Passive Acoustic Monitoring for Marine Mammals at Site A in Norfolk Canyon, June 2014 – April 2015

A Summary of Work Performed by Amanda J. Debich, Simone Baumann-Pickering, Ana Širović, John A. Hildebrand, Arial M. Brewer, Kait E. Frasier, Rohen T. Gresalfi, Sean T. Herbert, Sarah C. Johnson, Ally C. Rice, Leah M. Varga, and Sean M. Wiggins

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

AND

A Summary of Work Performed by Lynne E.W. Hodge, Joy E. Stanistreet, and Andrew Read

Duke University Marine Laboratory
135 Duke Marine Lab Road
Beaufort, NC 28516

Prepared by Lynne Hodge, Joy Stanistreet, and Andrew Read

Duke University Marine Laboratory
135 Duke Marine Lab Road
Beaufort, NC 28516

Submitted to:
The Department of the Navy
Norfolk, VA

Suggested Citation:

Hodge, L., J. Stanistreet, and A. Read. 2016. Passive Acoustic Monitoring for Marine Mammals at Site A in Norfolk Canyon, June 2014 – April 2015. Technical Report. Submitted to Naval Facilities Engineering Command (NAVFAC) Atlantic, Norfolk, Virginia, under Contract No. N62470-10-D-3011, Task Order CTO 0051, issued to HDR Inc., Norfolk, Virginia. Prepared 16 August 2016.

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

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.

Abstract

A High-frequency Acoustic Recording Package (HARP; Wiggins and Hildebrand 2007) was deployed between June 2014 and April 2015 in Norfolk Canyon, VA, at Site A in 982 m. This HARP sampled continuously at 200 kHz and recorded for 290 days between 19 June 2014 and 5 April 2015. 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, humpback whales, *Kogia* spp., Risso's dolphins, sperm whales, Cuvier's beaked whales, Gervais' beaked whales, possible Sowerby's beaked whales, and unidentified delphinids were detected in the data.

Methods

The June 2014 – April 2015 Norfolk Canyon Site A HARP (Norfolk Canyon 01A) was deployed at 37.16623° N, 74.46692° W on 19 June 2014 (recording started on 19 June 2014) and recovered on 7 April 2015 (recording ended on 5 April 2015). The instrument location is shown in Figure 1. Bottom depth at the deployment site was approximately 982 m. A schematic diagram of the Norfolk Canyon 01A HARP is shown in Figure 2.

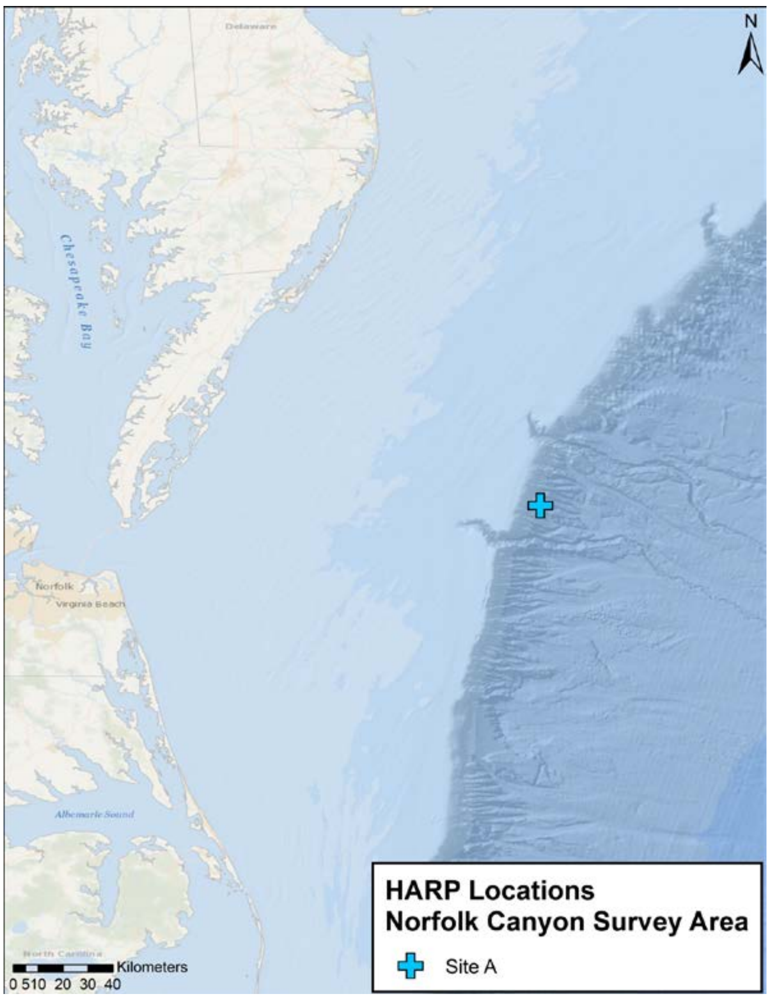

Figure 1. Location of Norfolk Canyon 01A HARP deployment in Norfolk Canyon.

