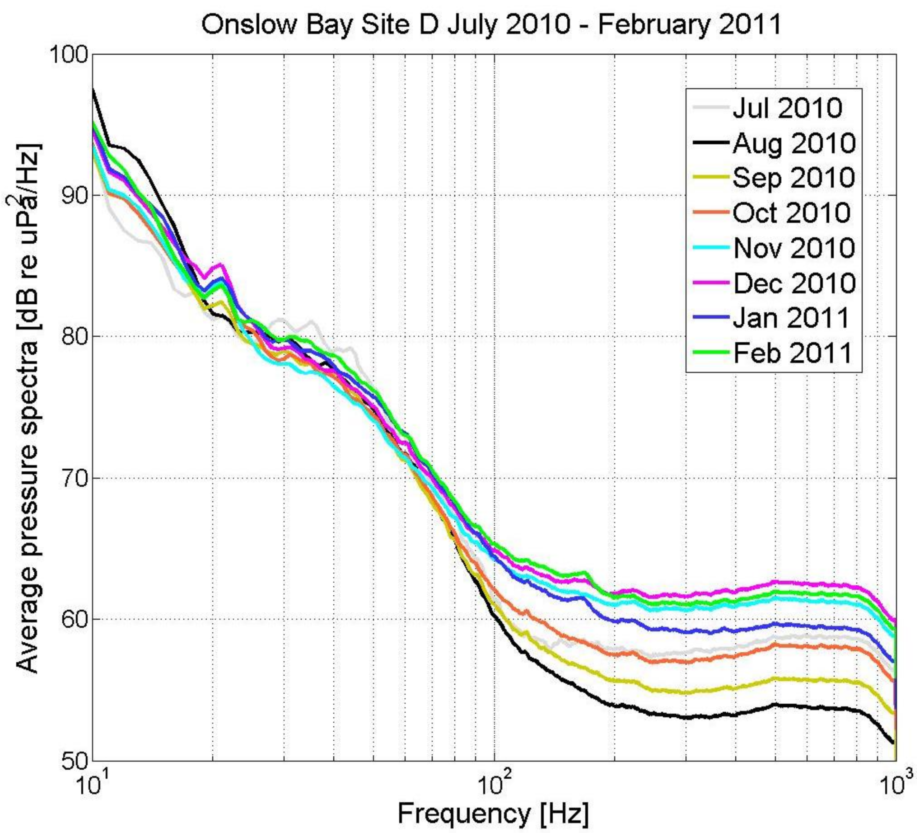

Figure 15. Monthly averages of ambient noise at Site D for July 2010 – February 2011.

Table 7. Summary of detections of marine mammal vocalizations at Site D for July 2010–February 2011. For both mysticetes and odontocetes, total duration of vocalizations (hours) and percentage of recording duration are based on data analyzed in minute bins.

Species	Call type	Total duration of vocalizations (hours)	Percent of recording duration	Days with vocalizations	Percent of recording days
Blue whale	A and B calls (mainly A)	72.45	2.65	103	49.05
Fin whale	20 Hz	105.37	3.85	64	30.48
Minke whale	pulse train (slow-down, speed-up, regular)	149.10	5.45	83	39.52
Possible sei whale	downsweep	6.02	0.22	24	11.43
Unidentified odontocete	clicks, whistles	632.9	23.15	208	99.05
Kogia spp.	clicks	0.10	0.004	3	1.43
Risso’s dolphin	clicks	30.3	1.11	46	21.90
Sperm whale	clicks	18.43	0.67	34	16.19

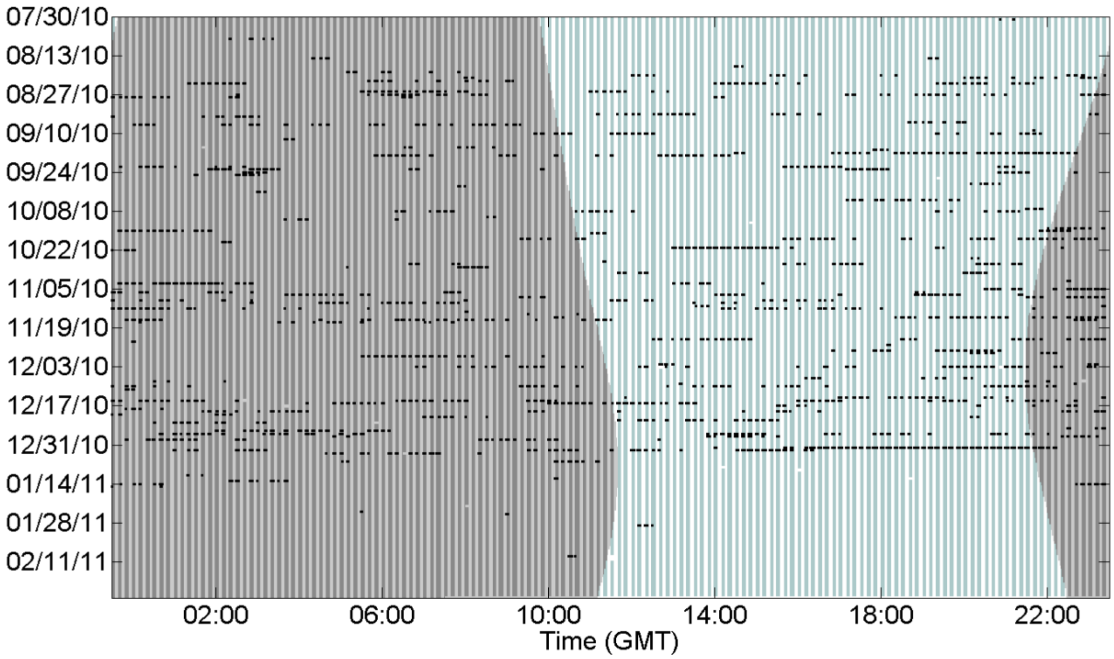

Figure 16. Blue whale Type A and B call detections (black bars) within the 2010-2011 Site D dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

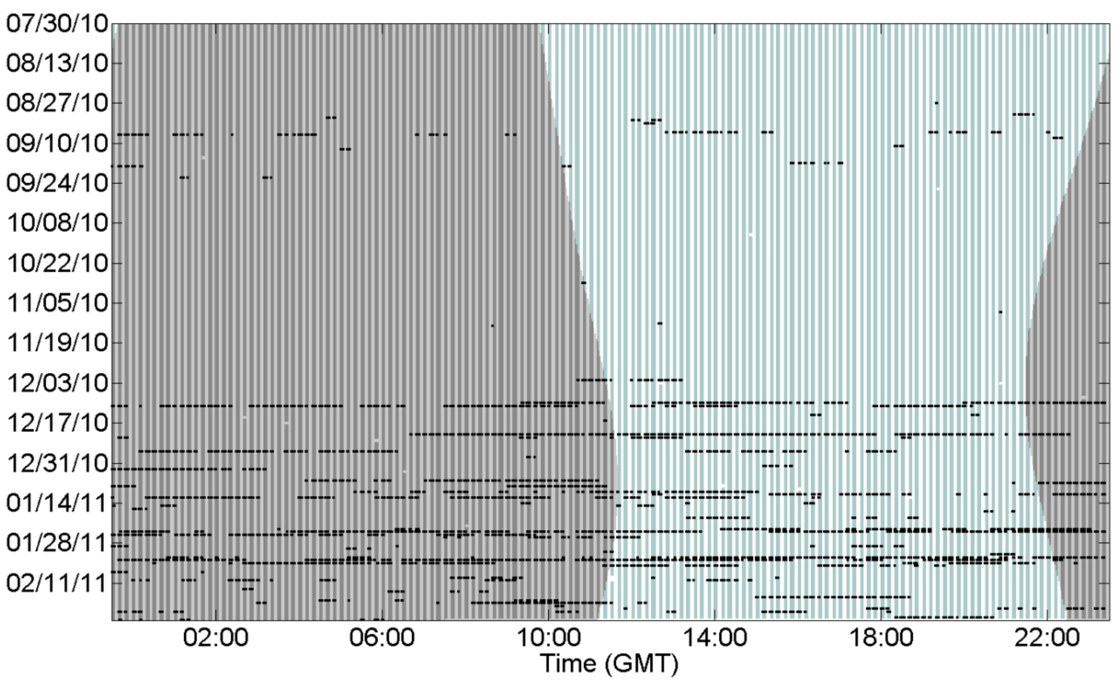

Figure 17. Fin whale 20-Hz pulse detections (black bars) within the 2010-2011 Site D dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

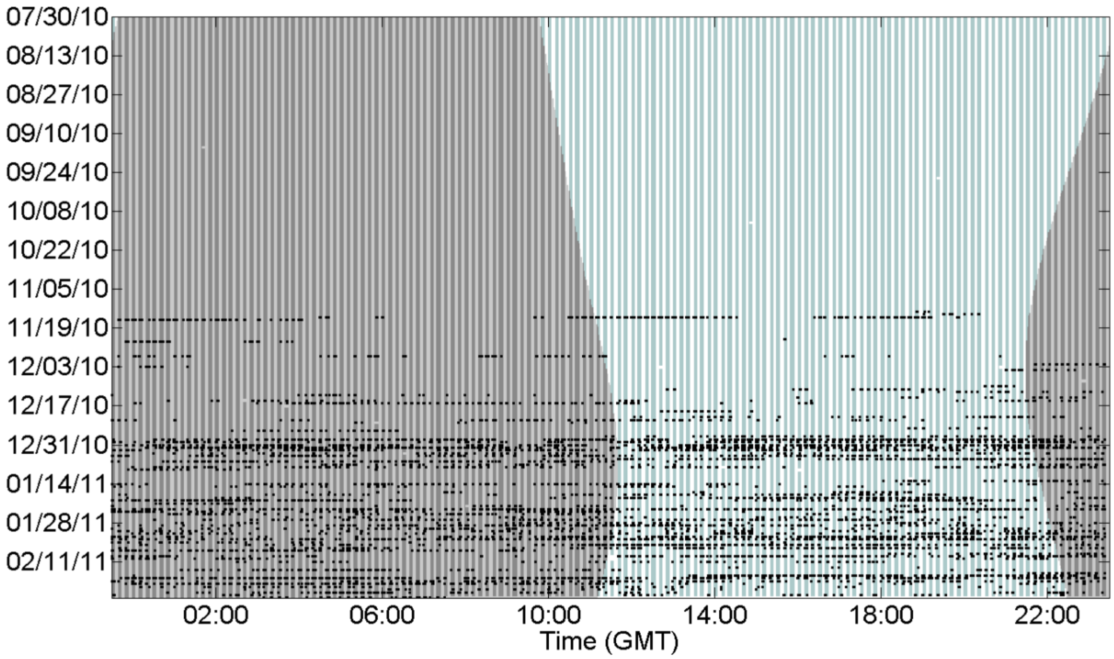

Figure 18. Minke whale detections (black bars) within the 2010-2011 Site D dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

