ANALYSIS OF ACOUSTIC OCCURRENCE AND ECOLOGY OF NORTH ATLANTIC SHELF BREAK SPECIES AND EFFECTS OF ANTHROPOGENIC NOISE IMPACTS

FY 2019 PROGRESS REPORT

PI's : Sofie Van Parijs & Danielle Cholewiak (Northeast Fisheries Science Center)

Collaborators: Sarah Weiss (Syracuse University), Bridget Mueller- Brennan (Northeast Fisheries Science Center), Kait Frasier, Jennifer Trickey, Simone Baumann-Pickering, John Hildebrand (Scripps Oceanographic Institute).

Introduction

Acoustically, the ocean is interconnected and sound travels great distances. Therefore, operational noise in shallow waters may displace coastal animals and drive these species offshore (e.g. North Atlantic right whales during migration), while Navy and/or oil and gas operations may displace resident shelf-break and deep- water animals from important habitats. However, shifts in distribution of animals may also occur due to ecological changes, independent of anthropogenic activities. Teasing apart the drivers of these changes can only be done through a clear, well designed project with a multi-year dataset that enables inference to be drawn before, during and eventually after operations, as well as between sites with low (controls) and high operational activity.

Acoustically sensitive species such as beaked whales, inhabit the North Atlantic shelf break region. While all ESA-listed baleen whales, such as the North Atlantic right whale (*Eubalaena glacialis),* fin (*Balaenoptera physalus)*, blue (*Balaenoptera musculus)*, and sei whales (*Balaenoptera borealis)* are known to use this area to different extents. NOAA's Northeast Fisheries Science Center and Scripps Institution of Oceanography (SIO) have been collaboratively deploying long-term high-frequency acoustic recording package (HARP) passive acoustic monitoring stations at eight sites along the western North Atlantic shelf break since 2015 in coordination with the Bureau of Ocean Energy Management (BOEM). Likewise, the US Navy has been monitoring the shelf break region at 3 to 4 sites since 2007. Together these combined efforts bring the total to 11 recording sites spanning the U.S. eastern seaboard, from New England to Georgia. Earlier HARP recorders have been analyzed (e.g. Davis et al. 2017; Stanistreet et al. 2017, 2018) and our focus in 2019 was on the 2015-2017 data, completing first pass analyses, and preparing a manuscript for publication. Data collected from 2017 to 2019, still require analysis and incorporation into the broader ecological framework.

Objectives

This work is aimed at moving the analytical component forward on a number of key scientific areas including:

1. Novel broad-scale approach to assessing acoustic niche and anthropogenic contributors
2. Seasonal and spatial occurrence of beaked whales and kogia
3. Occurrence and acoustic behavior of baleen whales
4. Anthropogenic drivers of distribution – identifying sonar, seismic and echo-sounder sources and assessing their potential impacts on species.

Acoustic Data Collection

Continuous passive acoustic recordings were collected along the continental shelf break of the northeastern United States at three sites beginning in 2015 and subsequently expanded to eight sites in 2016, mostly named according to nearby canyon features. These include: Heezen Canyon, Oceanographer Canyon, and Nantucket Canyon for the first set of three deployments and additionally include: Wilmington Canyon, Gulf stream, Babylon Canyon, Black Spur and Black Plateau (**Figure 1**). HARPs were deployed at depths of 800-1100 m, with the hydrophones suspended approximately 20 m above the seafloor. Recordings lasted from 27 June 2015 to 25 March 2016 at Heezen Canyon, 26 April 2015 to 9 February 2016 at Oceanographer Canyon, and from 27 April to 18 September 2015 at Nantucket Canyon (**Table 1**). The next round of recordings ran from late April 2016 to June 2017 (see **Table 2**).

Each HARP was programmed to record continuously at a sampling rate of 200 kHz with 16-bit quantization, providing an effective recording bandwidth from 0.01-100 kHz. HARPs include a hydrophone comprised of two types of transducers: a low-frequency (< 2 kHz) stage utilizing Benthos AQ-1 transducers (frequency response -187 dB re: 1V/µPa, ± 1.5 dB, www.benthos.com), and a high-frequency stage (> 2 kHz) utilizing an ITC-1042 hydrophone (International Transducer Corporation, frequency response -200 dB re: 1V/µPa, ±2dB), connected to a custom built preamplifier board and bandpass filter. Further details of HARP design are described in Wiggins and Hildebrand, 2007.

Figure 1. HARP deployment sites for data collected from 2015 through 2017.

