Passive Acoustic Monitoring for Cetaceans Across the Continental Shelf off Virginia:

2017 Annual Progress Report

Submitted to:

Naval Facilities Engineering Command Atlantic under Contract No. N62470-15-D-8006, Task Order 032.

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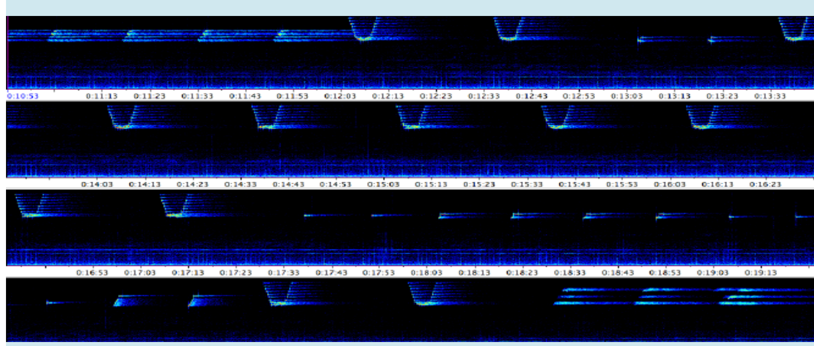

Submitted by:

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Virginia Beach, VA

March 2018

Suggested Citation:

Klinck, H., A.N. Rice, B.J. Estabrook, K. Klinck, D.P. Salisbury, and R.A. Charif. 2018. *Passive Acoustic Monitoring for Cetaceans Across the Virginia Continental Shelf: 2017 Annual Progress Report.* Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command (NAVFAC) Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006, Task Order 032. February 2018.

Cover Graphic Credit:

Spectrogram of naval sonar signals recorded off the coast of Virginia. Spectrogram created by Russ Charif using the Raven Sound Analysis software (Cornell University, Ithaca, NY, USA).

This project is co-funded by the Bureau of Ocean Energy Management and the U.S. Fleet Forces Command. Odontocete and sonar analysis is managed by the Naval Facilities Engineering Command Atlantic and HDR, Inc. as part of the U.S. Navy's marine species monitoring program.

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Acronyms and Abbreviations

AMAR	Autonomous Multichannel Acoustic Recorder
kHz	kilohertz
MARU	Marine Acoustic Recording Unit
ROCCA	Real-time Odontocete Call Classification Algorithm
WEA	Wind Energy Area

1. Background

Little is known about the seasonal and spatial occurrence of marine mammals off the coasts of Virginia and other mid-Atlantic states, especially in offshore areas. This data gap presents a challenge for effective marine spatial planning in the context of naval operations and offshore wind energy developments in the Virginia Wind Energy Area (WEA). As with other forms of human activity in the ocean, naval operations and wind energy developments have the potential to negatively affect marine mammals through increased ship traffic, construction, and operational noise. Consequently, collecting baseline data on spatial and temporal trends of cetacean occurrence in these areas is critical to minimize or mitigate risks to protected species.

Ten bottom-mounted passive acoustic recorders have been deployed off the coast of Virginia beginning in July 2015 and was maintained for two years. A combination of high-frequency Autonomous Multichannel Acoustic Recorders (AMARs), and low-frequency Marine Autonomous Recording Units (MARUs) was deployed in two spatial configurations (**Figure 1**), with the AMARs in a linear array extending east from the mouth of the Chesapeake Bay across the continental shelf and MARUs deployed as a synchronized localization array within the WEA. The initial deployment was conducted in July 2015, and the recorders have been recovered and redeployed—twice for the AMARs and four times for the MARUs (**Tables 1** and **2)**. AMARs recorded continuously but at alternating sampling rates (for 685 seconds at 8 kilohertz [kHz] and for 86 seconds at 375 kHz). MARUs recorded continuously at 2-kHz sampling rate.

These data are being analyzed using a combination of human analysts and automated approaches to describe the occurrence of the following:

- four species of mysticetes: fin whales (Balaenoptera physalus), humpback whales (Megaptera novaeangliae), minke whales (Balaenoptera acutorostrata), and North Atlantic right whales (Eubalaena glacialis)
- odontocetes
- Navy sonar signals.

The large geographic and temporal scale of the study enables a comparison of seasonal trends in cetacean presence across the continental shelf off the coast of Virginia, as well as inter-annual variability for this region. These results will help inform the Navy and Bureau of Ocean Energy Management of species occurrence, highly active seasonal periods, and high-use regions or corridors to assist with environmental regulatory compliance and spatial planning.