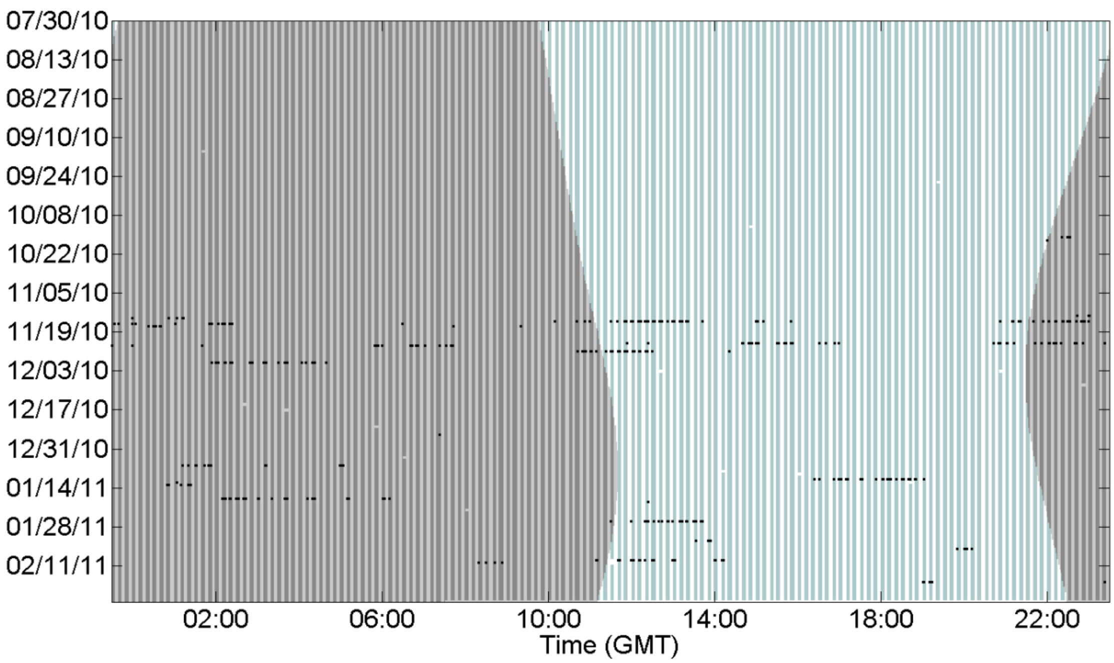

Figure 19. Downsweep detections (black bars) that are possibly sei whales within the 2010-2011 Site D dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

Detected odontocete vocalizations included clicks, whistles, and burst-pulses (**Figures 20 through 23**). Most of these detections (93 percent) were assigned to the unidentified odontocete category (**Figure 20**). Unlike during the 2010-2011 Site A deployment which occurred at the same time as this Site D deployment, there was no pattern of longer-duration and clustered unidentified odontocete vocal events during late night to early morning between November and January. *Kogia* spp. clicks were present on only three days during the 2010-2011 Site D deployment (**Figure 21**), consistent with the sporadic occurrence found during previous deployments. Risso's dolphins (*Grampus griseus*) were detected throughout the deployment with more detections at night, again agreeing with earlier findings (**Figure 22**). Sperm whales were detected between August and early September and between the end of December and mid- February, during both day and night (**Figure 23**).

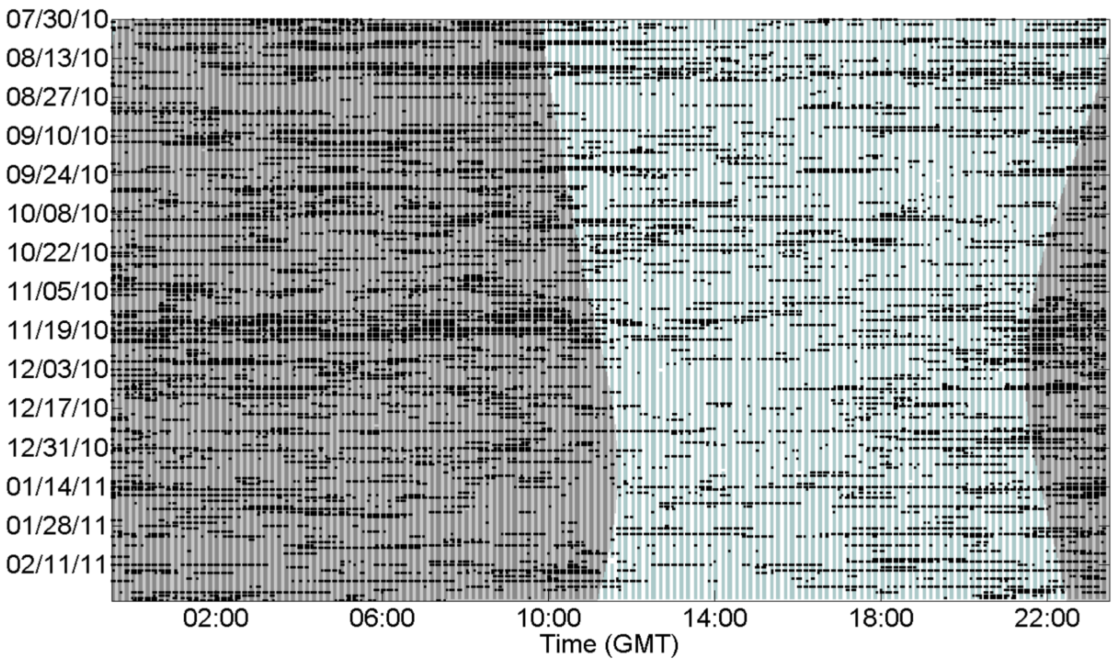

Figure 20. Unidentified odontocete vocalization detections (black bars) within the 2010-2011 Site D dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

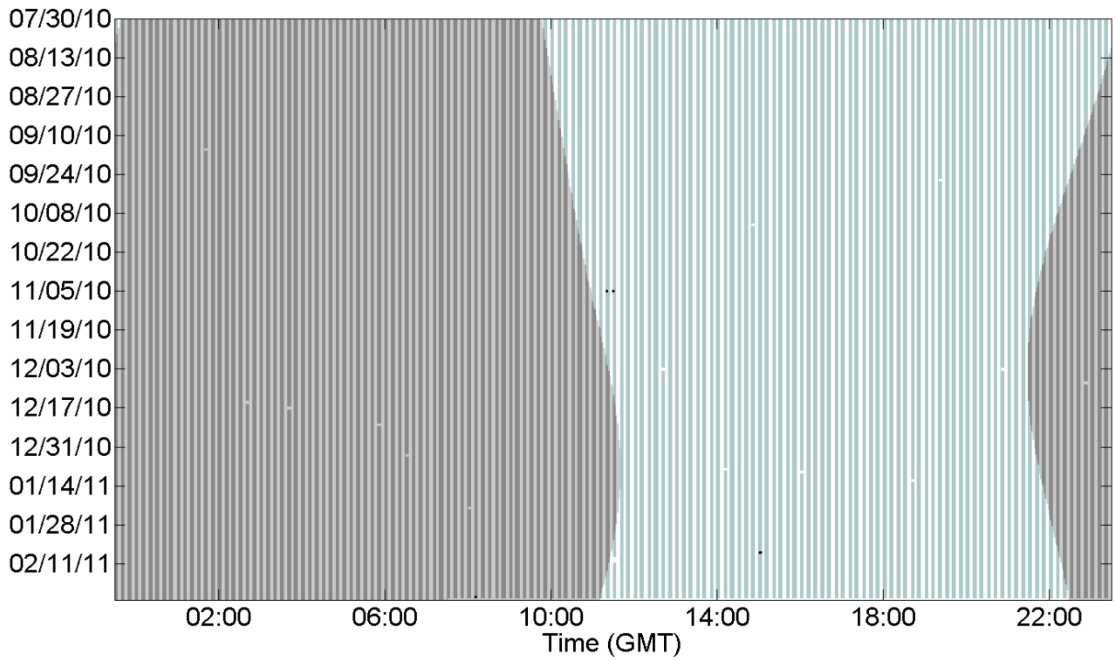

Figure 21. *Kogia* spp. click detections (black bars) within the 2010-2011 Site D dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

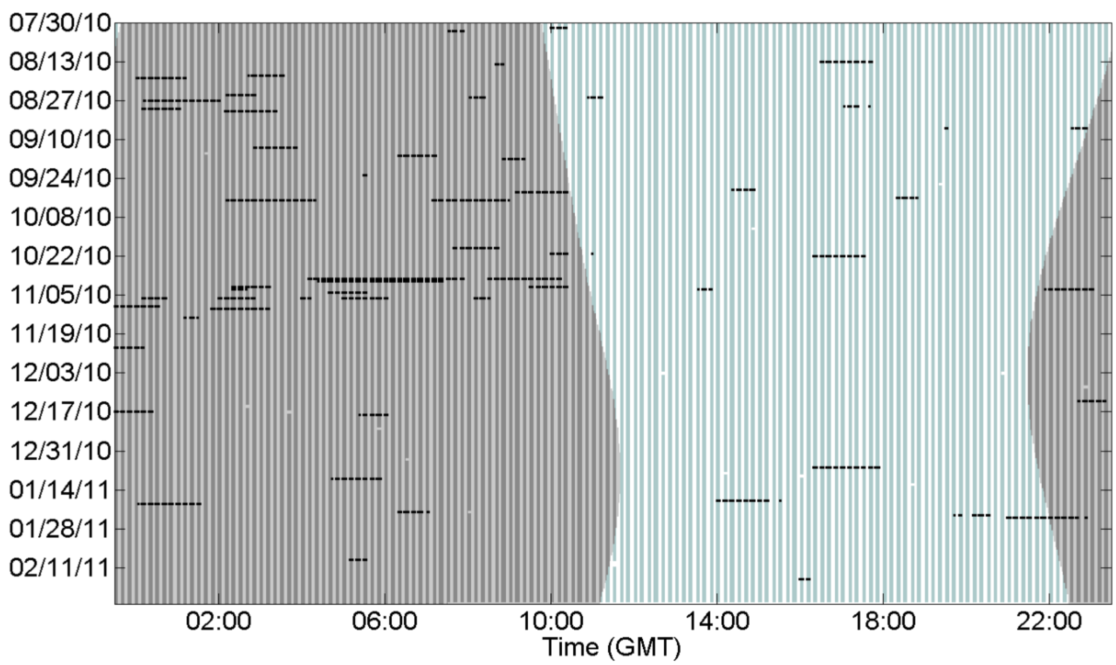

Figure 22. Risso's dolphin click detections (black bars) within the 2010-2011 Site D dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