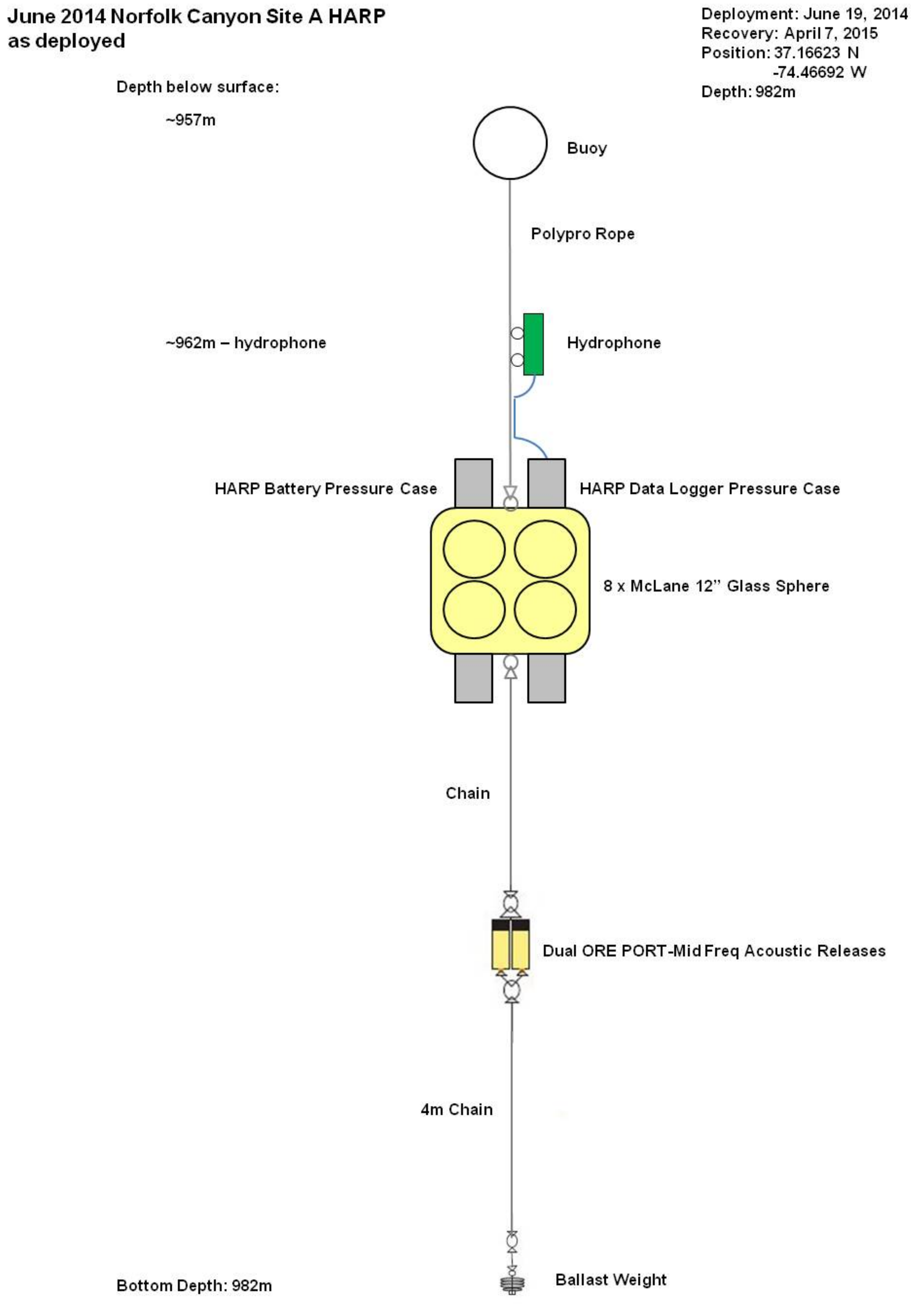

Figure 2. Schematic diagram showing details of the Norfolk Canyon 01A HARP. Note that diagram is not drawn to scale.

Data were acquired continuously at a 200 kHz sampling rate during the Norfolk Canyon 01A deployment. This deployment provided a total of 6951 hours of data over the 290 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 Norfolk Canyon 01A 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 are 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. Fin whale 20-Hz calls were detected using an energy detection method, which 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. 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).

Data Quality

Highly stereotyped broadband digital errors (‘glitches’) were found in this dataset. These glitches 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. It is believed that the glitches do not significantly impact the resulting data analysis.

Results

Table 1 summarizes the detected and identified marine mammal vocalizations for the Norfolk Canyon 01A HARP deployment. Figures 3-17 show the daily occurrence patterns for the marine mammals detected in this dataset. Figure 18 shows the occurrence of mid-frequency active sonar. Figure 19 shows the occurrence of low-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, and humpback whales. Blue whale calls were detected only on two days (Figure 3). Fin whale 20-Hz pulses (as measured by the acoustic index) were detected throughout the deployment, with a peak in calling in December (Figure 4). Fin whale 40-Hz calls were detected in low numbers, with peaks in hourly call detections between November and December (Figure 5). Compared to the Cape Hatteras and Onslow Bay HARP deployment sites during the winter, very few minke whale pulse trains were detected at Norfolk Canyon as seen in Figure 6. Sei whale downsweeps were detected mainly between November and April, with peaks in occurrence in December 2014 and April 2015 (Figure 7). Humpback whale calls were detected only on two days, once in August and once in November, during this deployment (Figure 8).

Detected odontocete vocalizations included clicks and whistles (Figures 9-17). Many of these detections were assigned to the unidentified odontocete category, with whistles divided into two categories based on frequency (Figures 9-10) and with the unidentified clicks being divided into five main groups based on spectral patterns (Figure 11). Altogether, the unidentified whistles and clicks were present nearly continuously throughout the deployment. For more details on each of the five groups of clicks and which species may have produced them, see Debich *et al.* (2016). Clicks produced by *Kogia* spp. were also detected throughout the deployment, but in very low numbers (Figure 12). Risso's dolphin clicks were detected in the months of August, September, January, and March, with a peak in detections in September (Figure 13). Sperm whales were detected throughout the deployment during both day and night, with peaks in click detections in August 2014 and April 2015 (Figure 14). There were also several click detections that were assigned to beaked whales. Cuvier's beaked whale clicks occurred during this deployment, with detections mainly between the end of December and March (Figure 15). Gervais' beaked whale clicks were also detected, with most detections between the end of November and mid-February (Figure 16). Finally, most beaked whale detections were clicks that were higher in frequency, possibly from Sowerby's beaked whale. These detections occurred throughout the deployment, with peaks between December and March (Figure 17).

Table 1. Summary of detections of marine mammal vocalizations at Norfolk Canyon Site A for June 2014 – April 2015 (Norfolk Canyon 01A). 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	3	0.04	2	0.69
Fin whale[a]	40 Hz	50	0.72	26	8.93
Minke whale[a]	pulse train (slow-down, speed-up, regular)	23	0.33	11	3.78
Sei whale[a]	downsweep	152	2.19	59	20.27
Humpback whale	variable	0.03	0.0005	2	0.69
Unidentified odontocete	whistles	2541.07	36.57	289	99.31
Unidentified odontocete	clicks	1058.72	15.24	282	96.91
Kogia spp.	clicks	1.73	0.02	59	20.27
Risso's dolphin	clicks	12.03	0.17	15	5.15
Sperm whale	clicks	787.53	11.33	160	54.98
Cuvier's beaked whale	clicks	16.78	0.24	59	20.27
Gervais' beaked whale	clicks	9.52	0.14	43	14.78
Possible Sowerby's beaked whale	clicks	19.13	0.28	103	35.40

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

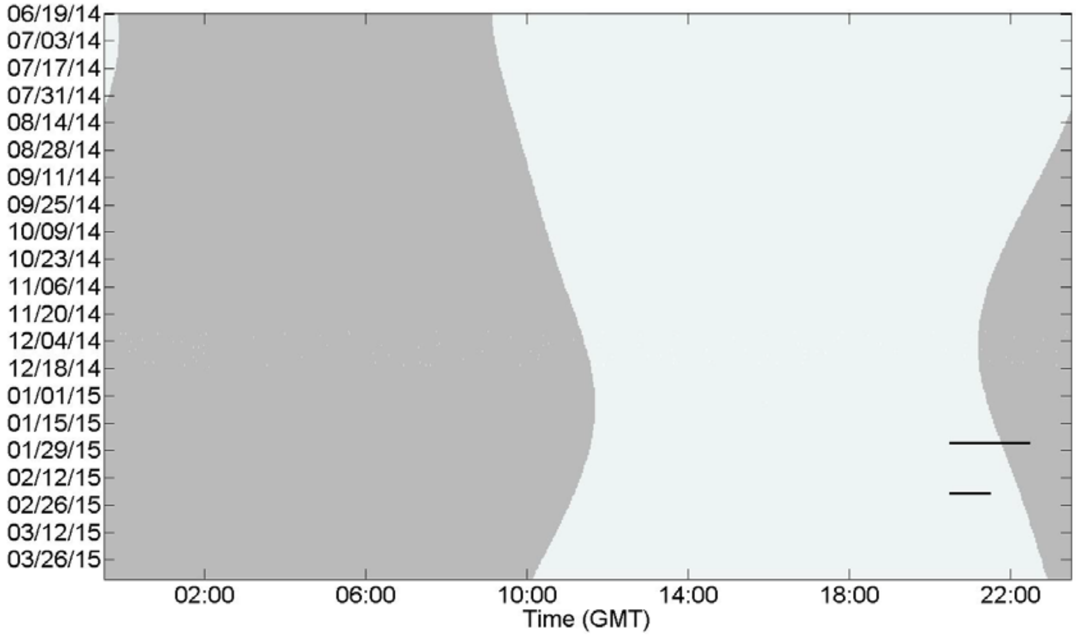

Figure 3. Blue whale call detections (black bars) in hourly bins for the Norfolk Canyon 01A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