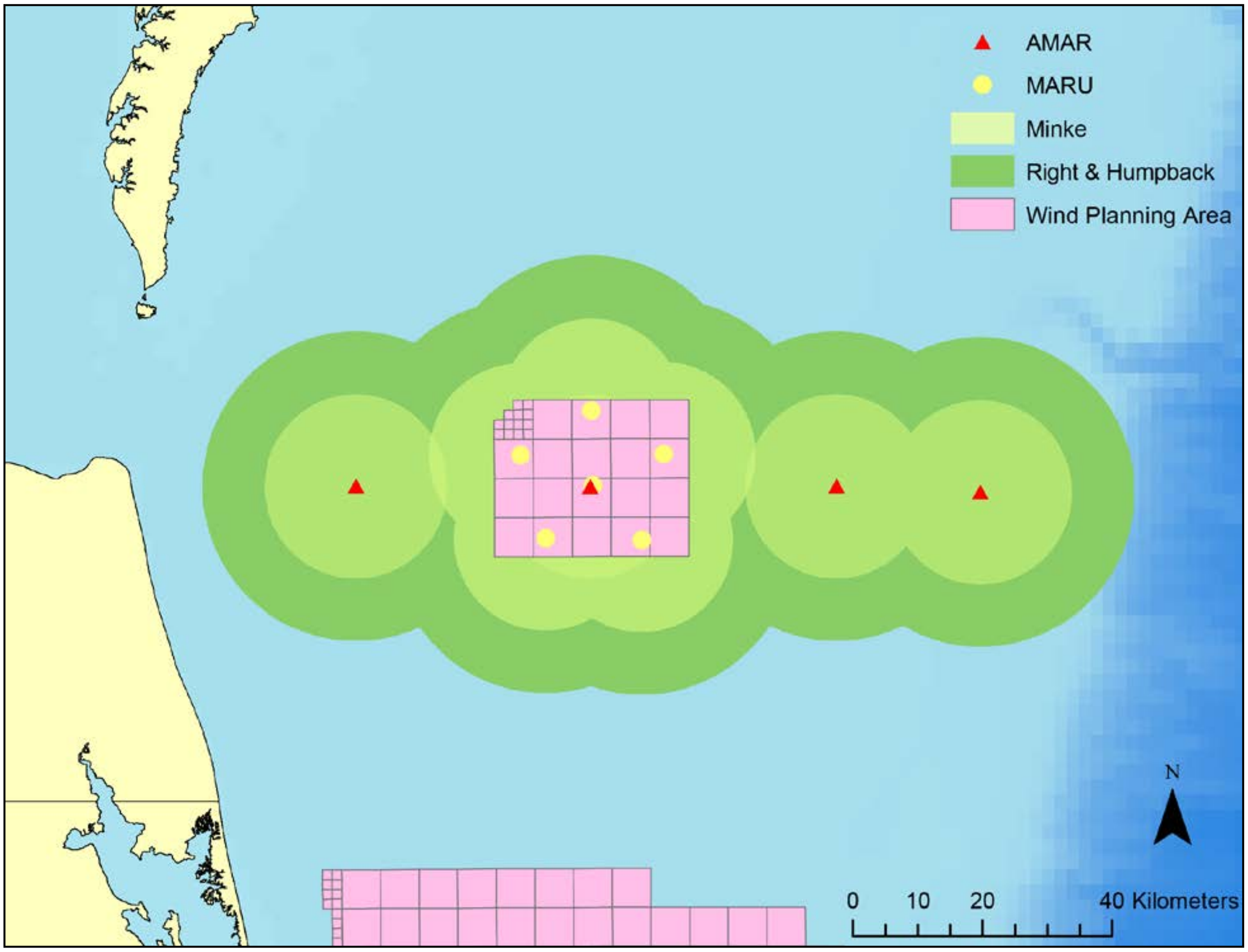

Figure 1. Locations of low-frequency (MARU, yellow circles) and high-frequency (AMAR, red triangles) recorders, indicating the wind planning area (pink) and the estimated detection ranges for minke, right, and humpback whales (green).

Table 1. AMAR deployment details.