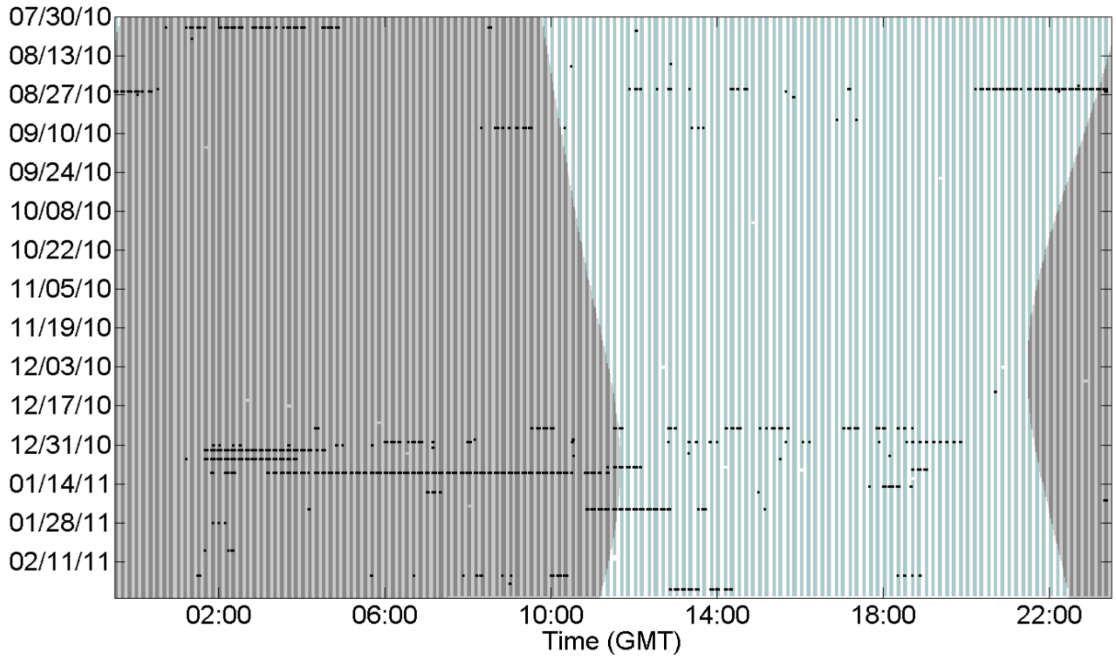

Figure 23. Sperm whale click detections (black bars) within the 2010-2011 Site D dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

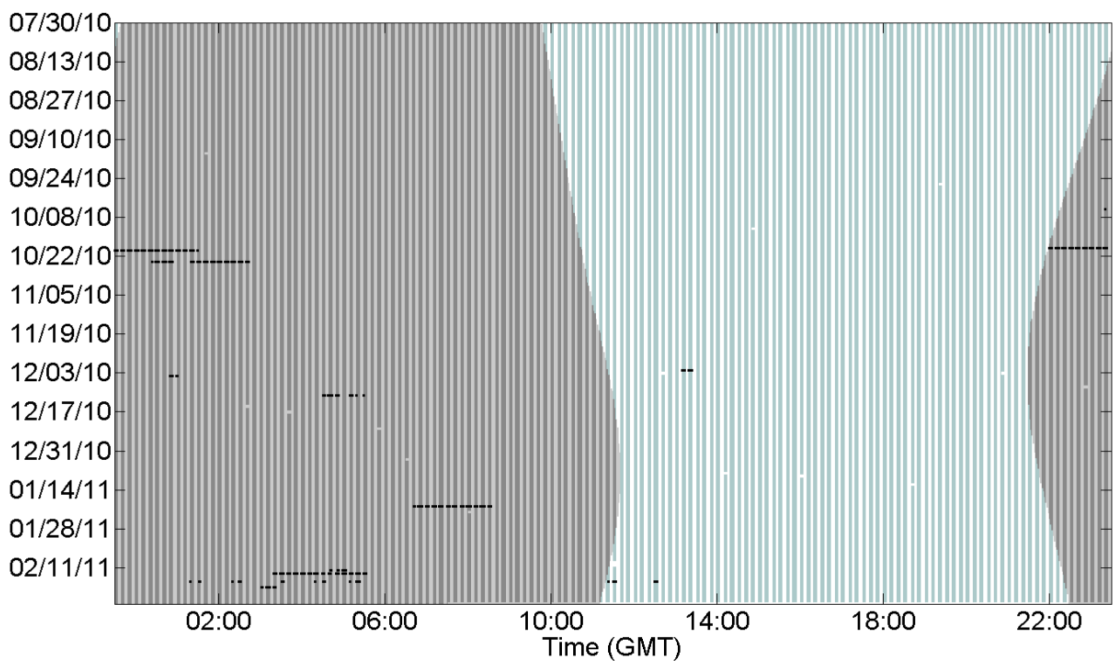

Figure 24. Mid-frequency active sonar (black bars) detected within the 2010-2011 Site D dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

October 2012–August 2013 Site E Deployment

Underwater ambient noise during the October 2012–August 2013 Site E deployment is shown in **Figure 25**. **Table 8** summarizes the detected and identified marine mammal vocalizations during this deployment. **Figures 26 through 31** and **33 through 41** show the daily occurrence patterns for the different marine mammal groups (classified to species when possible). **Figure 42** shows the occurrence of mid-frequency active sonar.

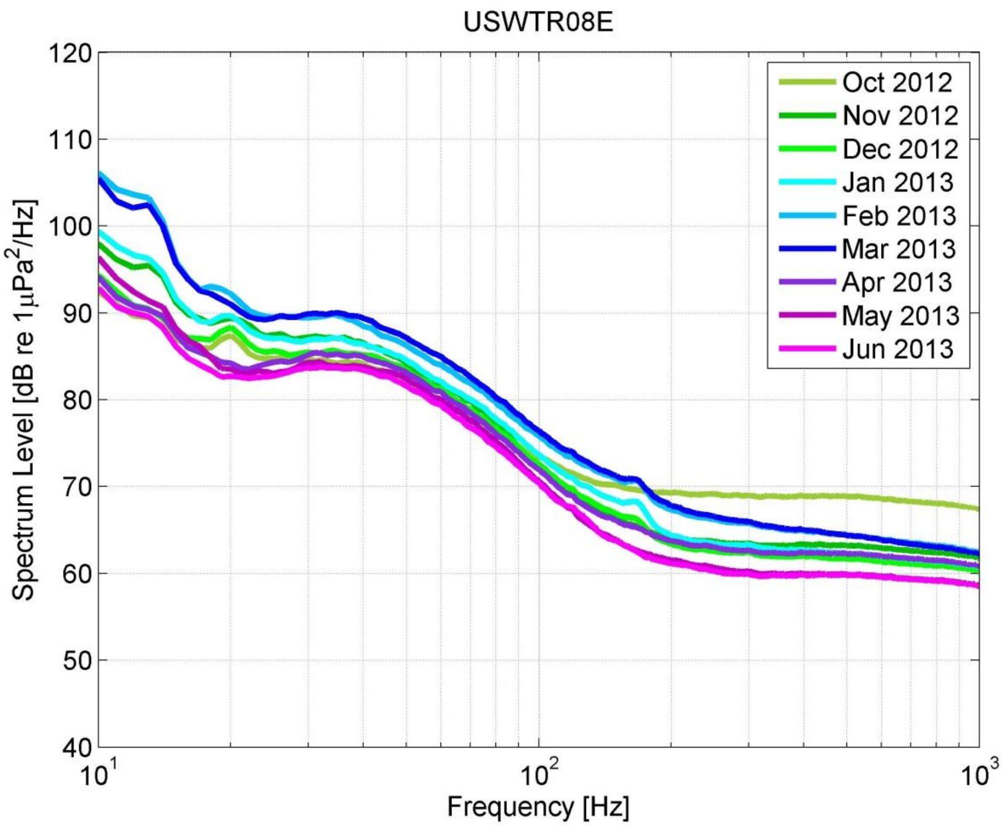

Figure 25. Monthly averages of ambient noise at Site E for October 2012–June 2013.

Table 8. Summary of detections of marine mammal vocalizations at Site E for October 2012–June 2013. For both mysticetes and odontocetes, total duration of vocalizations (hours) and percentage of recording duration are based on data analyzed in minute bins.

Species	Call type	Total duration of vocalizations (hours)	Percent of recording duration	Days with vocalizations	Percent of recording days
Blue whale	A and B calls	30.73	0.92	71	28.4
Fin whale	20 Hz	127.28	3.80	120	48
Minke whale	pulse train (slow-down, speed-up, regular)	751.08	21.88	184	73.6
Possible sei whale	downsweep	6.95	0.21	33	13.2
Unidentified mysticete	short duration downsweep	5.67	0.17	40	16
Unidentified mysticete	upsweep	0.1	0.003	3	1.2
Unidentified animal	2-kHz trill	0.62	0.02	2	0.8
Unidentified odontocete	clicks, whistles	1072.83	31.26	250	100
Unidentified beaked whale (BW38)	clicks	0.07	0.002	2	0.8
Blainville's beaked whale	clicks	1.38	0.04	12	4.8
Cuvier's beaked whale	clicks	1.78	0.05	16	6.4
Gervais' beaked whale	clicks	233.38	6.80	240	96
Kogia spp.	clicks	22.75	0.66	158	63.2
Risso's dolphin	clicks	12.2	0.36	24	9.6
Sperm whale	clicks	171.85	5.01	133	53.2

Mysticete detections included calls from blue whales, fin whales, minke whales, possible sei whales, and unidentified mysticetes. Blue whales were primarily present from the beginning of the recording period (October 2012) to the beginning of January 2013, with very few detections after that through mid-March (**Figure 26**). Fin whale 20-Hz pulses were present from the start of the recording period until mid-March (**Figure 27**). Minke whale pulse trains (mainly slow-down pulse trains) were detected mainly between mid-November 2012 and mid-April 2013 (**Figure 28**), but detections continued through May 2, 2013. High levels of pulse train calls occurred from December until mid-April. Downsweeps similar to those ascribed to sei whales by Baumgartner et al. (2008) were detected from the beginning of the recording period until February 8, 2013 (**Figure 29**), with peaks in occurrence in December. The general occurrence of this call type is similar to previous findings in Onslow Bay. Short duration downsweeps (short in duration compared to possible sei whale downsweeps) were detected from December 2012 through mid-March 2013 (**Figure 30**). Faint upsweeps were detected on three days in 2013 (four calls on February 6, two calls on February 10, and two calls on March 12) (**Figure 31**). These were similar to right whale up-calls (although shorter in duration) but could have been produced by a humpback whale(s) or other species.