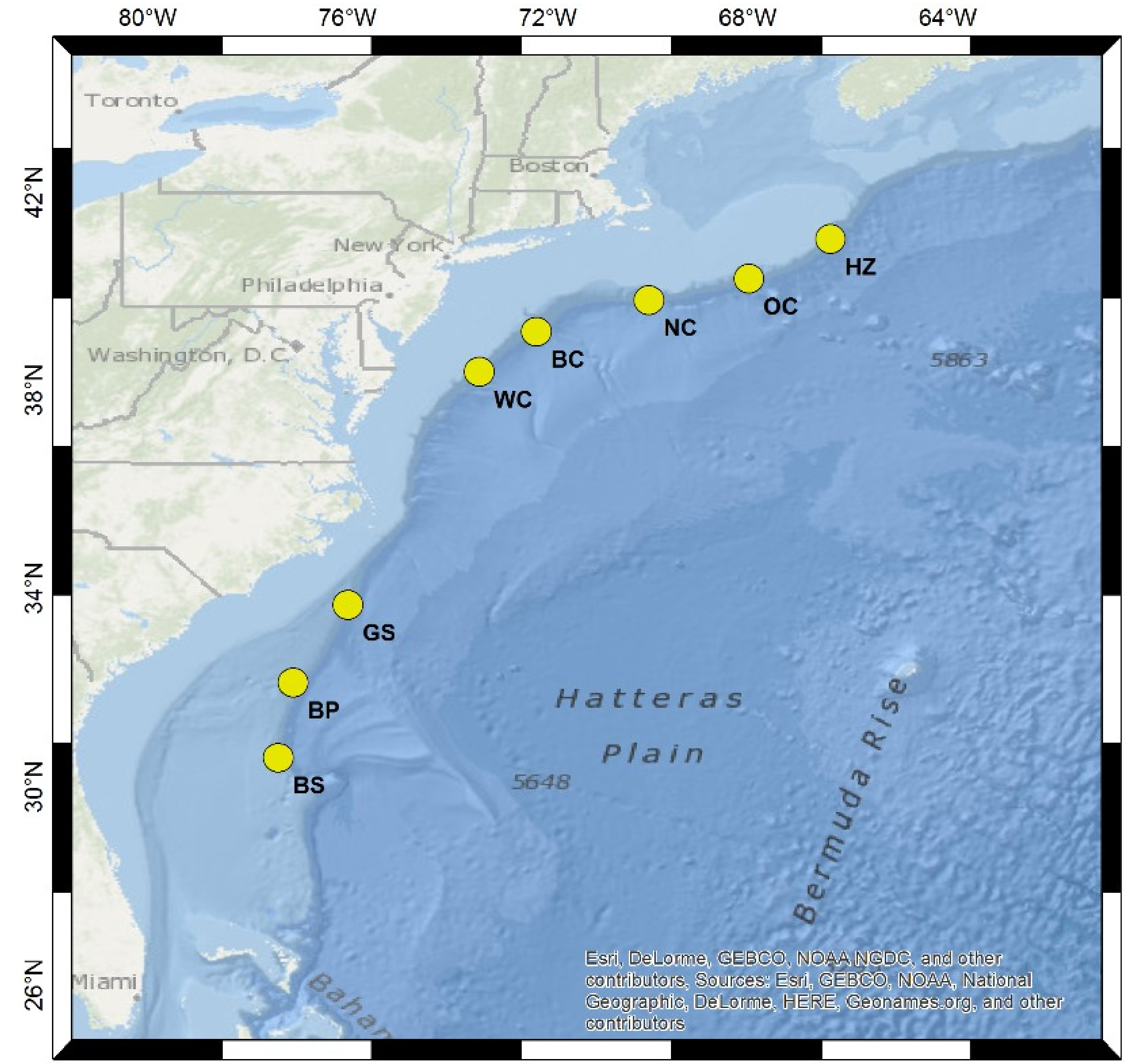

Table 2. HARP deployment sites, recording dates and recording durations for 2015-2016. All HARPs recorded continuously at a sampling rate of 200 kHz. The first and last day of each deployment represent partial recording days.

Site	Location (Lat/Lon)	Recorder Depth (m)	Recording Start Date	Recording End Date	Recording Duration (Days/Hours)
Heezen Canyon (HZ)	41.062, -66.352	845	06/27/2015	03/25/2016	273/6511
Oceanographer Canyon (OC)	40.263, -67.986	1100	04/26/2015	02/09/2016	290/6941
Nantucket Canyon (NC)	39.832, -69.982	977	04/27/2015	09/18/2015	145/3473

Table 2. HARP deployment sites, recording dates and recording durations for 2016-2017. All HARPs recorded continuously at a sampling rate of 200 kHz. The first and last day of each deployment represent partial recording days. Exact recording hours still need to be calculated because there were a number of errors that occurred during this deployment that required fixes to be made at SIO, therefore at this point data gaps still remain to be evaluated.

Site	Location (Lat/Lon)	Recorder Depth (m)	Recording Start Date	Recording End Date	Recording Duration (Days)
Heezen Canyon (HZ)	41.044N, 66.349W	845	04/22/2016	06/19/2017	423
Oceanographer Canyon (OC)	40.263N, 67.986W	1000	04/24/2016	05/18/2017	389
Nantucket Canyon (NC)	39.832N, 69.982W	977	04/21/2016	05/24/2017	398
Babylon Canyon (BC)	39.491N, 71.899W	1000	04/20/2016	06/10/2017	416
Wilmington Canyon (WC)	38.421N, 73.318W	1000	04/20/2016	06/29/2017	435
Gulf Stream (GS)	33.719N, 75.929W	954	04/29/2016	06/26/2017	423
Blake Plateau (BP)	32.248N, 76.919W	945	04/28/2016	06/26/2017	424
Blake Spur (BS)	30.817N, 77.465W	1005	04/23/2016	06/10/2017	413

Acoustic Data Analyses

Sound files were divided into three separate data sets to facilitate analyses based on the following frequency bands: (1) Low-frequency, 10-1000 Hz; (2) Mid-frequency, 10-5000 Hz; and (3) High-frequency, 1000-100,000 Hz. For the low-frequency band, the acoustic data were down-sampled by a factor of 100 to create sound files with an effective sampling rate of 2 kHz. For the mid-frequency band, sound files were down-sampled by a factor of 20 to create sound files with an effective sampling rate of 10 kHz.