Deployment	# of Units	Record Start	Record Stop	Recording Days	Remarks
1	4	03 Jul. 2015	23 Jan. 2016	205	N/A
2	4	08 Mar. 2016	28 Sep. 2016	205	AMAR #3 lost; presumably dragged
3a	1	21 Oct. 2016	13 May 2017	138 (A1)	AMAR #1 and 3 stopped prematurely; hardware failure
3b	3	28 Nov. 2016	13 May 2017 19 Mar. 2017	167 112 (A3)	

Table 2. AMAR deployment details.

Deployment	# of Units	Record Start	Record Stop	Recording Days	Remarks
1	4	03 Jul. 2015	23 Jan. 2016	205	N/A
2	4	08 Mar. 2016	28 Sep. 2016	205	AMAR #3 lost; presumably dragged
3a	1	21 Oct. 2016	13 May 2017	138 (A1)	AMAR #1 and 3 stopped prematurely; hardware failure
3b	3	28 Nov. 2016	13 May 2017 19 Mar. 2017	167 112 (A3)	

2. Progress to Date

2.1 Mysticete species

To date, all baleen whale analyses have been completed as well as the examination of sonar from all three deployment (**Table 3**). The first two deployments have been analyzed for odontocetes and analysis for the third deployment is expected to be completed spring 2018.

Table 3. Status of AMAR data analyses.

Deployment	Baleen Whales	Sonar	Odontocetes
1	x	x	x
2	x	x	x
3a	x	x	Ongoing
3b	x	x	Ongoing

Compiling preliminary results from analysis of all three AMAR transect deployments and historical MARU deployments from 2012 to 2015 shows seasonal and inter-annual variation in all four species of baleen whales (right, minke, fin and humpback whales). Fin whales were the most commonly detected species, while minke whales were the rarest. In addition to seasonal occurrence patterns shown in right, fin and humpback whales, inter-annual variation was present with the fall 2015–spring 2016 season showing fewer days of whale presence than the other four seasons (**Figure 2**).

The distribution of daily presence for all four whale species from the three AMAR transect deployments show differing patterns across the transect. Right whales were distributed relatively evenly, whereas minke, fin whale and humpback showed greater proportions of daily presence recorded on the farthest-offshore AMAR. The AMAR closest to shore showed the lowest presence for all whale species (**Figure 3**).