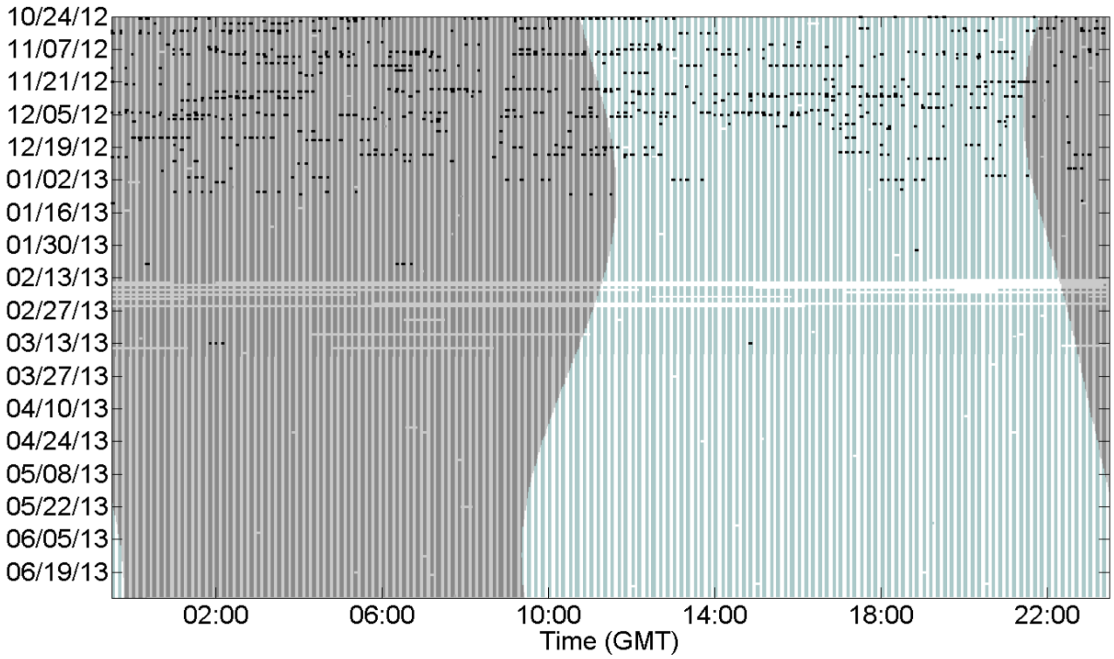

Figure 26. Blue whale Type A and B call detections (black bars) within the 2012-2013 Site E dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle and indicates times when masking may have occurred (shown in one-minute bins).

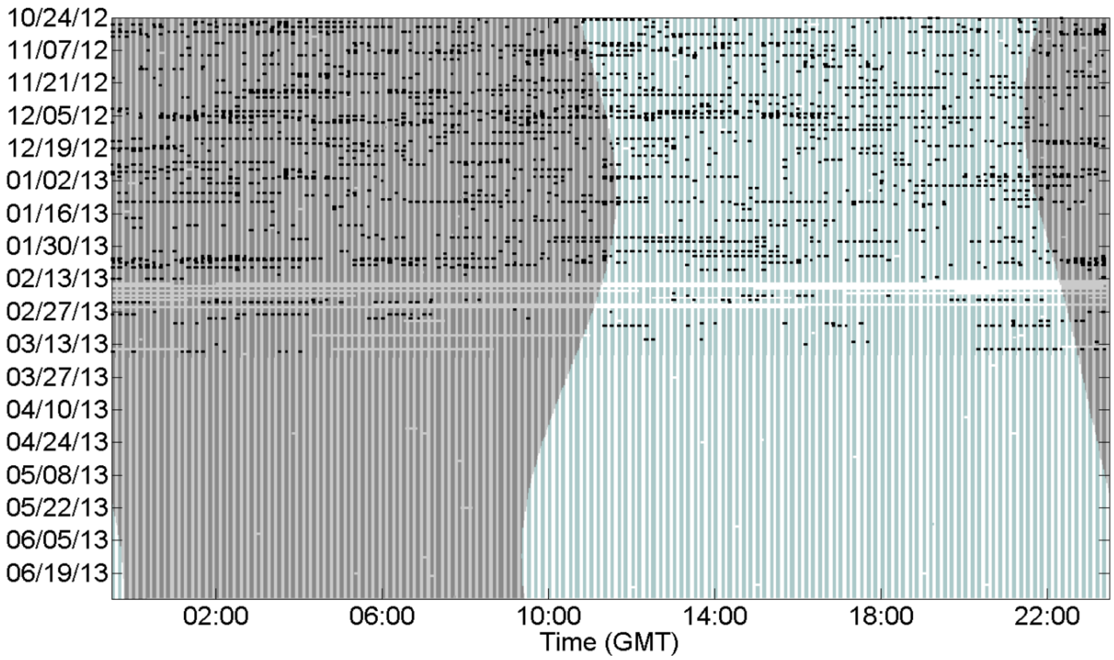

Figure 27. Fin whale 20-Hz pulse detections (black bars) within the 2012-2013 Site E dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle and indicates times when masking may have occurred (shown in 1-minute bins).

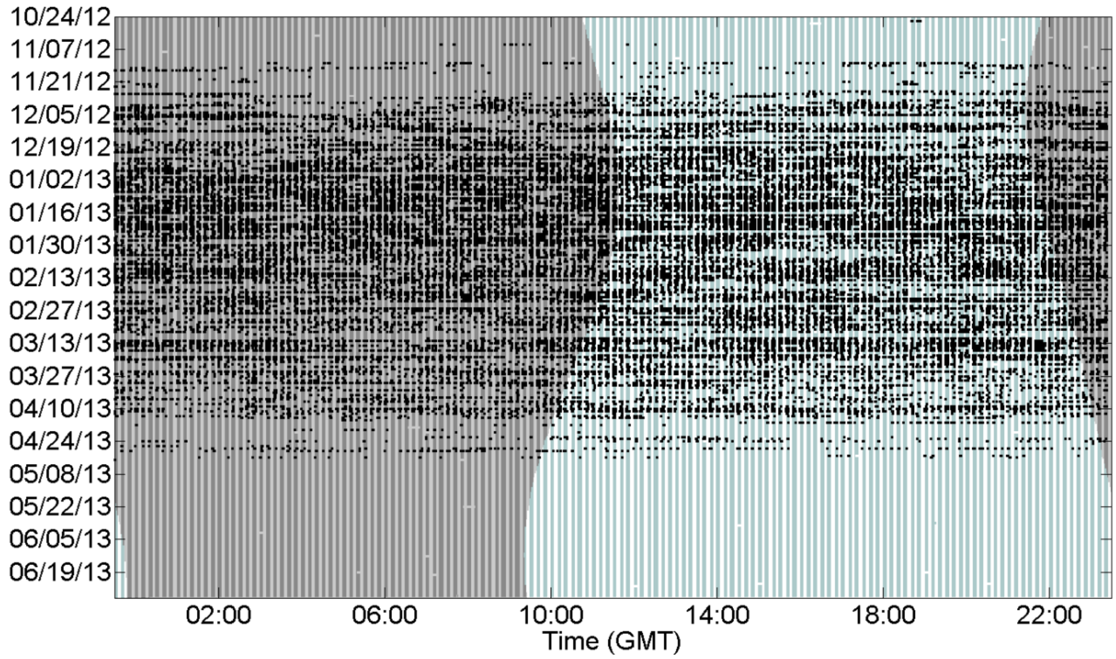

Figure 28. Minke whale detections (black bars) within the 2012-2013 Site E dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

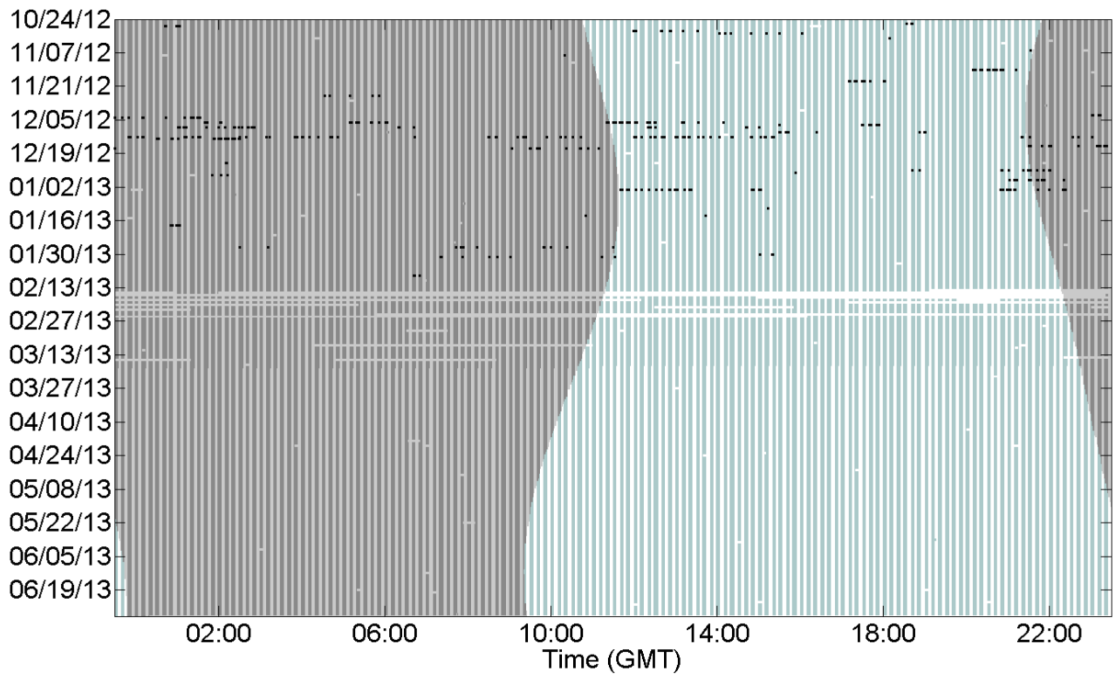

Figure 29. Downsweep detections (black bars) that are possibly sei whales within the 2012-2013 Site E dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle and indicates times when masking may have occurred (shown in 1-minute bins).

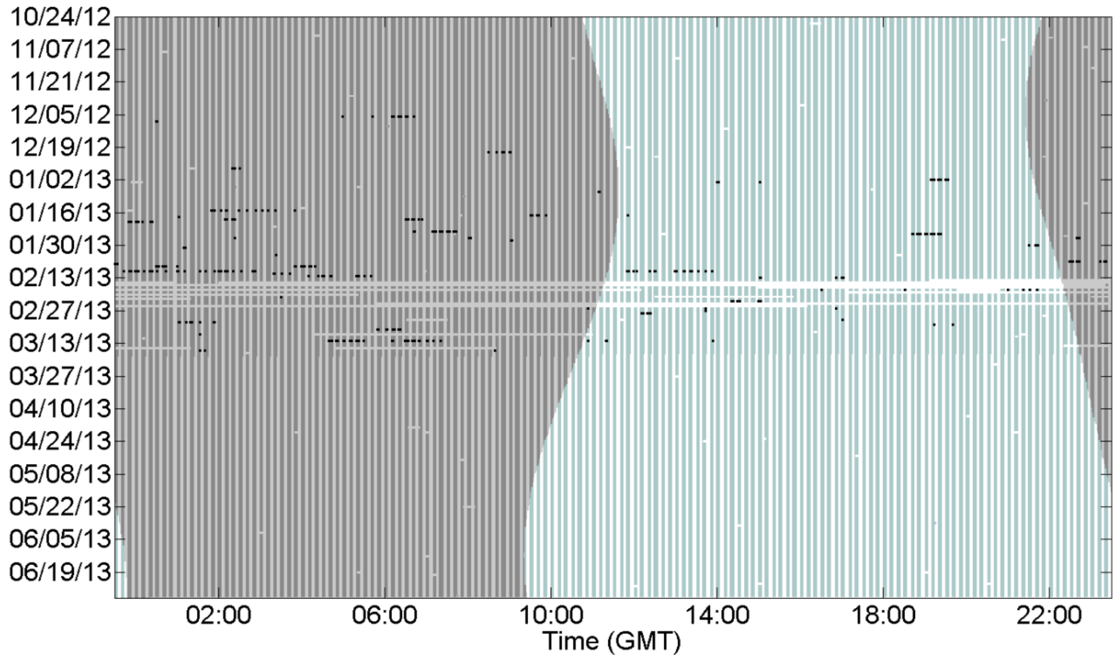

Figure 30. Short downsweep detections (black bars) within the 2012-2013 Site E dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle and indicates times when masking may have occurred (shown in 1-minute bins).