<u>Mysticetes Acoustic Analysis</u>

The low-frequency acoustic data sets for all sites were used to extract the presence of five mysticete species: blue (*Balaenoptera musculus*), fin (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*), North Atlantic right (NARW) (*Eubalaena glacialis*), and sei whales (*Balaenoptera borealis*).

An automated detector, the Low-Frequency Detection and Classification System (LFDCS), was used to identify and distinguish species-specific vocalizations. Our call library included the following species-specific vocalizations obtained from acoustic data collected in our region: blue, fin, North Atlantic right and humpback whales. Further details on the LFDCS are described in Davis et al., 2017.

The LFDCS outputs were manually reviewed by a trained analyst. Species presence was determined on a daily scale, in which a species was considered "present" on a given day if the number of verified true pitch-tracked detections met or exceeded minimum criteria established for each species.

<u>Odontocete Acoustic Analysis</u>

The high-frequency acoustic data sets were used to extract the presence of echolocation clicks from 20 potential odontocete species. These include six beaked whale species: (Blainville's beaked whales (*Mesoplodon densirostris*), Cuvier's beaked whale (*Ziphius cavirostris*), Gervais'/True's beaked whale (*Mesoplodon europaeus*/*Mesoplodon mirus* respectively), Northern bottlenose whales (*Hyperoodon ampullatus*), and Sowerby's beaked whale (*Mesoplodon bidens*)), as well as sperm whales (*Physeter macrocephalus*) and *Kogia* spp. At least 12 delphinid species may also occur in the region, including: (Atlantic spotted dolphins (*Stenella frontalis*), Atlantic white-sided dolphins (*Lagenorhynchus acutus*), bottlenose dolphins (*Tursiops truncatus*), Clymene dolphins (*Stenella clymene*), Risso's dolphins (*Grampus griseus*), rough-toothed dolphins (*Steno brendanensis*), short-beaked common dolphins (*Delphinus delphis*), striped dolphins (*Stenella coeruleoalba*), false killer whales (*Pseudorca crassidens*), killer whales (*Orcinus orca*), long-finned pilot whales (*Globicephala melas*), and short-finned pilot whales (*Globicephala macrorhynchus*)). However, it is not yet possible to reliably differentiate between all delphinid species based on acoustic characteristics. Therefore, for the purpose of this study, delphinids were treated as a single group and were not differentiated by species.

The acoustic presence of each species was determined using a combination of manual review and automated detectors. Using the custom software program Triton based in MATLAB (Mathworks, Natick, MA), long-term spectral averages (LTSAs) were calculated with a time average of 5 seconds and 10 Hz and 100 Hz, and were manually reviewed for echolocation clicks by trained analysts. As described below, species-specific spectral and temporal characteristics of echolocation clicks were used to determine call type classification and determine presence on a daily scale. Following similar methods to those described in Baumann-Pickering et al., 2013. Detections were classified to species except in the case of Gervais' and True's beaked whales, where overlap in the frequency characteristics of their echolocation clicks currently precludes definitive differentiation between the two species in the absence of visual data. The acoustic presence of sperm whales was determined by a trained analyst's manual verification of the LTSA, based on known species-specific characteristic frequency and temporal attributes.

The presence of dwarf and pygmy sperm whales (*Kogia* spp.) was determined using an automated detector to identify clicks with energy between 70-100 kHz but not below (to differentiate them from delphinids). All detected click bouts were manually reviewed and classified based on spectral characteristics. Although *Kogia* spp. echolocation clicks have peak frequencies near 130 kHz, energy from their clicks is evident in HARP data below 100 kHz, likely due to either a low-frequency tail in the click spectra or from aliasing above the Nyquist frequency of 100 kHz. Delphinid echolocation click occurrence was determined using an automated energy detector with a minimum received level threshold of 120 dB_{pp} re: 1 µPa.

Anthropogenic Acoustic Analysis

The HARP data were examined for the presence of four types of anthropogenic signals: broadband ship sounds, airguns, explosions, and echosounders. The mid-frequency dataset was examined for the presence of the first three signal types; the high-frequency dataset was examined for the presence of echosounders. As with the analyses of cetacean signals, analyses of anthropogenic noise incorporated a combination of automated detectors and manual review, using Triton software (Version 1.93) within the program Matlab (R20141; MathWorks, Inc., Natick, MA). The beginning and end of each acoustic event was estimated; if any given activity was detected on a day, then the activity was considered “present” for the daily presence analysis.

Broadband ship sound is typically detectable when a ship travels within a few kilometers of an acoustic recording device. These acoustic events may last from several minutes up to several hours, depending on the size of the vessel and distance to the recorder. Vessel occurrence was manually detected by a trained analyst reviewing LTSAs in three hour time bins, looking for characteristic frequency-range dependent interference patterns that are associated with ship noise acoustics.

Airguns are used regularly in seismic exploration, lasting from several hours to days, with most energy between 10 Hz and 250 Hz. The presence of airguns was automatically determined using a matched filter detector, where the timeseries was filtered with a 10^{th} order Butterworth bandpass filter between 25 and 200 Hz. A trained analyst then manually verified these airgun detections based on accurate interpulse intervals.