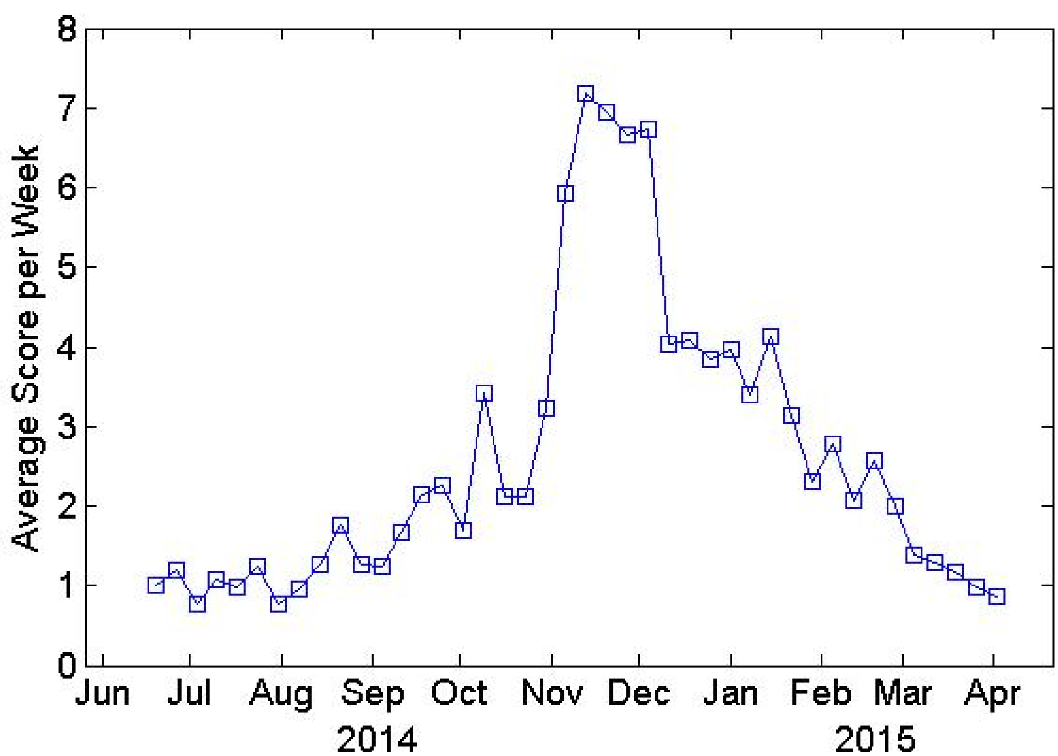

Figure 4. Weekly value of fin whale 20-Hz call acoustic index for the Norfolk Canyon 01A deployment.

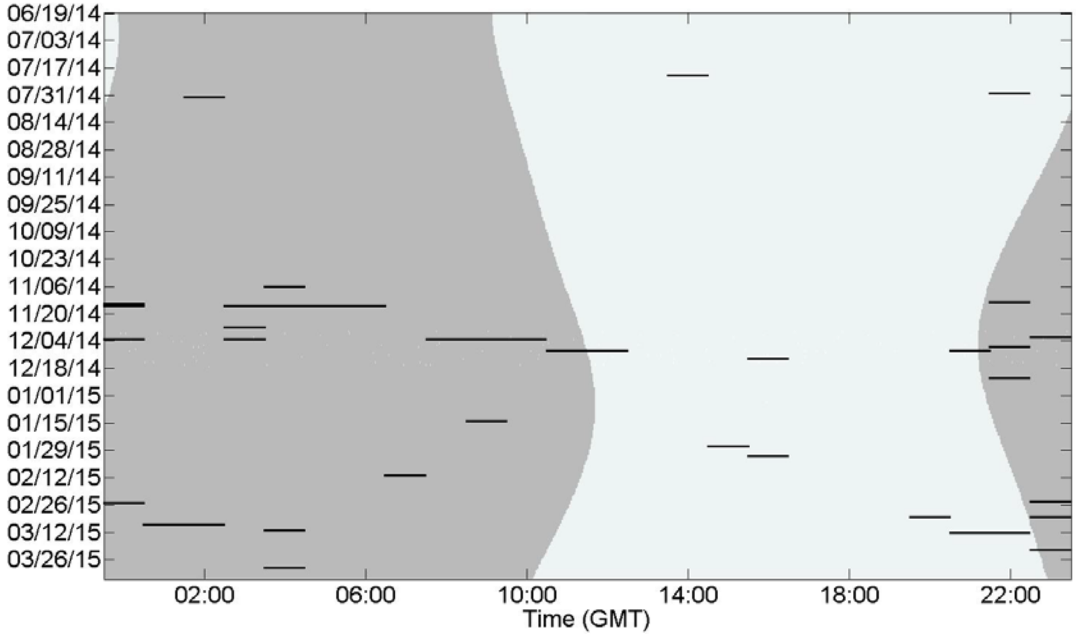

Figure 5. Fin whale 40-Hz call detections (black bars) in hourly bins for the Norfolk Canyon 01A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

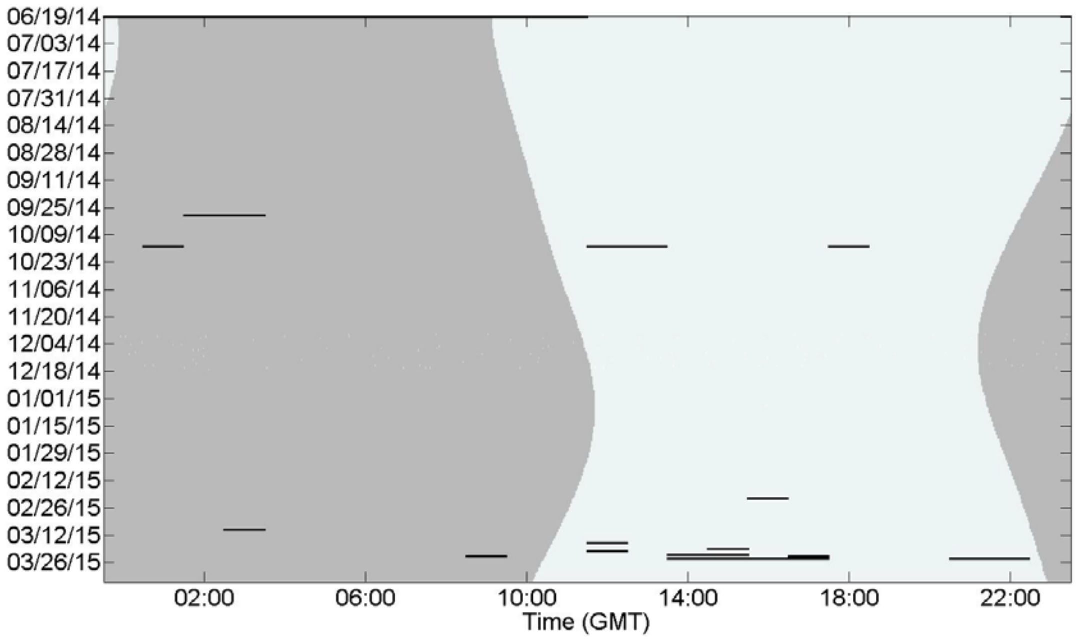

Figure 6. Minke whale pulse train detections (black bars) in hourly bins for the Norfolk Canyon 01A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