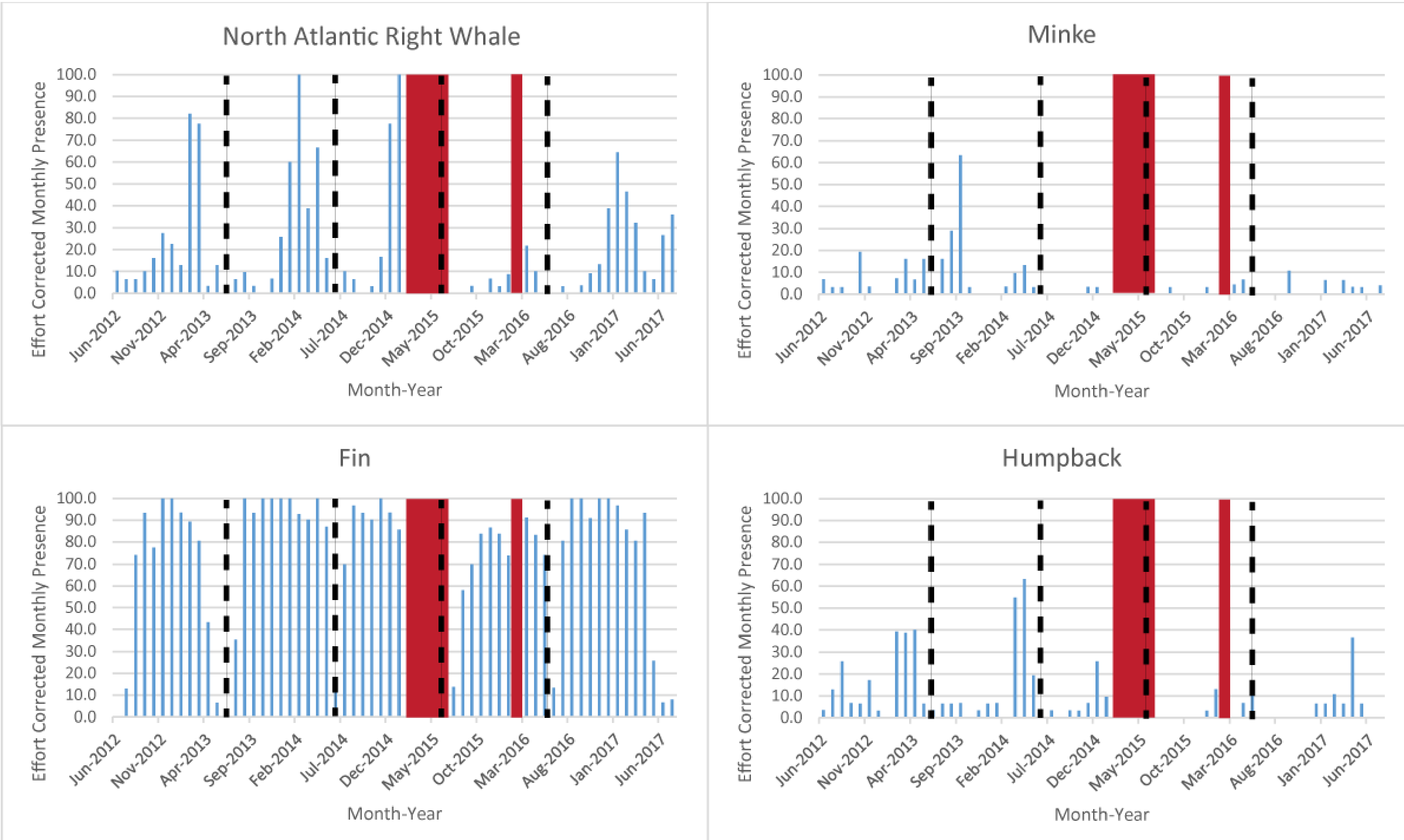

Figure 2. Average monthly presence (corrected for effort) for all four species of baleen whale from June 2012 through July 2017. The red bars show areas where no data were collected. The dotted black lines denote one year of data. Humpback whale analysis coverage was subsampled to 25 percent of days because of time and analysis constraints. Humpback presence is considered relative and cannot be directly compared to other species.

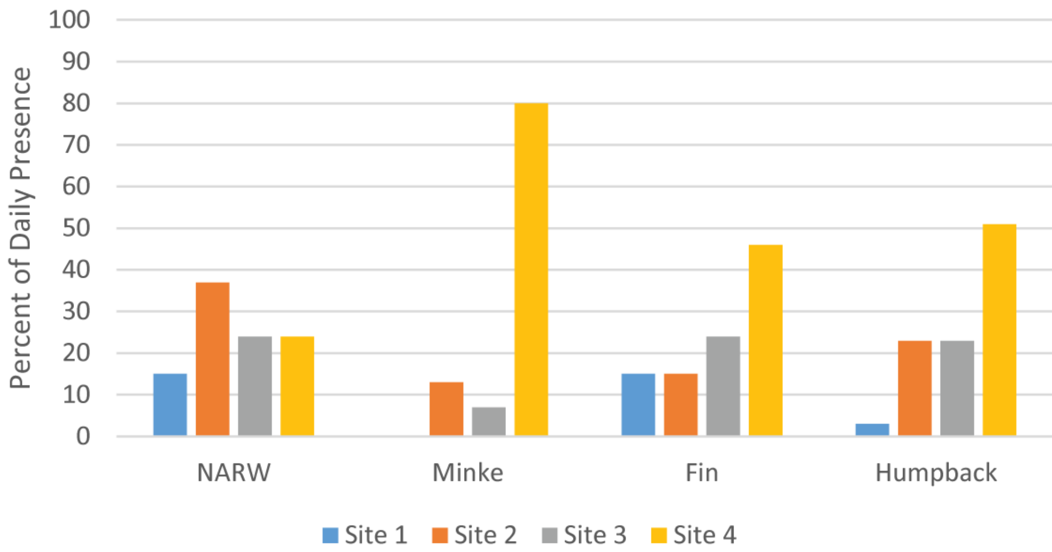

Figure 3. Percentage of all daily presence of whale occurrence displayed per species per AMAR site.

2.2 Odontocete species

The high-frequency AMAR data are collected at a sample rate of 375 kHz and a duty cycle of 86 seconds every 685 seconds (totaling in 402 seconds of data each hour). Data are analyzed as follows:

- High-Frequency (>100 kHz) odontocetes: An automated click detector was used to detect click trains of harbor porpoise (*Phocoena phocoena*) and *Kogia* species in the dataset. Every detection was visually reviewed by an analyst to confirm the detection and, if possible, to classify the signals to a species level.
- Mid-Frequency (1–100 kHz) odontocetes: Long-term spectral average plots with a temporal resolution of 5 seconds and a frequency resolution of 200 Hertz were calculated using the Triton Software Package (Scripps Whale Acoustics Lab, La Jolla, CA, USA). Data were visually and aurally inspected by experienced analysts for odontocete sounds. After initial screening, data containing odontocete whistles and clicks were analyzed using the Real-time Odontocete Call Classification Algorithm (ROCCA) software to potentially classify signals to species level. An example of an odontocete encounter is shown in **Figure 4**.