The presence of explosive sounds from sources such as military explosions, sub-seafloor exploration, and fishing industry seal bombs was detected in the acoustic data by a similar automatic matched filter detector with a timeseries filtered with a 10^{th} order Butterworth bandpass filter between 200 and 2000 Hz. A trained analyst then manually verified these detections for the presence of explosions.

Echosounders are used for a variety of purposes, including navigation, seafloor mapping, and detection of fish schools. The acoustic presence of echosounders was determined by a trained analyst manually scanning the LTSA plots in one-hour time bins. All echosounder events were then reviewed by a second trained analyst to determine the peak frequency(s) of each detected event. If multiple frequencies were observed in a single event, each peak frequency was treated independently and included in the analysis. Echosounder detections were divided into three frequency bands: (1) Low-frequency, <2 kHz; (2) Mid-frequency, 2-5 kHz; and (3) > 5 kHz, following designations by Rafter et al., (2018).

Data Summary and Visualization

Acoustic signals were grouped into 14 categories according to primary frequency bands, which include five mysticete and five odontocete categories, as well as four anthropogenic signals. Northern bottlenose whales and Blainville's beaked whales were never detected in our datasets, so they are not included in the frequency delineations. For each signal type, the overall frequency range and daily occurrence of that signal were graphed with spectrographic box displays (SBDs). Data visualizations were created using the software package R (version 3.5.1) and the library *tidyverse*. These "acoustic niche" displays were created for each site on a daily presence scale, over the entire recording period for that site, allowing for visualization of the temporal and spectral overlap between different biological species groups and anthropogenic activities.

Detailed acoustic niche results are presented here for the three sites monitored in 2015 – 2016, while an overview of these results are presented for all 8 sites for 2016 – 2017 data. Further review is still needed to assure ourselves of the accuracy of the 2016 – 2017 sites, in particular when it comes to the beaked whale species identification, so these figures should be taken as preliminary representations of the species present at these sites.

Results (2015 – 2016)

The HARP deployments at Heezen Canyon (HZ) and Oceanographer Canyon (OC), lasted for approximately 10 months, the former from June 27, 2015 to March 25 2016 (n= 273 days) and the latter from April 26, 2015 to February 9, 2016 (n= 290 days) (**Table 1**). The deployment at Nantucket Canyon (NC) lasted for 5 months, from April 27, 2015 to September 18, 2015 (**Table 1**). The reduced recording period for this deployment resulted from a hardware issue impacting the available data storage on the HARP.

Heezen Canyon

At the eastern most site, HZ, four mysticetes species were acoustically detected (**Figure 2**). Blue whales were present across six months from September to February, on a total of 14.3% (n=39) of days across the entire recording period. Fin whales were much more commonly detected, on 67.0% (n=183) of days throughout the recording period. In contrast, humpback whale presence was even shorter, being detected over three months from September to December, on 8.4% (n=23) of days across the entire recording period. Sei whale detections were present primarily across four months from October through February, on 21.6% (n=59) of days throughout the recording period. North Atlantic right whales were not acoustically detected at this site.