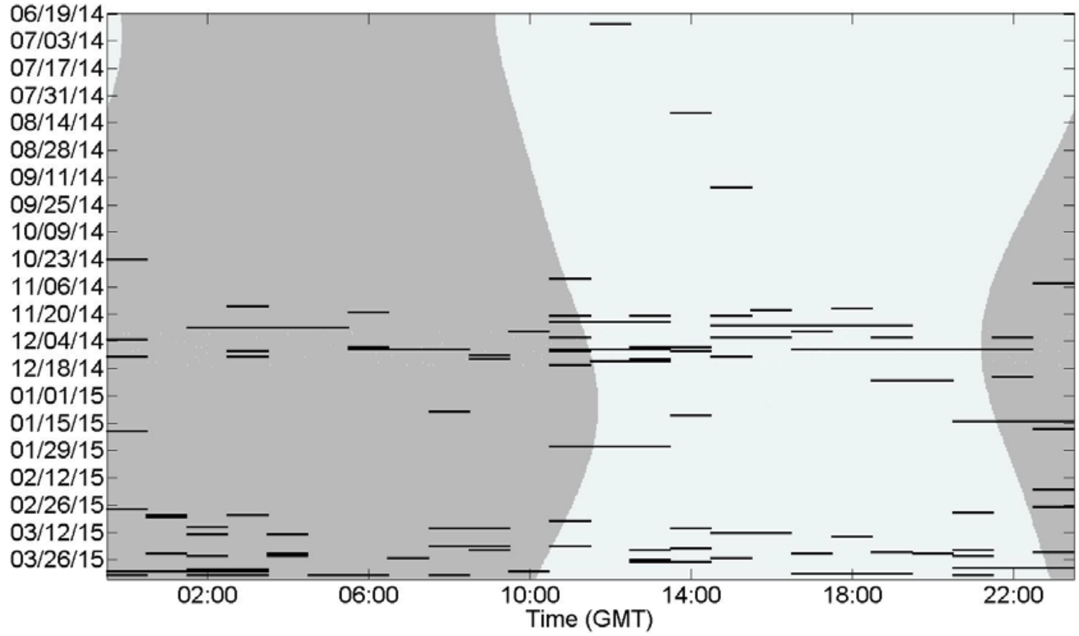

Figure 7. Sei whale downsweep detections (black bars) in hourly bins for the Norfolk Canyon 01A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

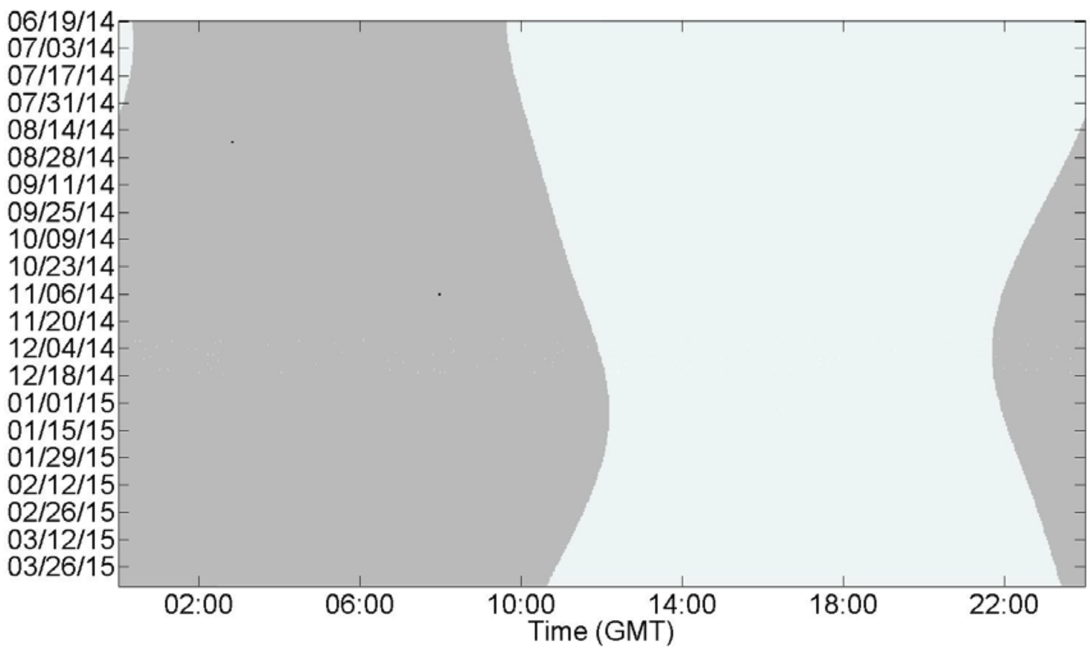

Figure 8. Humpback whale call detections (black bars) in one-minute bins for the Norfolk Canyon 01A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

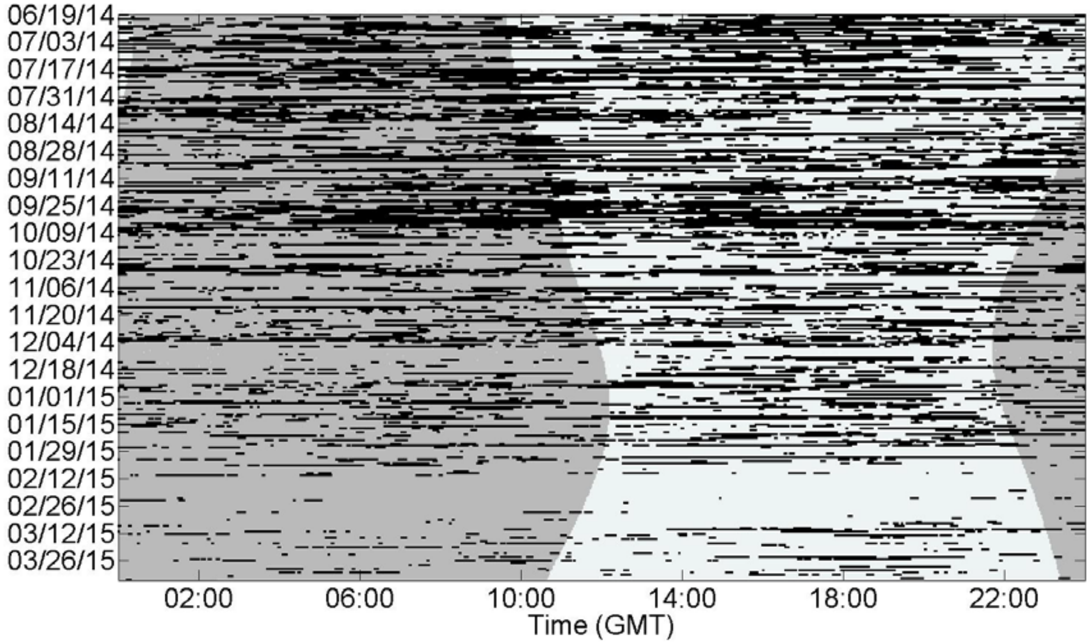

Figure 9. Unidentified odontocete whistle detections that were less than 5 kHz (black bars) in one-minute bins for the Norfolk Canyon 01A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