Preliminary results indicate a high number of odontocete encounters in the datasets with a clear inshore-offshore pattern in total number of encounters. Most encounters were registered in the inshore AMAR 1 dataset (**Figure 5**). Calling activity was significantly higher during the summer months and lower during the winter months. The data also suggest a diel pattern in the recorded calling activity (**Figure 6**). Recorded calling rates (percent hours with calls) significantly increased after sunset and decreased again after sunrise.

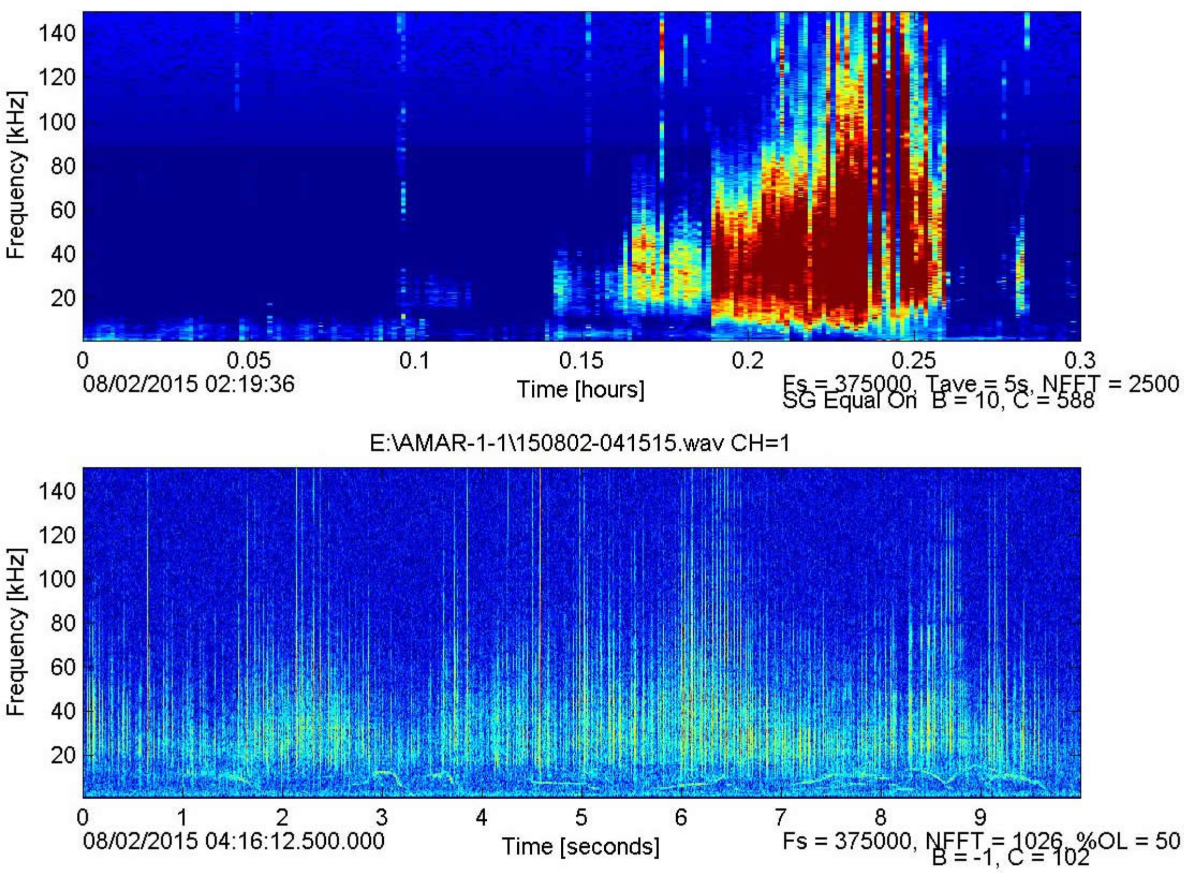

Figure 4. Long-term spectral average plot (top) indicating an odontocete encounter recorded with the inshore AMAR in August 2015. The spectrogram (bottom) shows the corresponding whistles (tonal sounds in the 10–20 kHz range) and echolocation clicks (broadband transient signals).