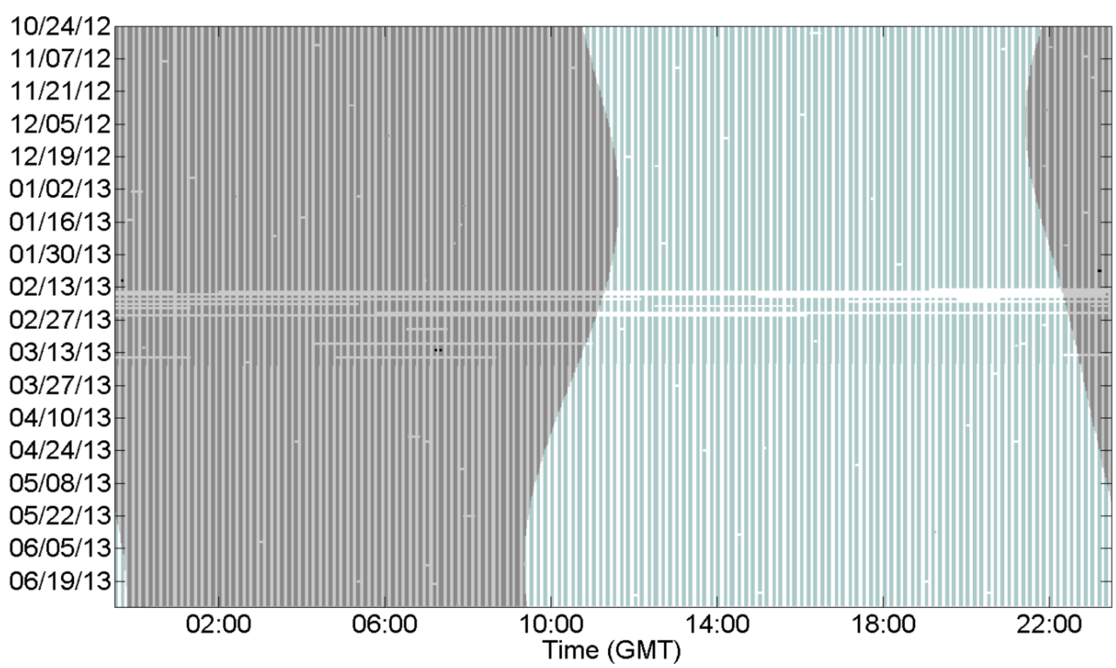

Figure 31. Upsweep detections (black bars) within the 2012-2013 Site E dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle and indicates times when masking may have occurred (shown in 1-minute bins).

One call type that has not been described previously, a three part "2-kHz trill" (see **Figure 32**), was detected on December 12, 2012 (34 times) and December 16, 2012 (three times) (**Figure 33**). The source of the call is unknown at this time. The call was detected mainly at night (**Figure 33**).

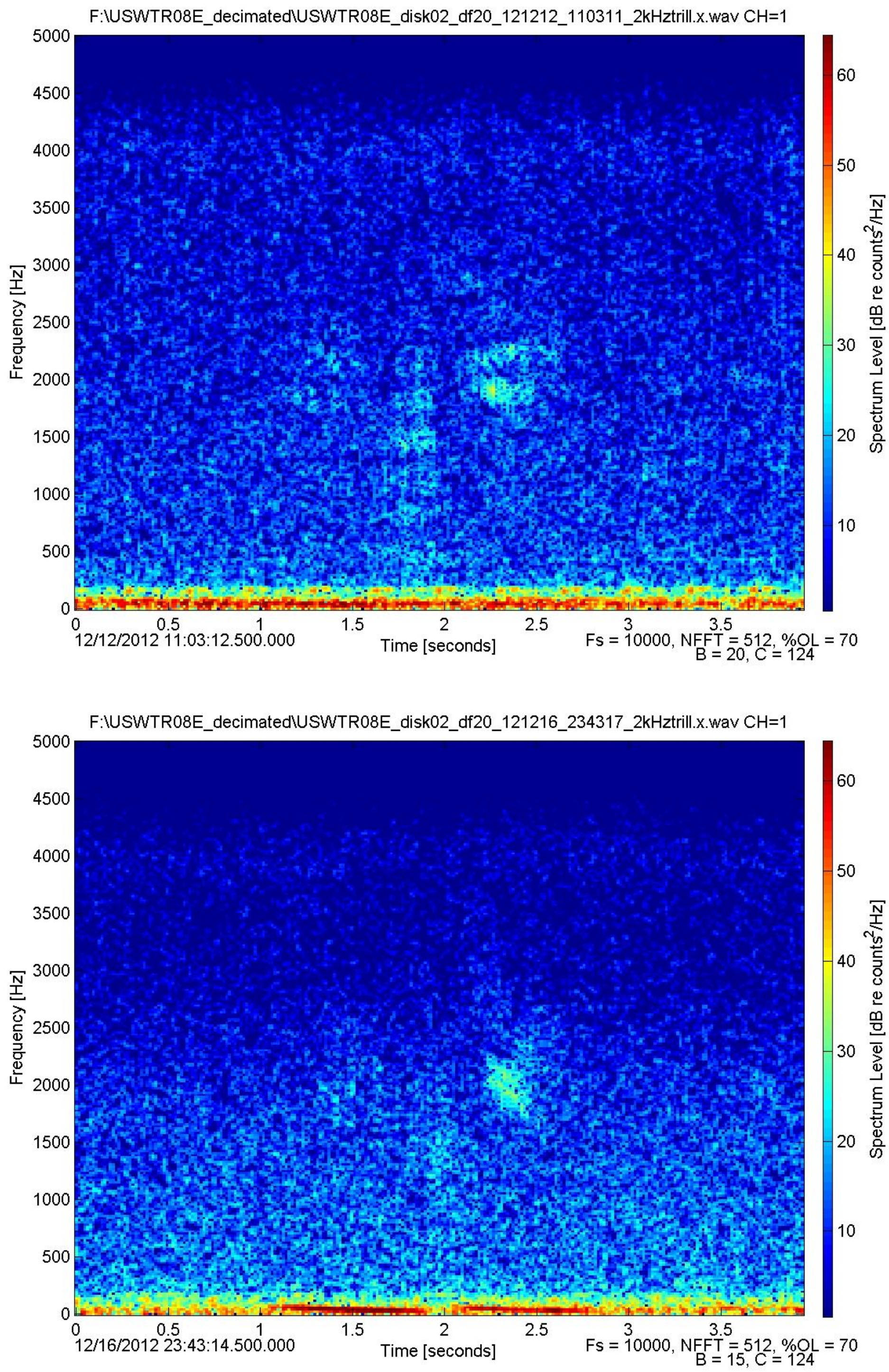

Figure 32. Spectrograms of the three part "2-kHz trill" recorded at Onslow Bay Site E on December 12, 2012 (top) and December 16, 2012 (bottom).

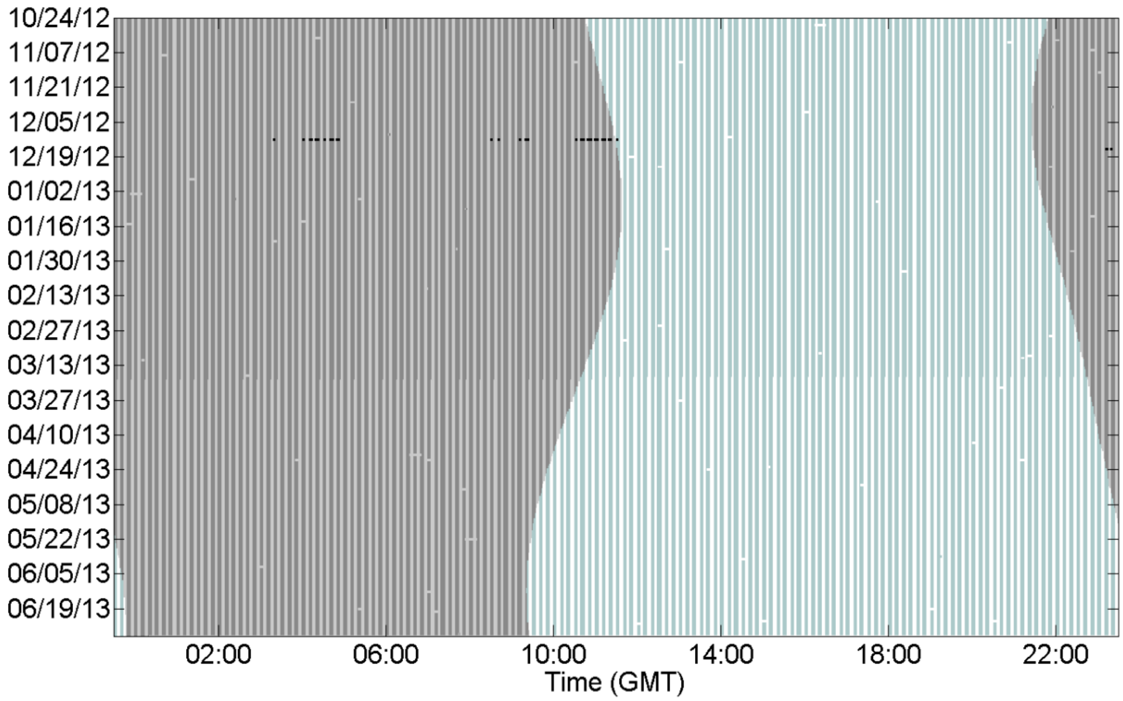

Figure 33. 2-kHz trill detections (black bars) within the 2012-2013 Site E dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

Detected odontocete vocalizations included clicks, whistles, and burst-pulses (**Figures 34 through 41**). Many of these detections were assigned to the unidentified odontocete category (**Figure 34**). For odontocete detections that could be assigned to species, there were several click detections that were assigned to beaked whales. There were two detections in December 2012 of a click type assigned to an unidentified beaked whale species (BW38) (**Figure 35**). Blainville's beaked whale clicks were detected on several days during this deployment, mainly in April and May of 2013 (**Figure 36**). Cuvier's beaked whale clicks were also detected on several days during this deployment, although mainly in November 2012, with a few detections in January and February 2013 and a single detection in June 2013 (**Figure 37**). This peak in November of Cuvier's beaked whale clicks matches what was found previously at Site E for this species. As previously found, there were significantly more Gervais' beaked whale detections than any other beaked whale. While detections occurred throughout the deployment with no specific diel pattern, there were more detections from October 2012 through the end of March 2013 (**Figure 38**). Other detected odontocete clicks included *Kogia* spp. clicks **(Figure 39)**, Risso's dolphins (**Figure 40**), and sperm whales (**Figure 41**). *Kogia* spp. clicks were present throughout the deployment, with no specific temporal pattern in occurrence (**Figure 39**). This deployment had the most detections of *Kogia* spp. clicks out of any other deployment in Onslow Bay. Risso's dolphins were detected mainly from April to June 2013, with no detections from October 2012 through late February 2013 and no detections in March 2013 (**Figure 40**). Unlike in previous deployments in Onslow Bay, there did not seem to be a significant nocturnal click occurrence pattern. Sperm whales were detected without an apparent diel pattern throughout this deployment, with peaks in mid-December 2012 through mid-January 2013 and May through June 2013 (**Figure 41**).