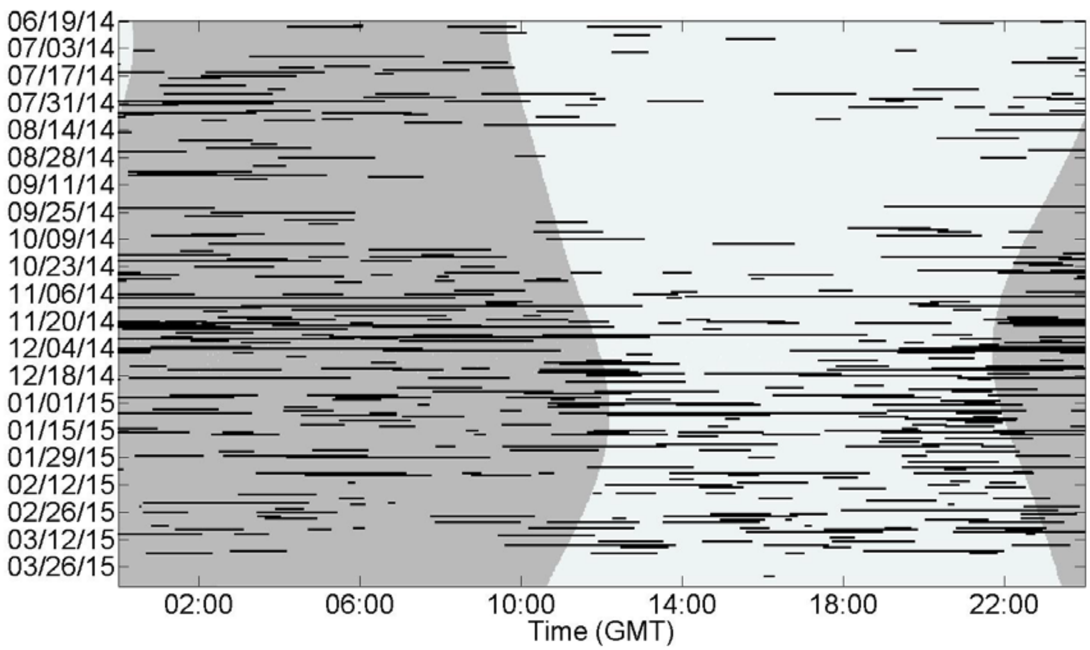

Figure 10. Unidentified odontocete whistle detections that were greater than 5 kHz (black bars) in one-minute bins for the Norfolk Canyon 01A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

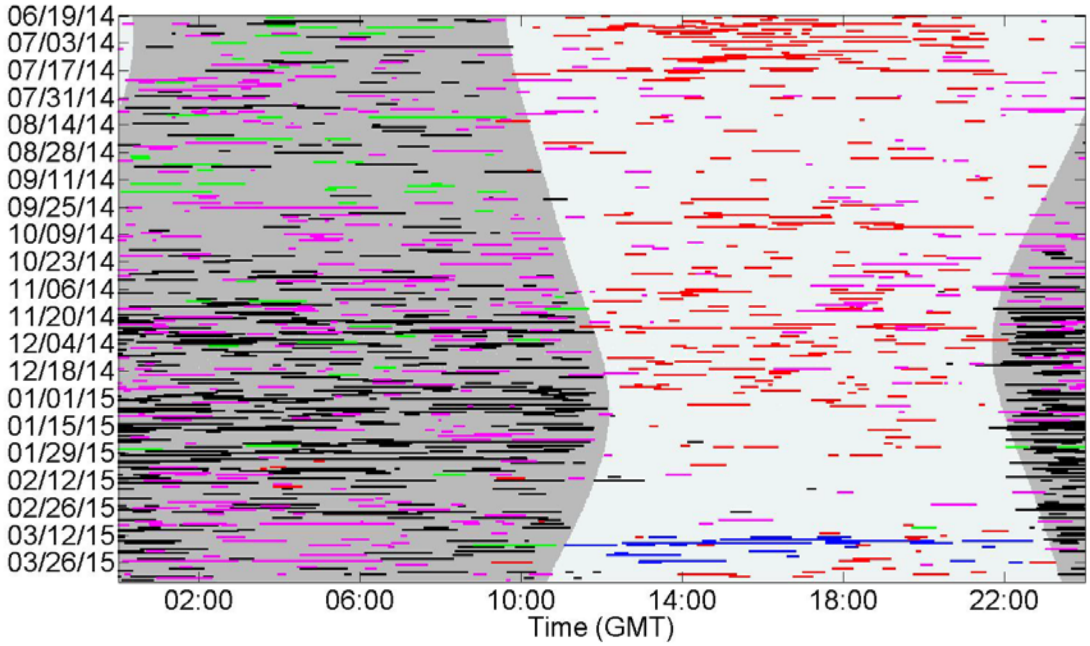

Figure 11. Unidentified odontocete click detections (different colored horizontal bars represent the different groups clicks were divided into for this report) in one-minute bins for the Norfolk Canyon 01A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

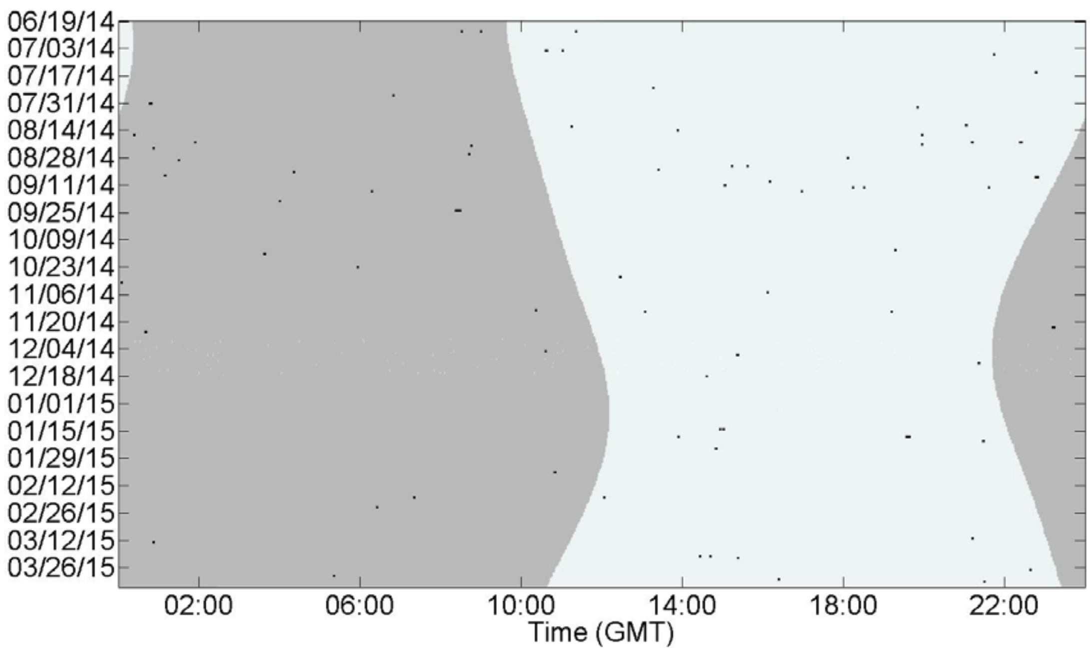

Figure 12. *Kogia* spp. click detections (black bars) in one-minute bins for the Norfolk Canyon 01A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

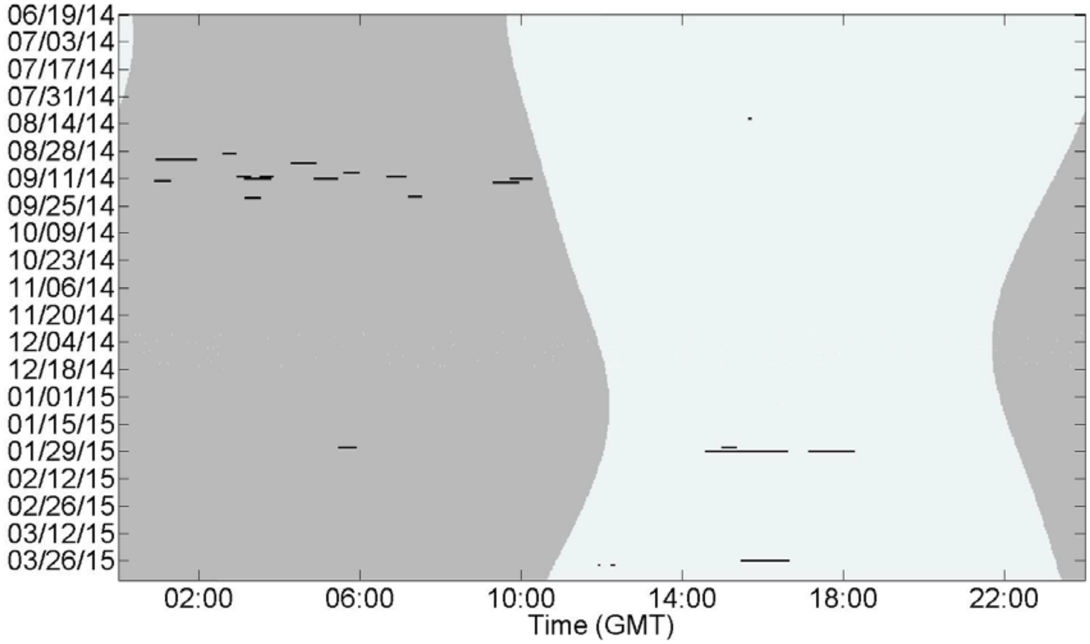

Figure 13. Risso's dolphin click detections (black bars) in one-minute bins for the Norfolk Canyon 01A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