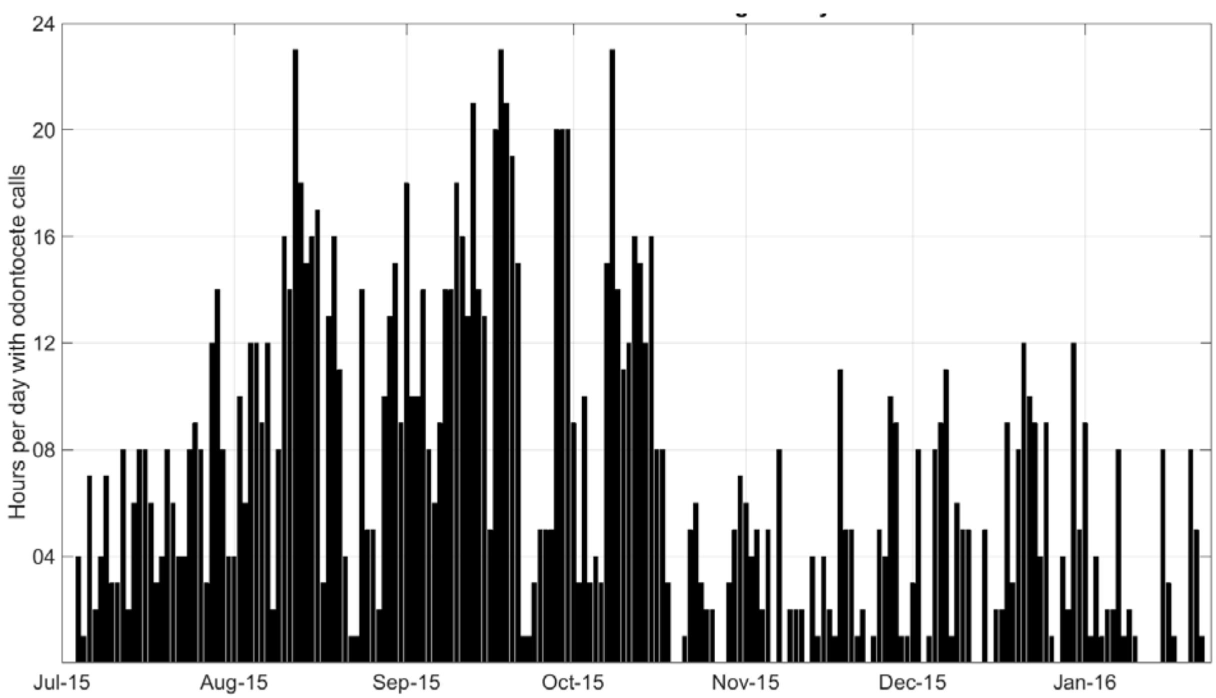

Figure 5. Time series of calling activity at AMAR 1, July 2015 to January 2016.