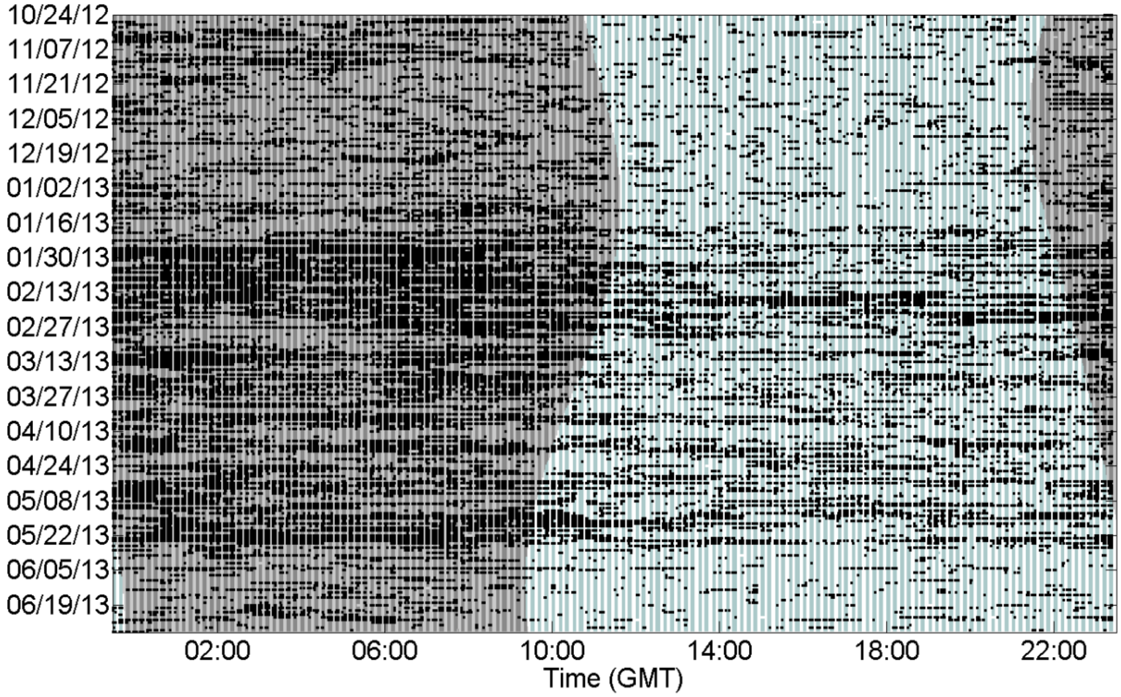

Figure 34. Unidentified odontocete vocalization detections (black bars) within the 2012-2013 Site E dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

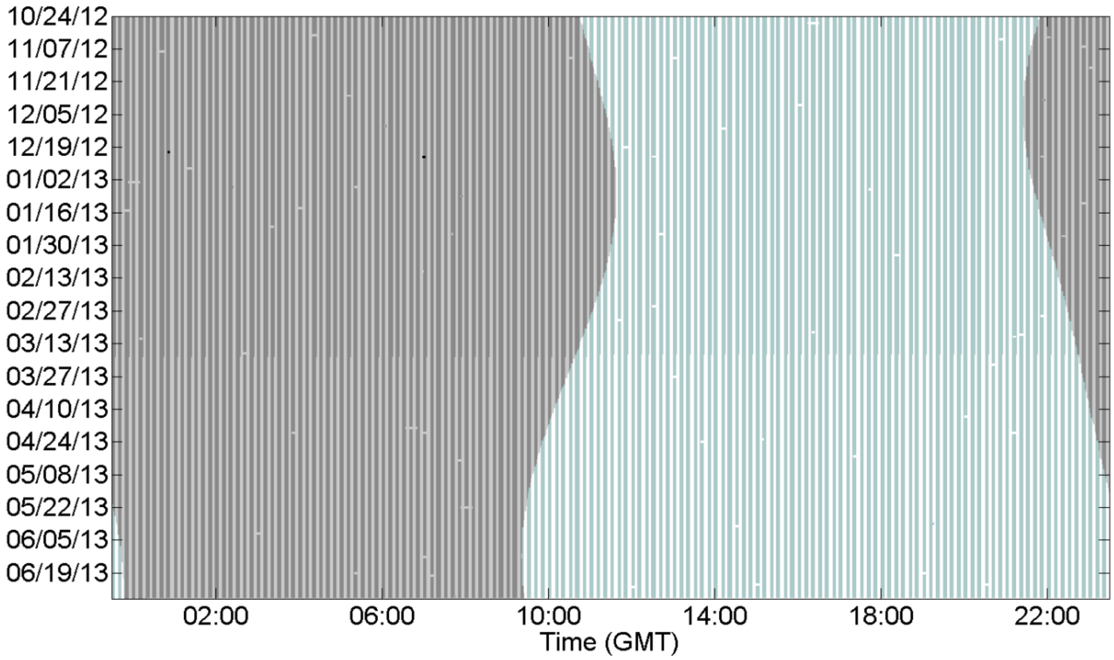

Figure 35. Unidentified beaked whale (BW38) click detections (black bars) within the 2012-2013 Site E dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

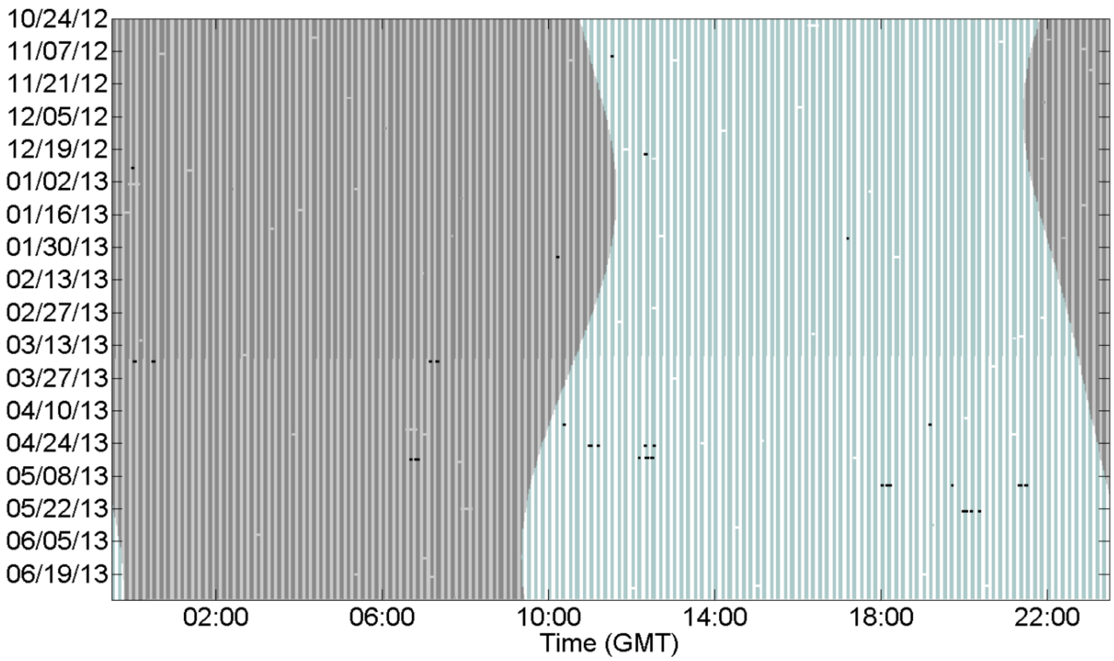

Figure 36. Blainville's beaked whale click detections (black bars) within the 2012-2013 Site E dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

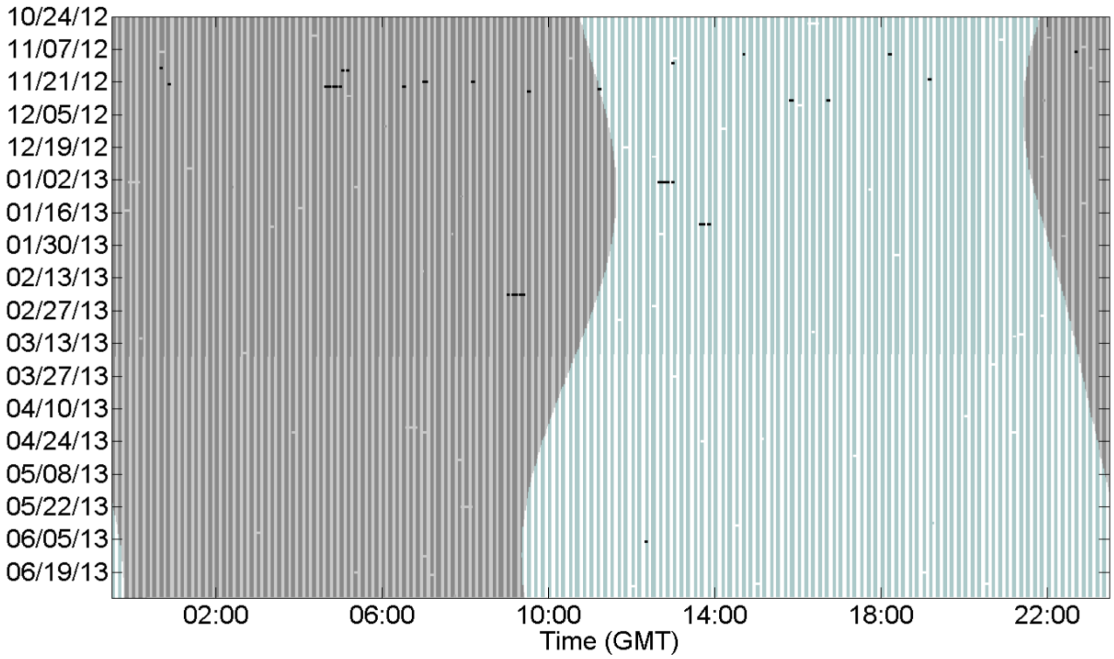

Figure 37. Cuvier's beaked whale click detections (black bars) within the 2012-2013 Site E dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