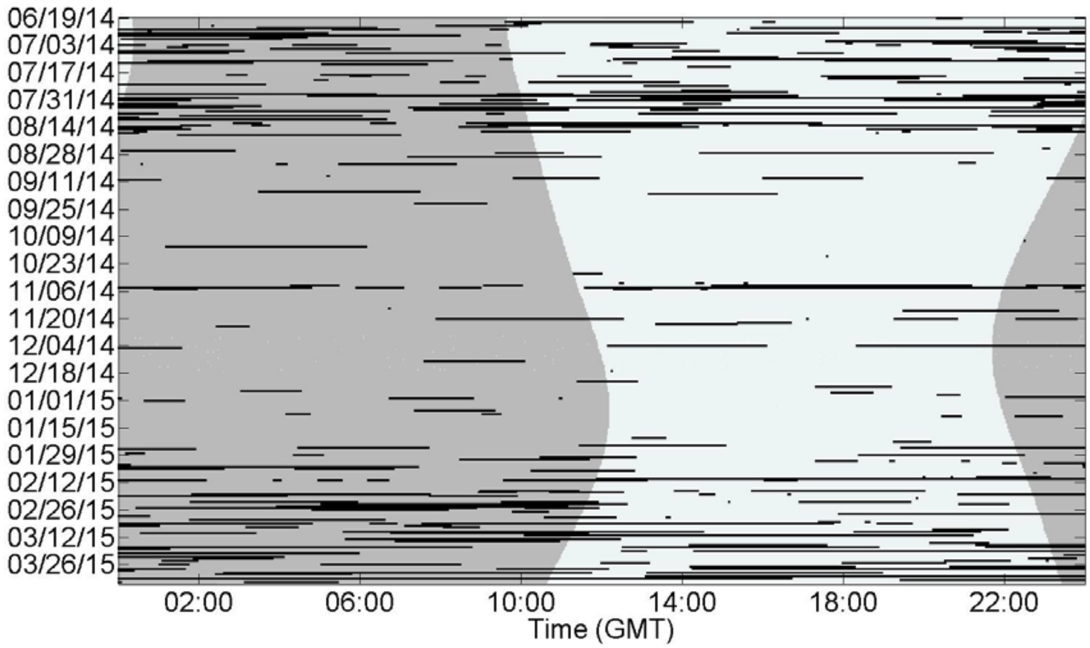

Figure 14. Sperm whale click detections (black bars) in one-minute bins for the Norfolk Canyon 01A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

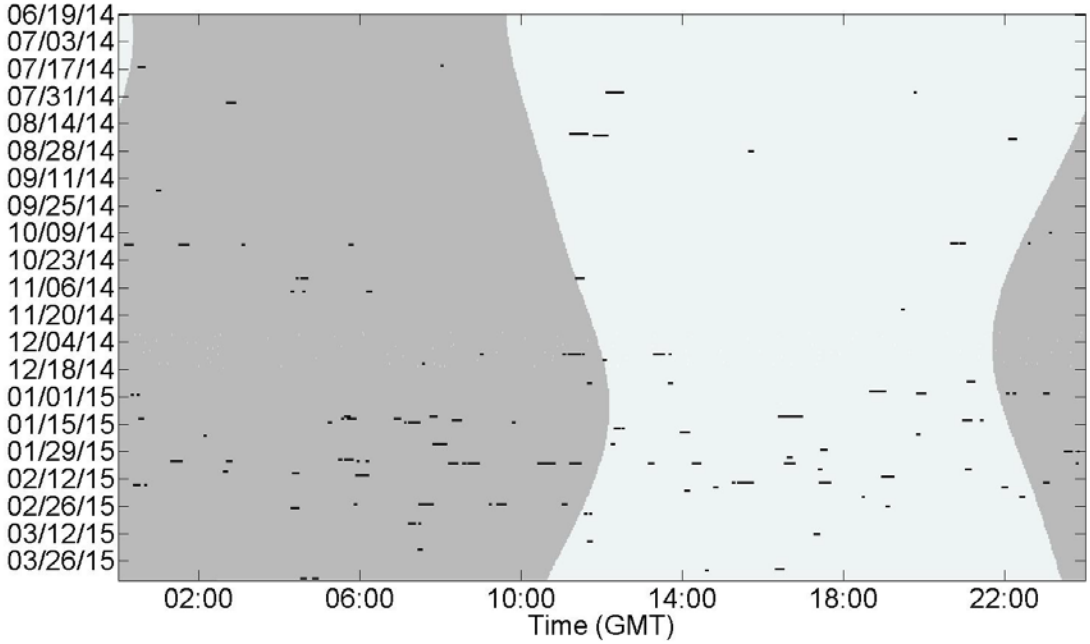

Figure 15. Cuvier's beaked whale click detections (black bars) in one-minute bins for the Norfolk Canyon 01A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

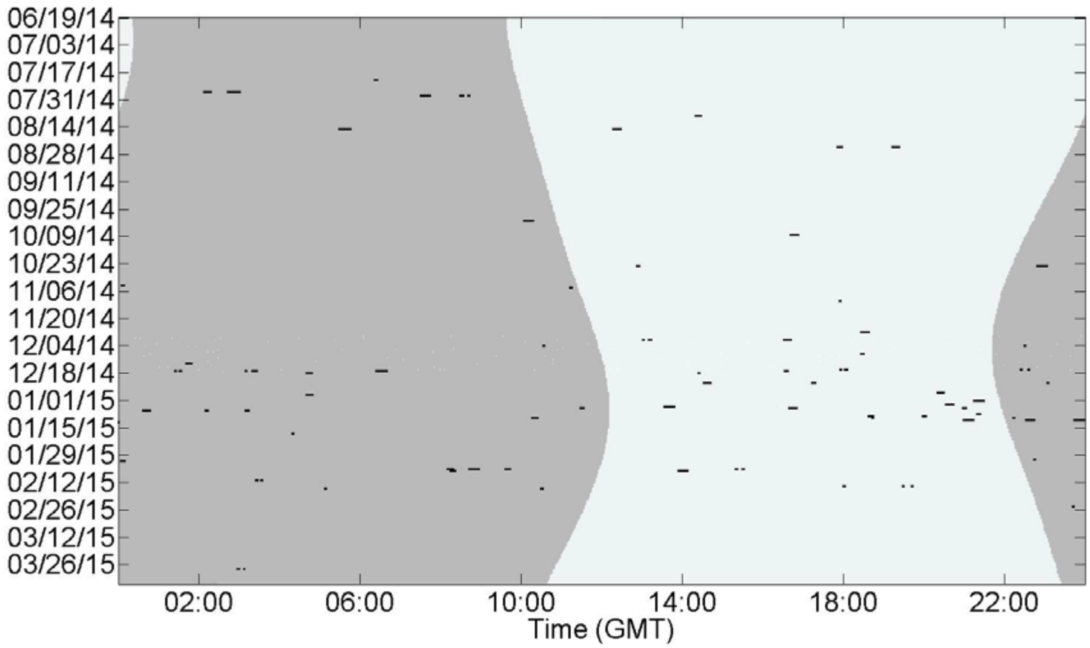

Figure 16. Gervais' beaked whale click detections (black bars) in one-minute bins for the Norfolk Canyon 01A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