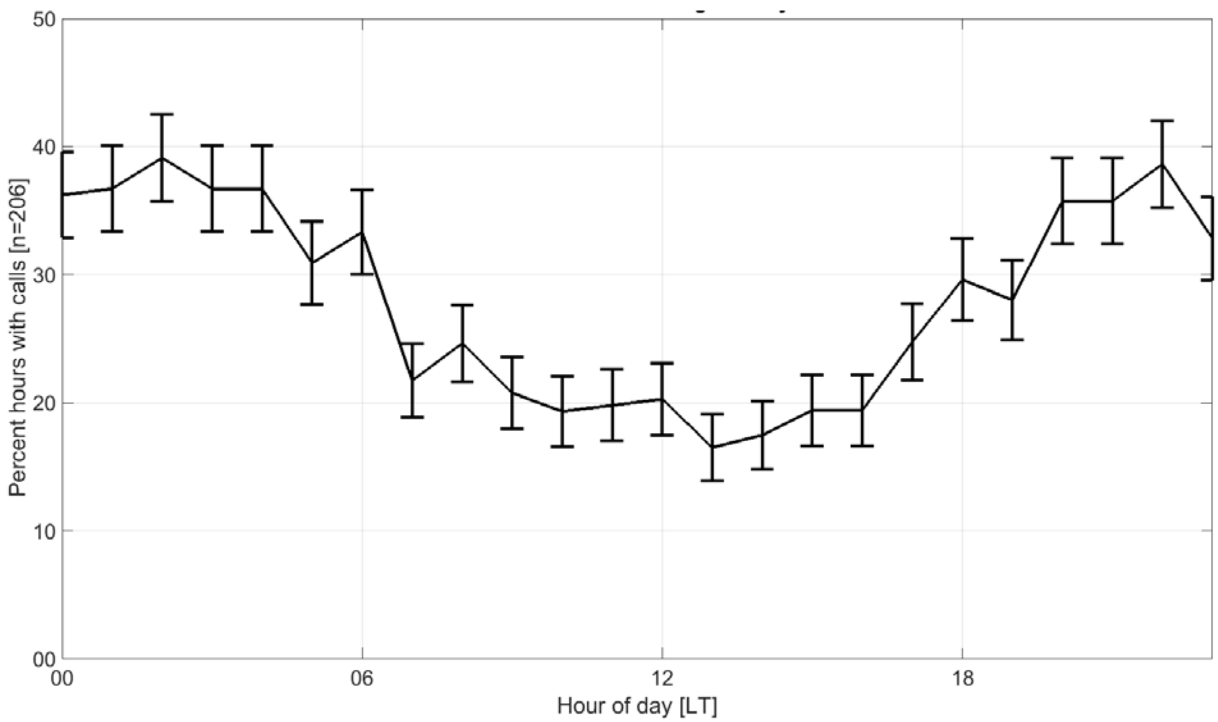

Figure 6. Diel calling activity at AMAR 1, July 2015 to January 2016.

We are currently finishing the manual odontocete analysis. We also obtained the latest version of the ROCCA classifier, which considers both signal types: clicks and whistles. We execute ROCCA though Pamguard to detect and classify odontocete encounters in all datasets. The goal is to gain insights into the odontocete species composition at each recording site. Because this analysis is slow (files are analyzed at a speed of 5–10x real-time), this analysis is ongoing. However, we should complete this analysis in early spring 2018.

2.3 Sonar analysis

A variety of sonar signals was recorded by the AMARs during the deployment (**Figure 7**).