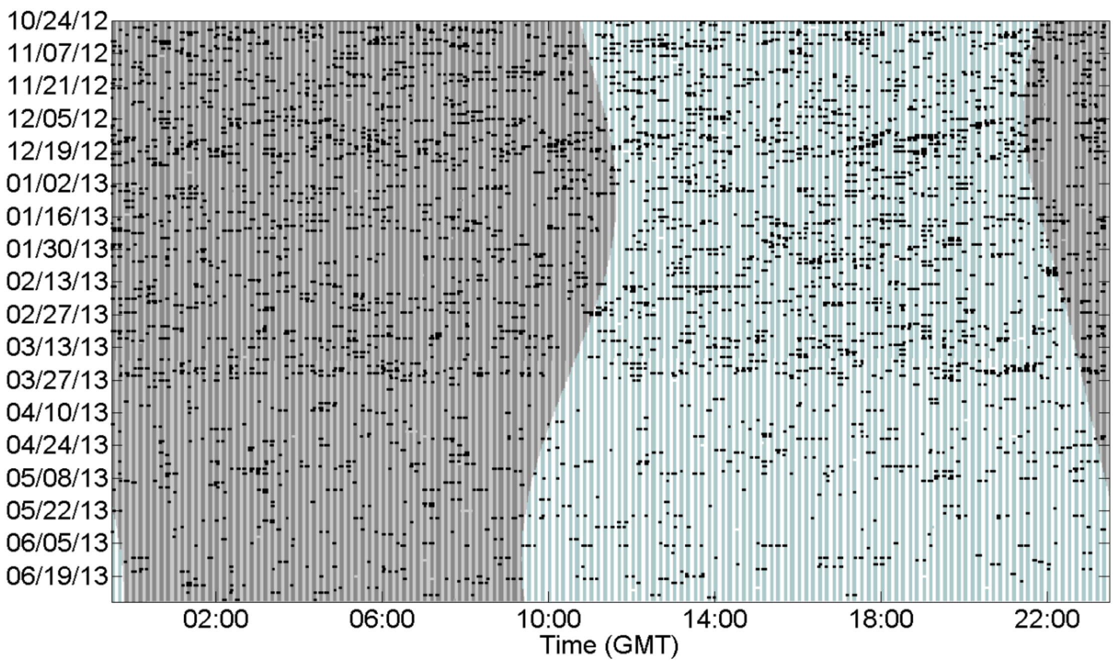

Figure 38. Gervais' beaked whale click detections (black bars) within the 2012-2013 Site E dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

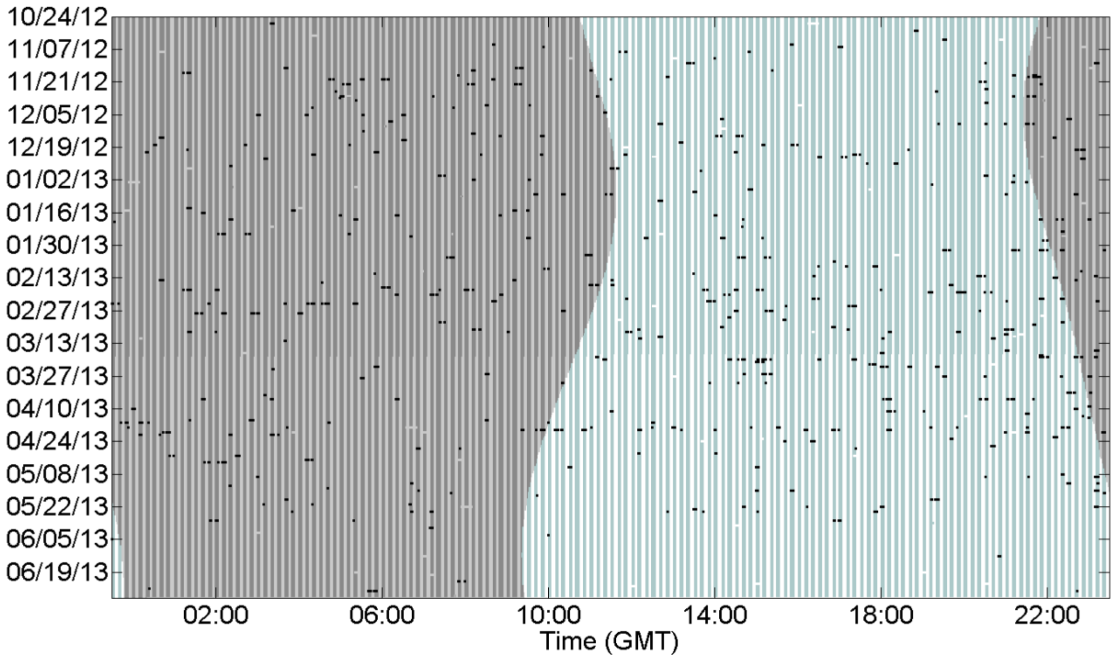

Figure 39. *Kogia* spp. click detections (black bars) within the 2012-2013 Site E dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

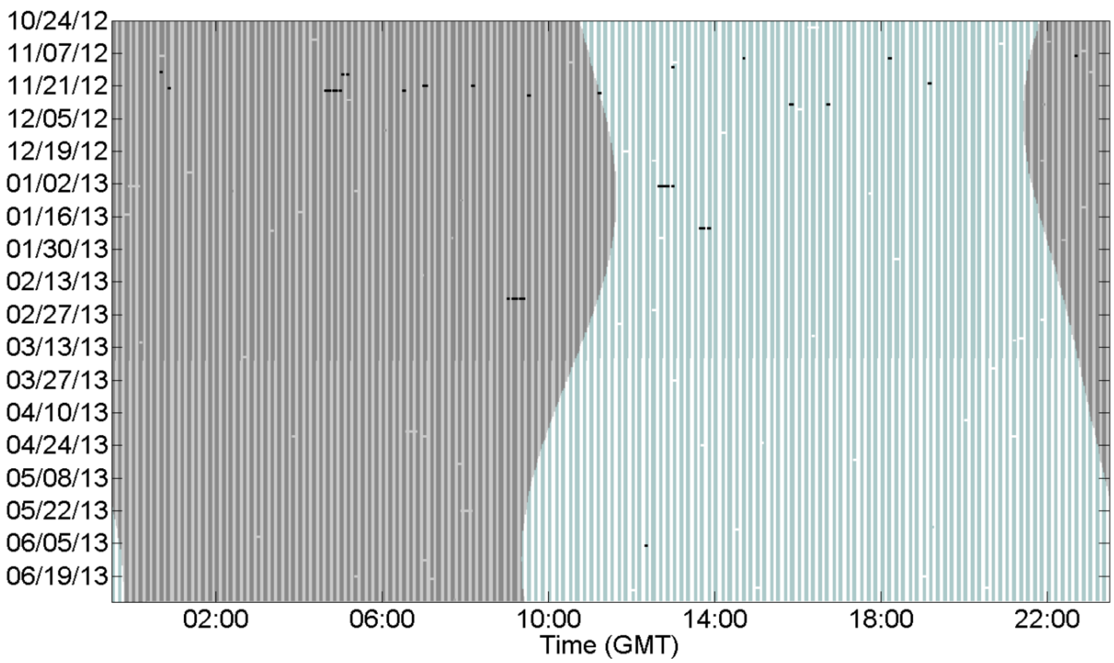

Figure 40. Risso's dolphin click detections (black bars) within the 2012-2013 Site E dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

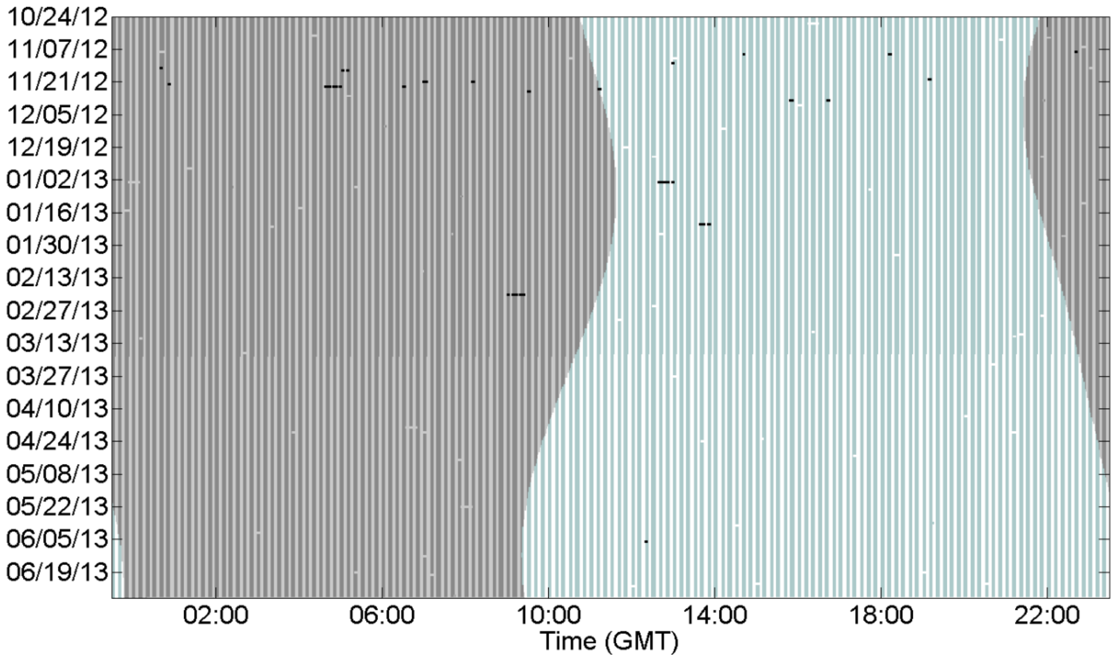

Figure 41. Sperm whale click detections (black bars) within the 2012-2013 Site E dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

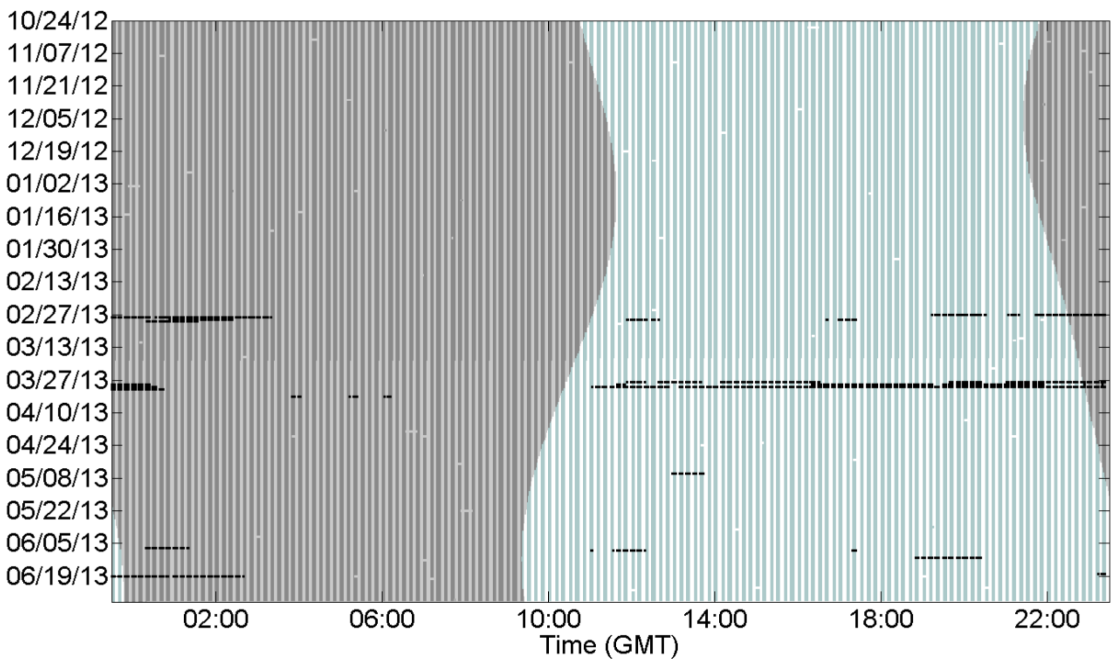

Figure 42. Mid-frequency active sonar (black bars) detected within the 2012-2013 Site E dataset. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil). Other shading (blue shading during day, darker gray shading during night) indicates recording/analysis effort based on a 5 minute on/5 minute off duty cycle.