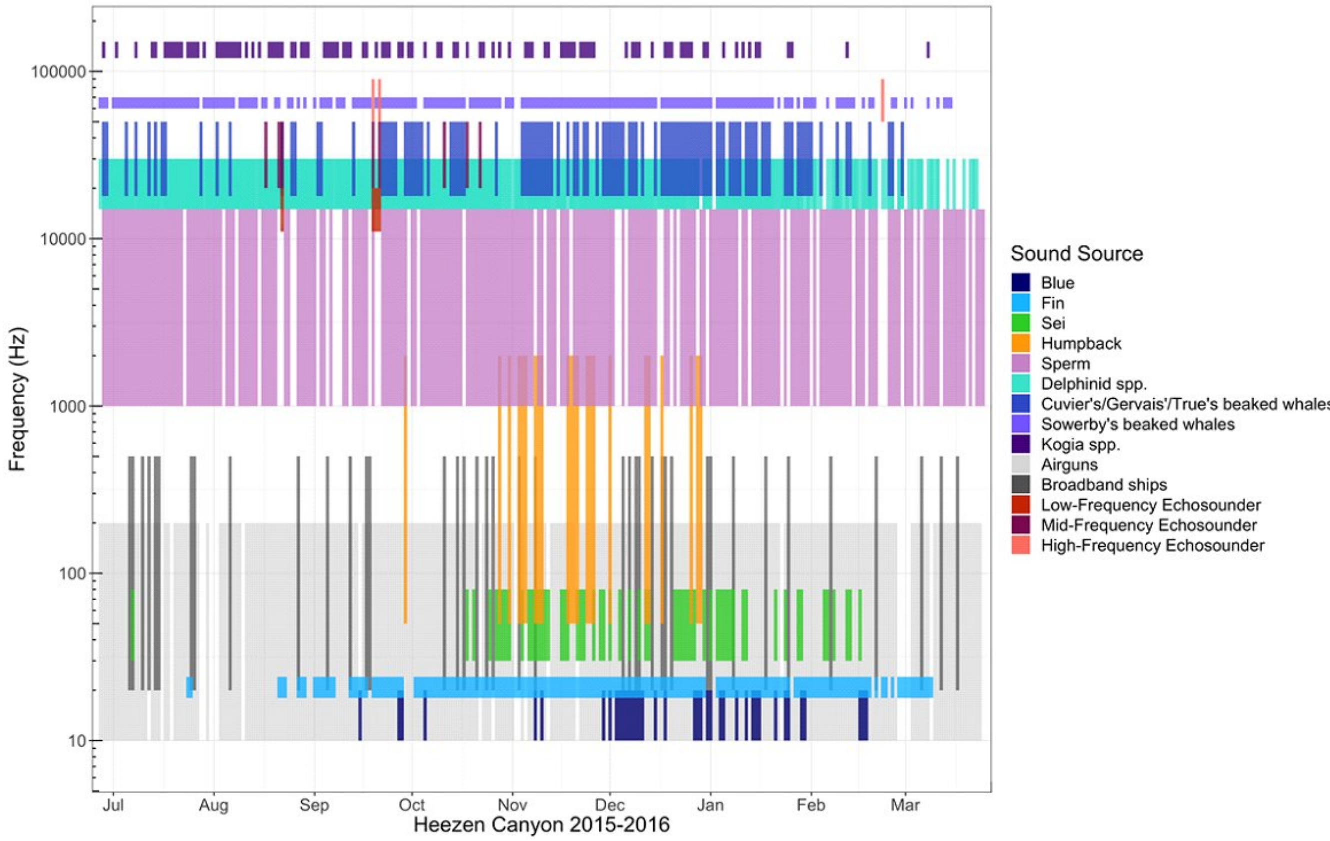

Figure 2. Spectrographic Box Display for Heezen Canyon. The frequency range and time period is designated by a separate color for each acoustically active species or sound source, highlighting the acoustic niches utilized by a variety of cetacean groups concurrent with anthropogenic activities. Over the 10-month deployment, airgun noise, Delphinid spp., sperm whales, fin whales, and Sowerby's beaked whales were the most frequently detected sound sources.

The presence of all five odontocete categories were detected based on their echolocation clicks: Cuvier's/Gervais' /True's beaked whale, Sowerby's beaked whale, sperm whales, *Kogia* spp., and Delphinid species (**Figure 2**). Beaked whale detections were present across all seasons in the deployment, with Cuvier's/Gervais'/True's species detected on 40.3% (n=110) of all recording days and Sowerby's detected nearly ubiquitously, occurring on 80.2% (n=211) of all recording days. Sperm whales and delphinids were nearly ubiquitous across the recording period, detected on 81.3% (n=222), and 94.5% of days (n=258), respectively. *Kogia* spp. were detected on 38.5% (n=105) of days across all months of the recording period.

Three sources of anthropogenic sounds were detected at this site throughout the deployment (**Figure 2**). Airgun signals were nearly ubiquitous, detected throughout all months on 91.2% (n=249) of days. Broadband ship activity was present intermittently across all months, detected on 14.7% of days (n=40). Echosounder presence was sparse across frequencies, with low-frequency echosounders detected in August and September on only 1.5% (n=4) of days, mid-frequency echosounders detected across three months from August to October on 2.9% (n=8) of days, and high-frequency echosounders detected only in September and February, on 1.1% (n=3) of days. Underwater explosions were not detected at this site.

When considering the overlap between cetaceans and anthropogenic noise, the most frequent source of overlap was from airguns, which co-occurred with the presence of mysticetes more than 85% of the time at this site. Airguns were acoustically detectable on 97.4 % (n=38) when blue whales were acoustically present, 92.3% (n=169) when fin whales were acoustically present, on 87.0 of days (n=20) in which humpback whales were acoustically present, and on 96.6% (n=57) when sei whales were acoustically present. Broadband ship noise co-occurred with mysticete presence less often overall, with broadband ships detected on 23.1% (n=9) of days when blue whales were acoustically present, on 14.8% (n=27) of days when fin whales were acoustically present, on 13.0% (n=3) of days when humpback whales were acoustically present, and on 10.2% (n=6) of days when sei whales were acoustically present.

At HZ, overlap between echosounders and four odontocete species or species groups was also observed. Low-frequency and mid-frequency echosounders were each detected on 0.9% (n=1) when Cuvier's/Gervais'/True's beaked whales were present, and on 1.5% (n=4) and 3.1% (n=8) days, respectively, when delphinids were present. Finally, overlap between low-frequency echosounders and sperm whales was found to occur on 0.5% (n=1) of days with detected sperm whale presence. Of the 3 days where high-frequency echosounders were detected, overlap was found to occur on 0.5% (n=1) days with detected Sowerby's presence.

Oceanographer Canyon

At OC, all five mysticete species were acoustically detected (**Figure 3**). Blue whales were acoustically detected over three months from December-February, on a total of 4.5% (n=13) of days throughout the recording period. Fin whales were detected on 45.9% (n=133) of days, primarily from August to February. Humpback whale presence was detected on 8.6% (n=25) of days with most detections occurring over a three-month period from April-June, with sporadic presence detected in

August and from November to January. North Atlantic right whales were detected over three months from May to July, on 3.4% (n=10) of days throughout the recording period. Sei whale detections were present over three months from April-June and across a four-month period from September to February on 24.1% (n=70) of days throughout the recording period.