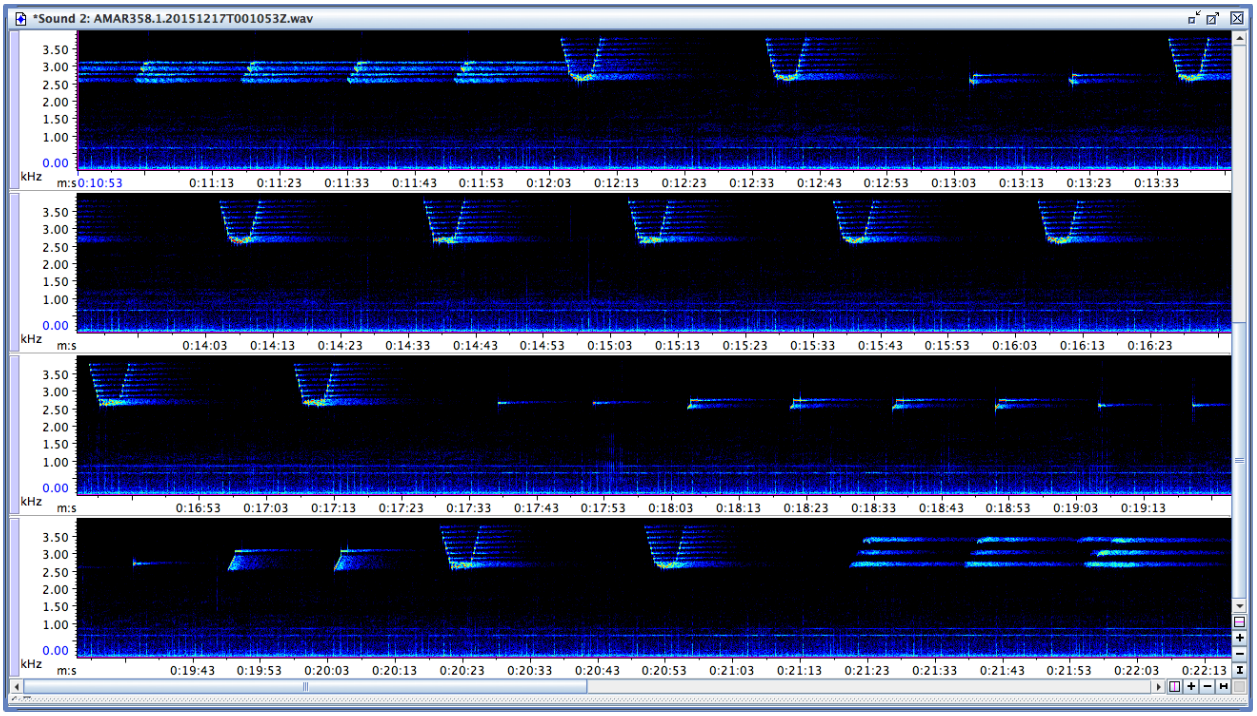

Figure 7. Example of Navy sonar signals recorded off the Virginia coast in December 2015.

A template detector was used in Raven–X (Cornell University, Ithaca, NY, USA), a MATLAB-based toolbox, to detect sonar signals in the high-frequency dataset. Data from all AMAR sites in the first 6 months of recording (deployment 1) were manually browsed and annotated for sonar events in order to evaluate the performance (precision-recall) of the template detector. Only data from AMAR 3 were used to tweak the detector and empirically assess a suitable threshold (**Table 4**). Based on this analysis, we determined that a correlation threshold between a detection and a template of >0.35 would be optimal to use for the remaining data, to significantly reduce the number of false positive detections while maintaining sufficient recall performance. The template detector was then run against AMAR sites 1, 2, and 4 to evaluate performance. The performance showed a clear inshore-offshore pattern, with more false positives occurring at site AMAR 1 (false positive rate: 3.0 detections per hour). The average recall and precision rates (AMARs 1, 2, and 4) were 0.77 and 0.20, respectively. The average false positive rate was 1.4 detections per hour. It should be noted that although not all individual sonar pings were detected, the detector did not miss any sonar bouts. The detector was run over all available datasets, and we are in the process of reviewing detections.

Table 4. Detector performance results for site A3 deployment 1 data. FP/hr represents the mean number of false positive detections per clock hour. TP Truth represents the number of sonar events that were detected, while FN Truth represents the number of true sonar events that were missed by the detector. Total Truth represents the number of true sonar events in the test dataset. FP Test represents the number of detections that did not detect a true sonar event. The row in bold italics highlights the threshold that was used for further analysis.

Threshold	Recall	Precision	FP/hr	TP Truth	FN Truth	Total Truth	FP Test
0.2	0.941	0.007	35.83	903	57	960	175494
0.25	0.906	0.018	13.42	870	90	960	65732
0.3	0.86	0.073	2.79	826	134	960	13669
0.35	***0.805***	***0.262***	***0.53***	***773***	***187***	***960***	***2597***
0.4	0.743	0.631	0.09	713	247	960	458
0.45	0.626	0.886	0.02	601	359	960	82
0.5	0.506	0.943	0.01	486	474	960	31
0.55	0.379	0.957	0	364	596	960	17
0.6	0.278	0.958	0	267	693	960	12
0.65	0.181	0.962	0	174	786	960	7
0.7	0.118	0.95	0	113	847	960	6
0.75	0.07	0.957	0	67	893	960	3
0.8	0.04	0.974	0	38	922	960	1
0.85	0.018	0.944	0	17	943	960	1
0.9	0.007	0.875	0	7	953	960	1
0.95	0.002	0.667	0	2	958	960	1

3. Future Work

Within the next few months we will complete the data analysis and prepare a draft technical report for the project. The remaining data analysis focuses on five major tasks:

- Explore correlations in environmental parameters, ambient noise, and oceanographic processes to the patterns of temporal occurrence and spatial distributions of baleen whales that we observed.
- Continue to determine the temporal occurrence and spatial distributions of vocalizing marine mammals (odontocetes and baleen whales) identified using a combination of automated call detection/classification software and expert human validation.
- Estimate spatial locations and movements of baleen whales, especially right whales, within and near the Virginia WEA, using an acoustic-localization array. For each right whale contact call recorded by three or more hydrophones, the location of the calling right whale will be estimated using software that computes the most likely location for the whale based on arrival time differences.
- Assess ambient sound levels throughout the Virginia WEA and across the continental shelf by analyzing historic and current acoustic datasets.

- Synthesize all data products to determine the potential impacts of noise generated by the construction and operation of a wind energy facility on the ecosystem.

The draft technical report will be submitted in April 2018, with the final report planned for no later than 9 August 2018. This report will cover details on the data collection, the baleen and odontocete acoustic data analysis, and derived results.