6. Jacksonville, Florida

6.1 Methods

Data Collection

The small mooring HARP deployed in 88 m at 30.32643 N, -80.20493 W (Site C) on February 17, 2014 was recovered on August 23, 2014 (**Table 9**; **Figure 43**). The deployment period was 188 days. The HARP was then deployed that same day (August 23, 2014) in approximately 806 m at 30.15060 N, -79.77005 W (Site D) (**Table 9**; **Figure 43**). Both HARPs were set to sample continuously at 200 kHz. A schematic diagram of the HARP mooring for the August 2014 deployment can be seen in **Figure 44**.

Table 9. Jacksonville, Florida, HARP data sets analyzed and detailed in this report.

Site	Deployment Date	Retrieval Date	Recording Start Date	Recording End Date	Latitude	Longitude	Depth (m)	Sampling Rate	Duty Cycle
9C	12-May-13	17-Feb-14	13-May-13	20-Jun-13	30.33287	-80.20071	94	200 kHz	continuous
10C	17-Feb-14	23-Aug-14	17-Feb-14	23-Aug-14	30.32643	-80.20493	88	200 kHz	continuous
11D	23-Aug-14	N/A	23-Aug-14	N/A	30.15060	-79.77005	~806	200 kHz	continuous

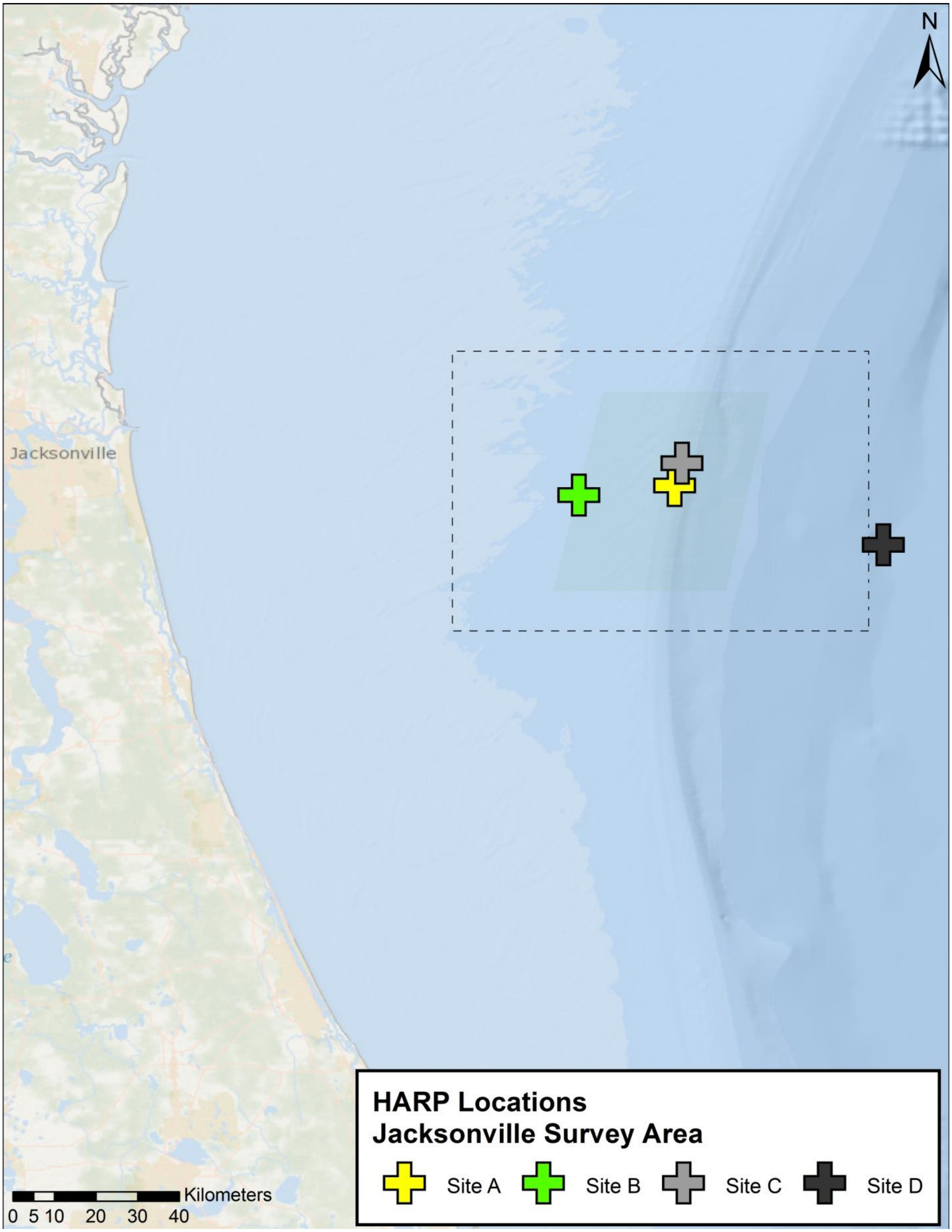

Figure 43. Location of HARP deployment sites in the Jacksonville, Florida, survey area.

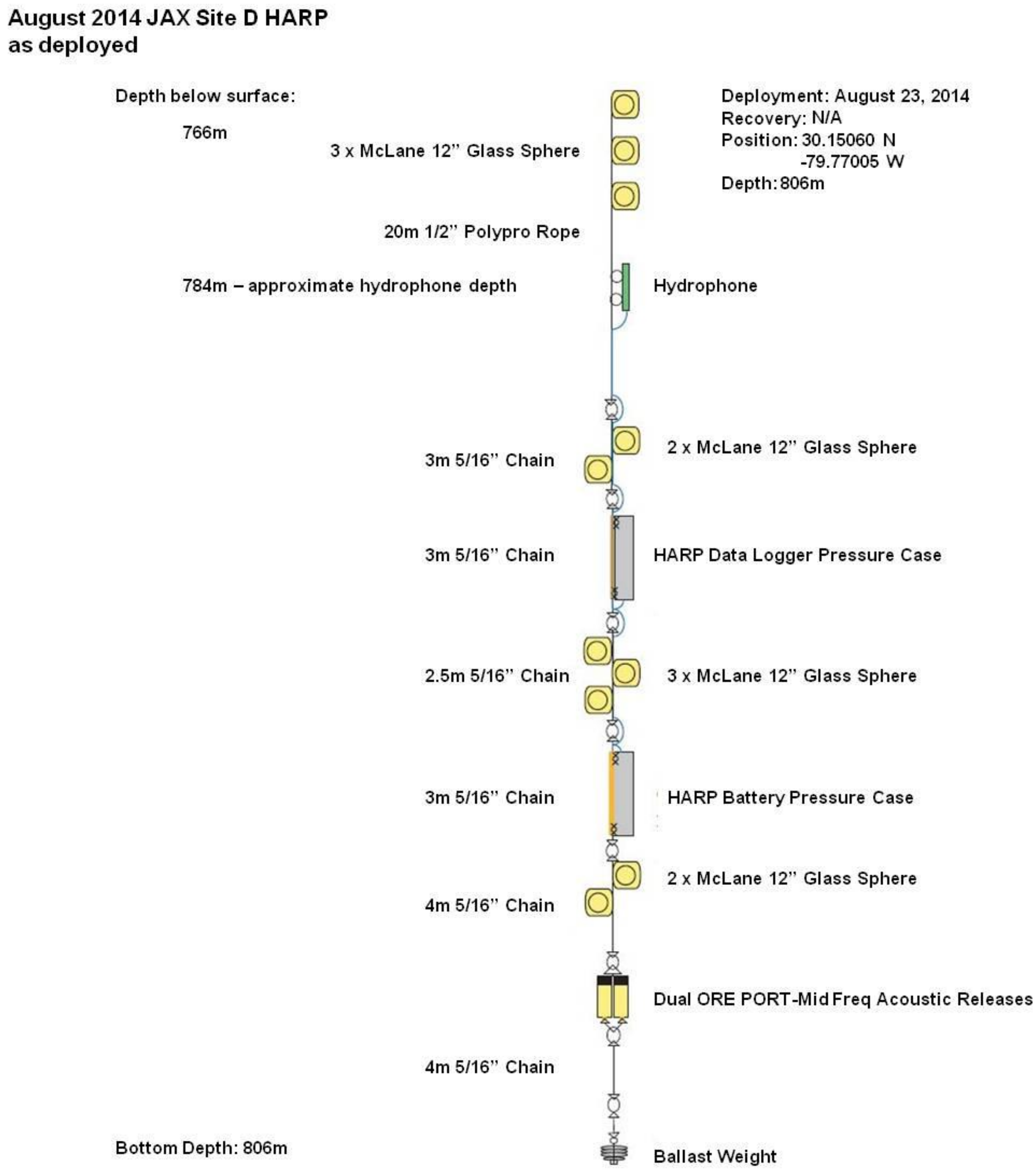

Figure 44. Schematic diagram showing details of the Site D Jacksonville HARP deployment (small mooring) made in August 2014. Note that diagram is not drawn to scale.

6.2 Data Analysis

Data from the two deployments at Site C (May 2013–February 2014 and February–August 2014) have been analyzed for marine mammal and anthropogenic sounds but have not yet been prepared for a report. These data will be included in next year's annual report.

7. Current and Anticipated Analyses for 2015

7.1 Norfolk Canyon

Once the HARP deployed in Norfolk Canyon at Site A (deployed June 19, 2014) is recovered, that dataset will be fully analyzed by Scripps Institution of Oceanography over the next year. A detailed and technical report will be provided once the analysis of the dataset is complete.

7.2 Cape Hatteras

Scripps Institution of Oceanography is currently analyzing the 2012-2013 dataset from Cape Hatteras Site A. Next, they will analyze data from the 2013-2014 Cape Hatteras Site A deployment, followed by data from the HARP currently deployed at Cape Hatteras Site A (scheduled to be recovered in April 2015). Detailed and technical reports will be provided once analyses of these datasets are complete.

7.3 Jacksonville

Once the HARP deployed in Jacksonville at Site D (deployed August 23, 2014) is recovered, that dataset will be fully analyzed by Scripps Institution of Oceanography over the next year. A detailed and technical report will be provided once the analysis of the dataset is complete.

8. Acknowledgements

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