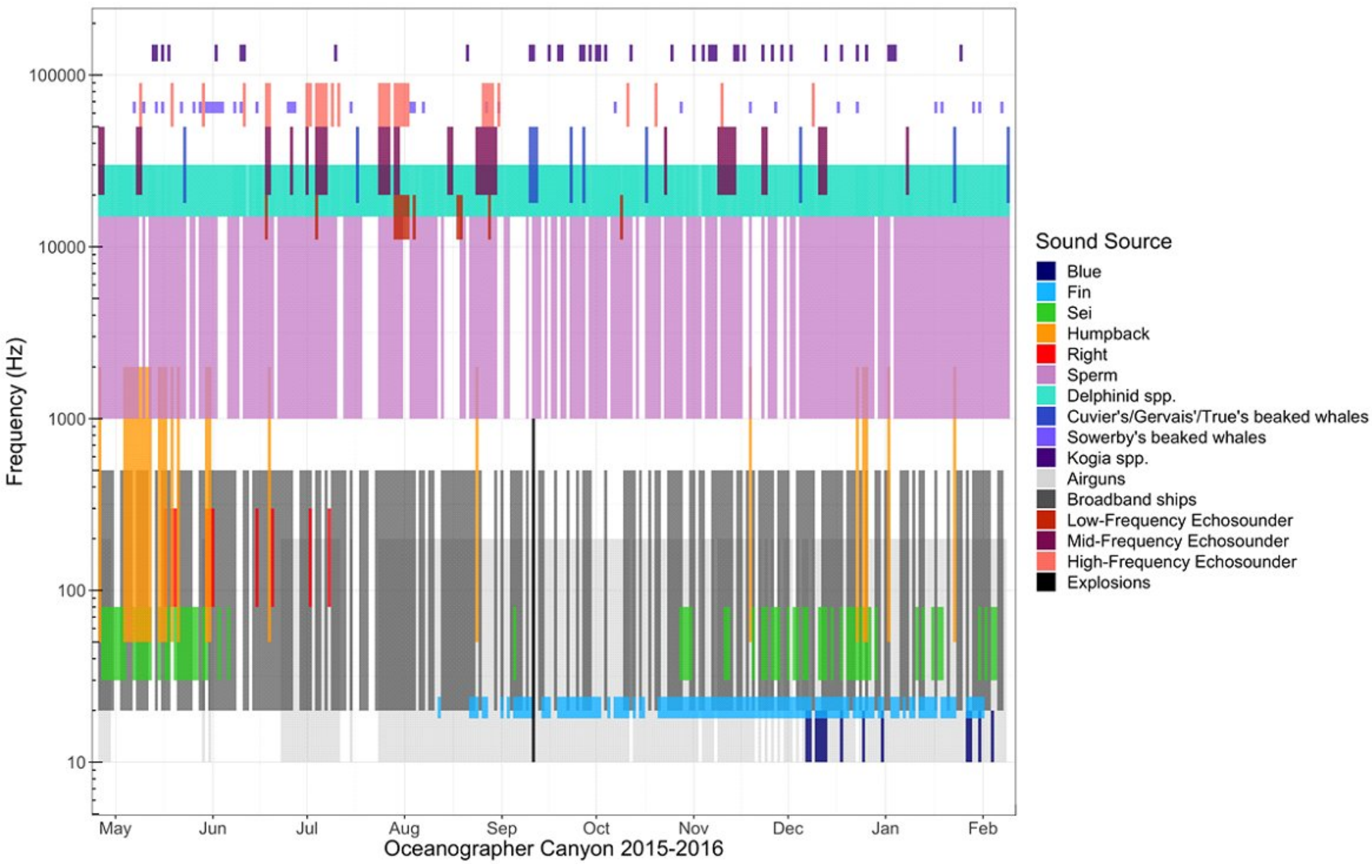

Figure 3. Spectrographic Box Display for Oceanographer Canyon. The frequency range and time period is designated by a separate color for each acoustically active species or sound source, highlighting the acoustic niches utilized by a variety of cetacean groups concurrent with anthropogenic activities. Over the 5-month deployment, airgun noise, broadband ship noise, Delphinid spp., sperm whales, and Kogia spp., were the most frequently detected sound sources.

Similar to HZ, the presence of all five odontocete categories were detected from echolocation clicks. These include: Cuvier's/Gervais' /True's beaked whales, Sowerby's beaked whales, sperm whales, *Kogia* spp., and Delphinid spp. (**Figure 3**). Overall, beaked whale detections were sparse, with Cuvier's/Gervais'/True's species detected on only 4.0% (n=11) of days throughout the recording period, peaking in September and occurring across six additional months in May, July, October, and December through February. Sowerby's beaked whales were detected across nine months from May to August and

October to February on 12.9% (n=36) of days throughout the recording period. Peak detections of Sowerby's occurred during the summer season. In contrast, sperm whales were nearly ubiquitous across the recording period, detected on over 80.3% (n=232) of days, and delphinids were present on every day throughout the recording period (n=290). *Kogia* spp. were detected on 14.5% (n=42) of days across the recording period from May to January.

Four sources of anthropogenic sounds were detected at this site throughout the recording period **(Figure 3**). Broadband ship activity was present across all months, detected on 65.1% (n=188) of days throughout the recording period. Nearly ubiquitous airgun presence was detected across all months, on 73.7% (n=213) of days throughout the recording period. Occurring intermittently throughout the recording period, low-frequency, mid-frequency echosounders, and high-frequency echosounders were detected on 4.1%(n=12), 13.8%(n=40), and 11.0% (n=32) of days throughout the recording period respectively. Mid-frequency echosounders were observed most frequently, detected across nine months from April to August and October to January. One explosion was detected at this site in September.