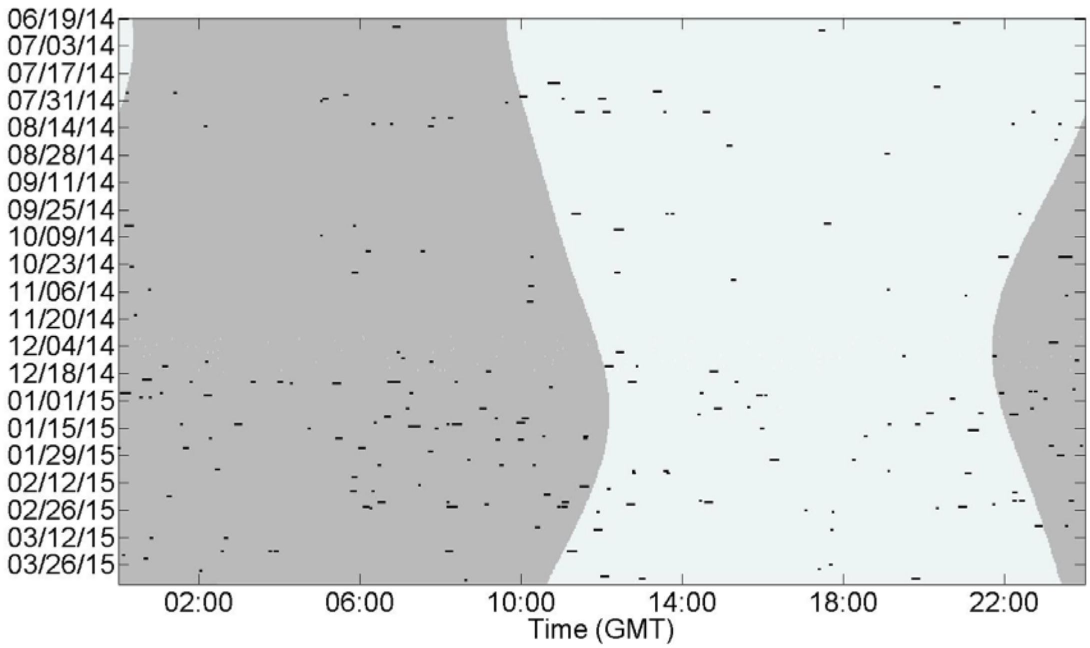

Figure 17. Possible Sowerby's beaked whale click detections (black bars) in one-minute bins for the Norfolk Canyon 01A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

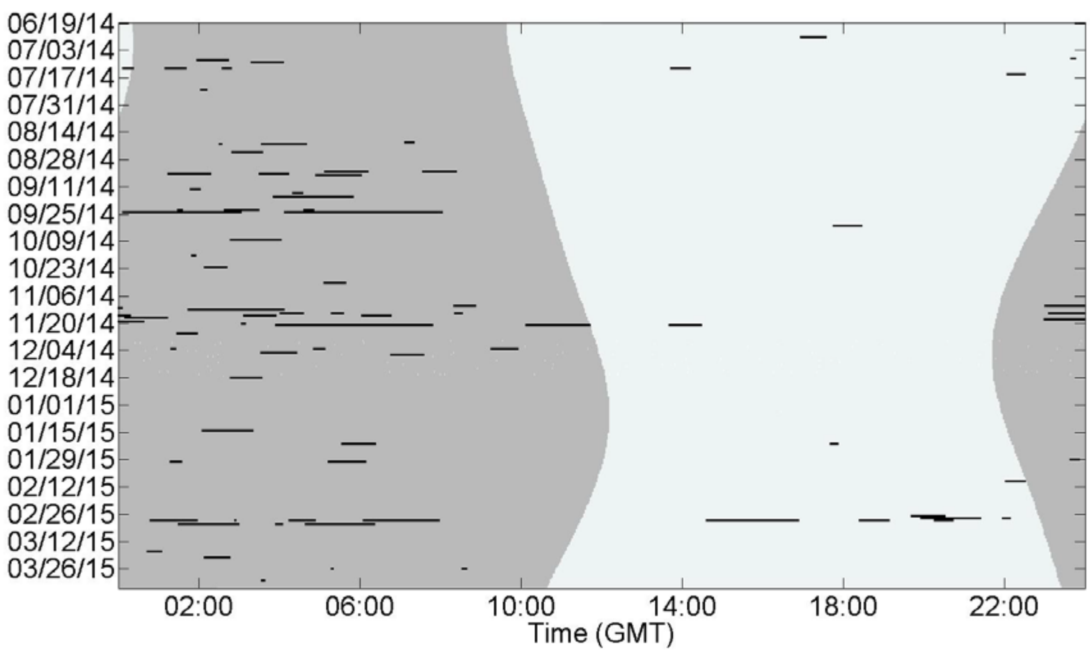

Figure 18. Mid-frequency active sonar (black bars) detected during the Norfolk Canyon 01A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

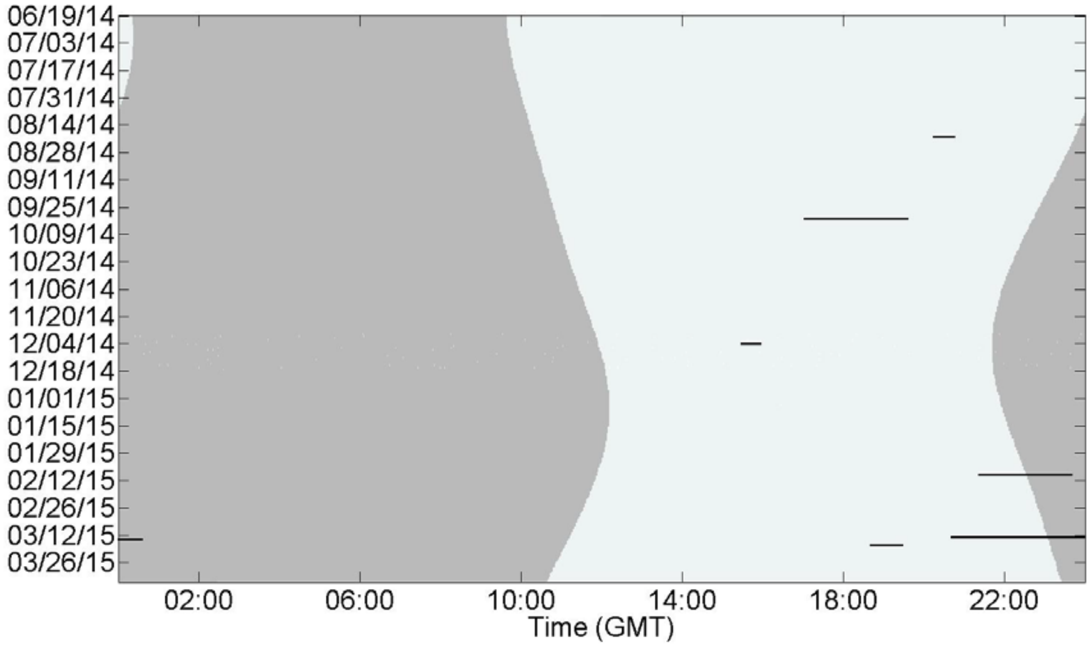

Figure 19. Low-frequency active sonar (black bars) detected during the Norfolk Canyon 01A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