At OC, two sources of anthropogenic sound (broadband ship noise and airguns) were found to overlap with five species of mysticetes (blue, fin, humpback, NARW, and sei whales). Similar to HZ, airgun noise was the most frequently detected anthropogenic signal and source of overlap across species. Airguns were acoustically detected on 84.6% (n=11) of days when blue whales were acoustically present, 91.0% (n=121) of days when fin whales were acoustically present, 28.0% (n=7) of days when humpback whales were acoustically present, on 30.0% (n=3) of days when NARW were acoustically present, and 57.1% (n=40) of days when sei whales were acoustically present. Broadband ship noise was also found to co-occur with mysticete presence with broadband ships detected on 53.8% (n=7) of days when blue whales were acoustically present, 57.1% (n=76) of days when fin whales were acoustically present, 60.0% (n=15) of days when humpback whales were acoustically present, 60% (n=6) of days when NARW were acoustically present, and 67.1% (n=70) of days when sei whales were acoustically present. In addition, overlap between fin whales and explosions was observed on 0.8% (n=1) of days when fin whales were acoustically present.

At OC, overlap between three odontocete species or species group and echosounders was also observed. Low-frequency echosounders were detected on 4.1% (n=12) when Delphinid spp. were acoustically present, and on 3.9% (n=9) of days when sperm whales were acoustically present. Additionally, mid-frequency echosounders were detected on 13.8 (n=40) of days when Delphinid spp.

were acoustically present. Overlap with high-frequency echosounders was found to only occur with Sowerby's, on 5.6% (n=2) days when Sowerby's were acoustically present.

Nantucket Canyon

Four baleen whale species were acoustically detected at NC during the five-month recording period (**Figure 4**). Fin whale detections occurred primarily from July to September on 17.9% (n=26) of days throughout the recording period. Humpback whales were detected over three months from April to June, on 14.5% (n=21) of days throughout the recording period. North Atlantic right whale presence was sparse, only detected in May, on a total of 2.1% (n=3) of days throughout the recording period. Sei whale detections were also present from April to June, on 11.0% (n=16) of days throughout the recording period. Blue whales were not acoustically detected at this site.

The presence of all five odontocete categories was detected from echolocation clicks: Cuvier's /Gervais'/True's beaked whales, Sowerby's beaked whales, sperm whales, *Kogia* spp., and Delphinid spp. (Figure 4). Beaked whale detections from Cuvier's/Gervais'/True's species were present across nearly all months over the recording period, detected on 27.6% (n=34) of days throughout the recording period. Sowerby's presence was detected intermittently, on 12.2% (n=15) of days throughout the recording period. Sperm whales were nearly ubiquitous across the recording period, detected on 72.4% (n=105) of days throughout the recording period. Delphinid spp. were present on every day throughout the recording period (n=145). *Kogia* spp. were detected on 40.1% (n=59) of days throughout the recording period.