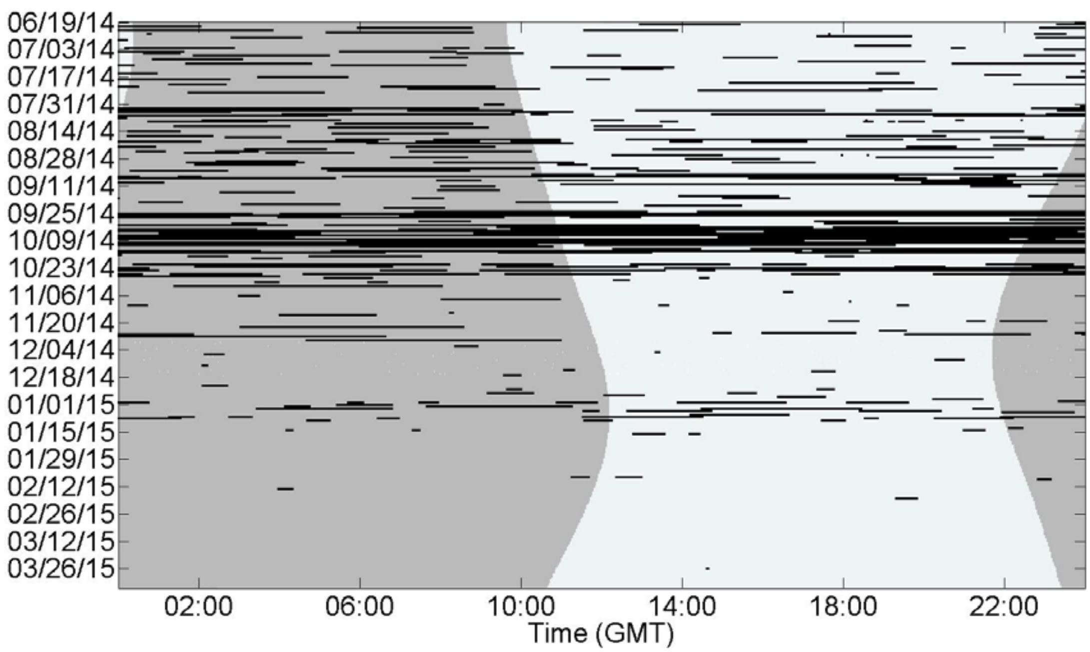

Figure 20. Airgun detections (black bars) during the Norfolk Canyon 01A deployment. Dark gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

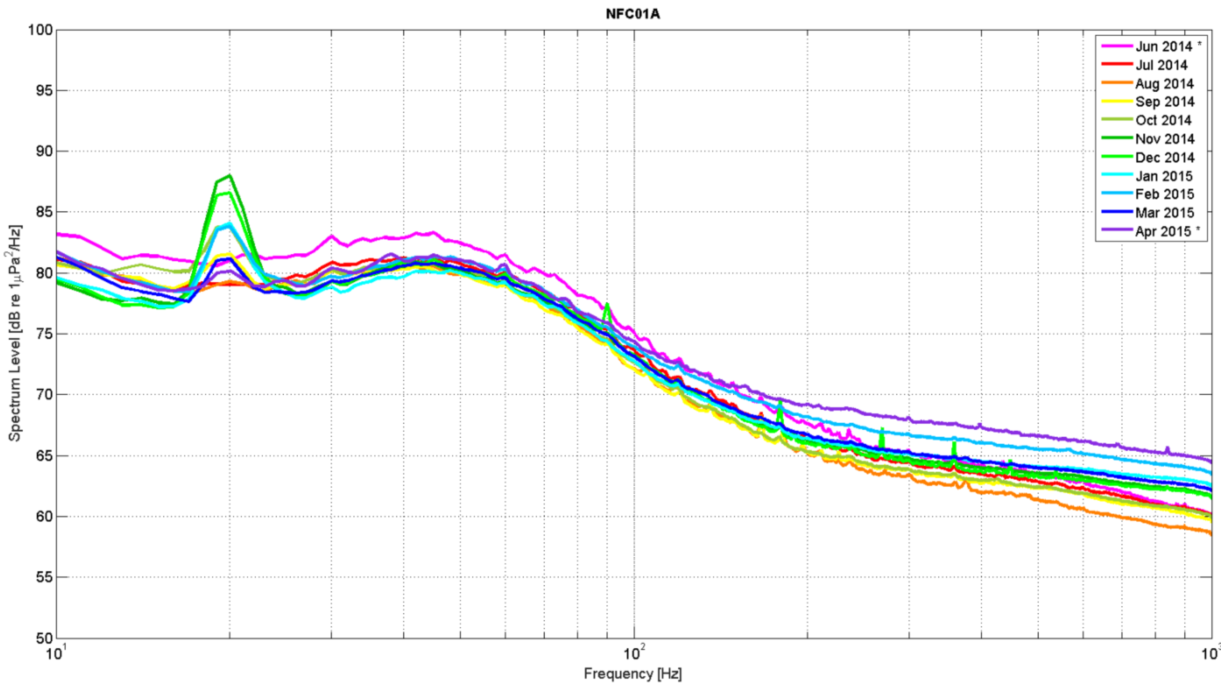

Figure 21. Monthly averages of ambient noise at Norfolk Canyon, VA, Site A for June 2014 – April 2015. Months with an asterisk (*) are partial recording periods. Figure from Debich *et al.* (2016).

References

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

Debich, A.J., S. Baumann-Pickering, A. Širović, J.A. Hildebrand, A.M. Brewer, K.E. Frasier, R.T. Gresalfi, S.T. Herbert, S.C. Johnson, A.C. Rice, L.M. Varga, S.M. Wiggins, L.E.W. Hodge, J.E. Stanistreet, and A.J. Read. 2016. Passive acoustic monitoring for marine mammals in the Virginia Capes Range Comples October 2012 – April 2015. Final Report, Marine Physical Laboratory Technical Memorandum #559. August 2016. Submitted to Naval Facilities Engineering Command (NAVFAC) Atlantic, Norfolk, Virginia, under Contract No. N62470-10-D-3011 – Task Order Number 051 – issued to HDR, Inc.

Debich A.J., S. Baumann-Pickering, A. Širović, J.S. Buccowich, Z.E. Gentes, R.S. Gottlieb, S.C. Johnson, S.M. Kerosky, L.K. Roche, B. Thayre, J.T. Trickey, S.M. Wiggins, J.A. Hildebrand, L.E.W. Hodge, and A.J. Read. 2014. Passive Acoustic Monitoring for Marine Mammals in the Cherry Point OPAREA 2011-2012. Final Report, Marine Physical Laboratory Technical Memorandum #545. Submitted to Naval Facilities Engineering Command (NAVFAC) Atlantic, Norfolk, Virginia, under Contract No. N62470-10D-3011 issued to HDR, Inc.

Frasier, K.E. 2015. Density estimation of delphinids using passive acoustics: A case study in the Gulf of Mexico. Doctoral dissertation, University of California San Diego, Scripps Institution of Oceanography, La Jolla, CA, USA. 321 pp.

Roch, M.A., H. Klinch, S. Baumann-Pickering, D.K. Mellinger, S. Qui, M.S. Soldevilla, and J.A. Hildebrand. 2011. Classificaiton of echolocation clicks from odontocetes in the Southern California Bight. *Journal of the Acoustical Society of America* **129**: 467-475.

Wiggins, S.M. and J.A. Hildebrand. 2007. High-frequency Acoustic Recording Package (HARP) for broad-band, long-term marine mammal monitoring. In: *International Symposium on Underwater Technology 2007 and International Workshop on Scientific Use of Submarine Cables & Related Technologies 2007*: 551-557. Tokyo, Japan: Institute of Electrical and Electronics Engineers.