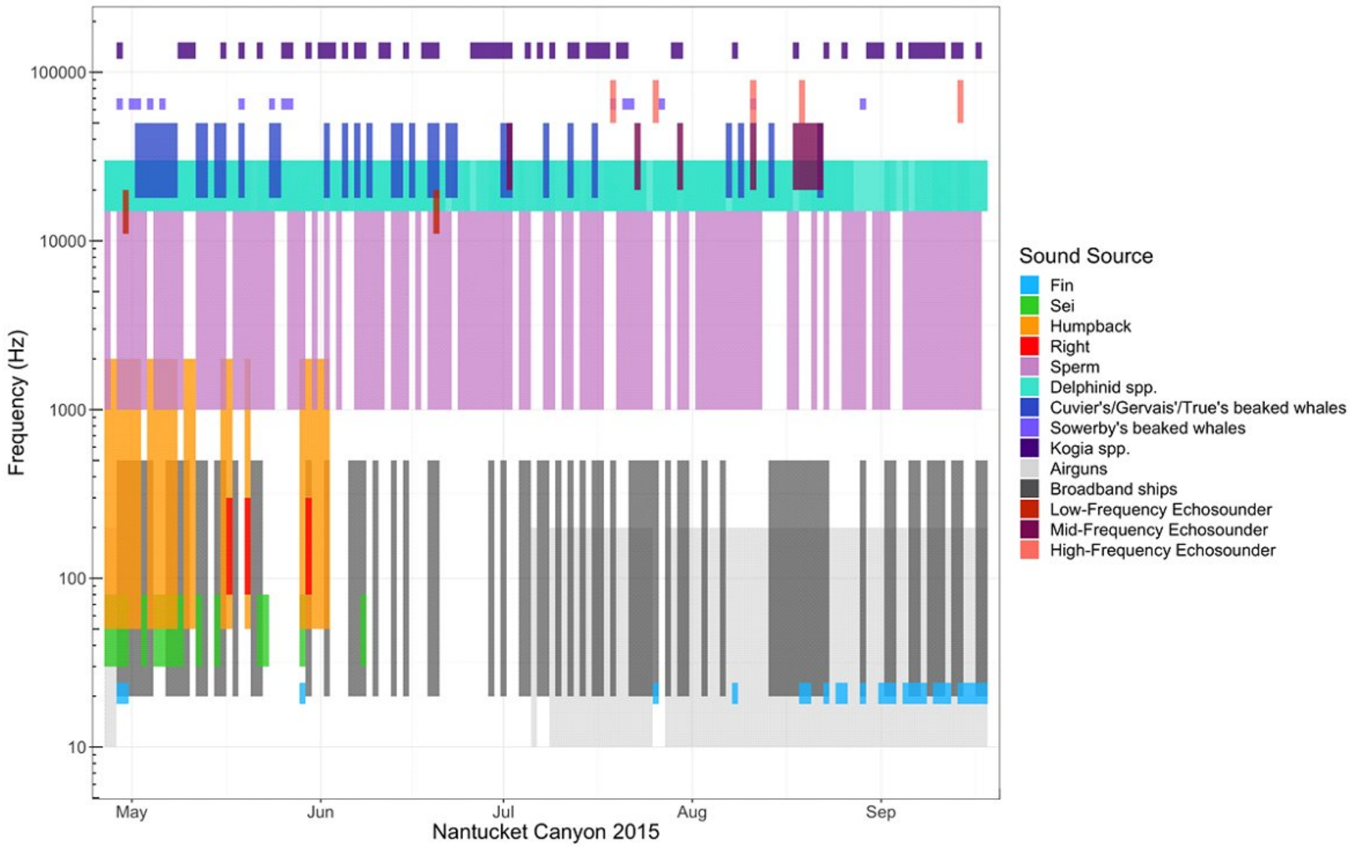

Figure 4. Spectrographic Box Display for Nantucket Canyon. The frequency range and time period is designated by a separate color for each acoustically active species or sound source, highlighting the acoustic niches utilized by a variety of cetacean groups concurrent with anthropogenic activities. Over the 10-month deployment, broadband ship noise, airgun noise, Delphinid spp., sperm whales, and fin whales, were the most frequently detected sound sources. This site showed a marked decrease in the presence of Sowerby's and Cuvier's/Gervais'/True's beaked whales, as well as *Kogia* spp.

Three sources of anthropogenic sounds were detected at this site throughout the recording period (**Figure 4**). Broadband ship activity was present across all months, detected on 48.6% (n=70) of days throughout the recording period. Nearly ubiquitous airgun presence was detected across three months from July through September, present on 50.3% (n=73) of days throughout the recording period. In comparison, echosounder presence was sparse across frequencies, with low-frequency echosounders detected on only 1.4% (n=2) of days, mid-frequency echosounders detected on 6.2% (n=9) of days, and high-frequency echosounders detected on 3.4% (n=5) of days throughout the recording period. There was no detected presence of explosions at this site.

Similar to HZ, two sources of anthropogenic noise (broadband ships and airguns) were found to overlap with four species of mysticetes (fin, humpback, NARW, and sei whales) at NC. The greatest percentage of overlap was found to occur between fin whales and airgun noise, as airgun noise was detected on 84.6% (n= 22) of days when fin whales were acoustically present. Additionally, airgun noise was detected on 9.5% (n=2) of days when humpback whales were acoustically present and on 12.5% (n=2) of days when sei whales were acoustically present. No overlap was found between NARW and airgun noise. Broadband ship noise similarly served as a common source of overlap with mysticete species, occurring on 61.5% (n=16) of days when fin whales were acoustically present, 52.4% (n=11) of days when humpback whales were acoustically present, 33.3% (n=1) of days when NARW were acoustically present, and 62.5% (n=10) of days when sei whales were acoustically present.

In addition, overlap between four odontocete species or species group and echosounders was also observed at NC. Low-frequency echosounders were found to occur on 2.9% (n=1) of days when Cuvier's/Gervais'/True's species were acoustically present, 1.4% (n=2) of days when Delphinid spp. were acoustically present, and on 1.9% (n=2) of days when sperm whales were acoustically present. Similarly, mid-frequency echosounders were detected on 5.9% (n=2) of days when Cuvier's/Gervais'/True's species were acoustically present, and on 6.2% (n=9) of days when Delphinid spp. were acoustically present. As seen at both HZ and OC, the only overlap with high-frequency echosounders was observed with Sowerby's, occurring on 13.3% (n=2) of days when Sowerby's were acoustically present.

Results (2016 – 2017)

During this deployment, 8 HARPs were deployed (**Table 2**), ranging from the shortest recording in Oceanographer's Canyon (OC) which was 13 months to Wilmington Canyon (WC) with the longest with 14 ½ months of data. Preliminary spectral plots of the species and anthropogenic sources presence were created for all 8 sites. Although, the species detections for beaked whales still need to be fine-tuned and checked for species accuracy, it is clear that there is considerable variation between all sites (**Figure 5**). The 6 northern most sites are heavily dominated by sperm whales compared to the 2 sites off the Blake Plateau to the south of them. Humpback whales were dominant across the 5 northern most sites with fin whales seasonally present in the same recordings. Blue whales were more sporadic across recordings with right whales showing brief appearances in Heezen, Babylon and Wilmington canyons. Delphinids dominated the northern most sites with beaked whale species showing species differences across sites (however, final species ID needs to be checked). Airguns and broad band ships dominate the anthropogenic presence for all 8 sites, with Babylon and Wilmington Canyons showing heavier ship traffic compared to the other sites. Further more detailed analyses of these data are pending however, using this methodology as a cursory way to look for species variation, it is clear that there are variations in both species presence and anthropogenic sources across sites.

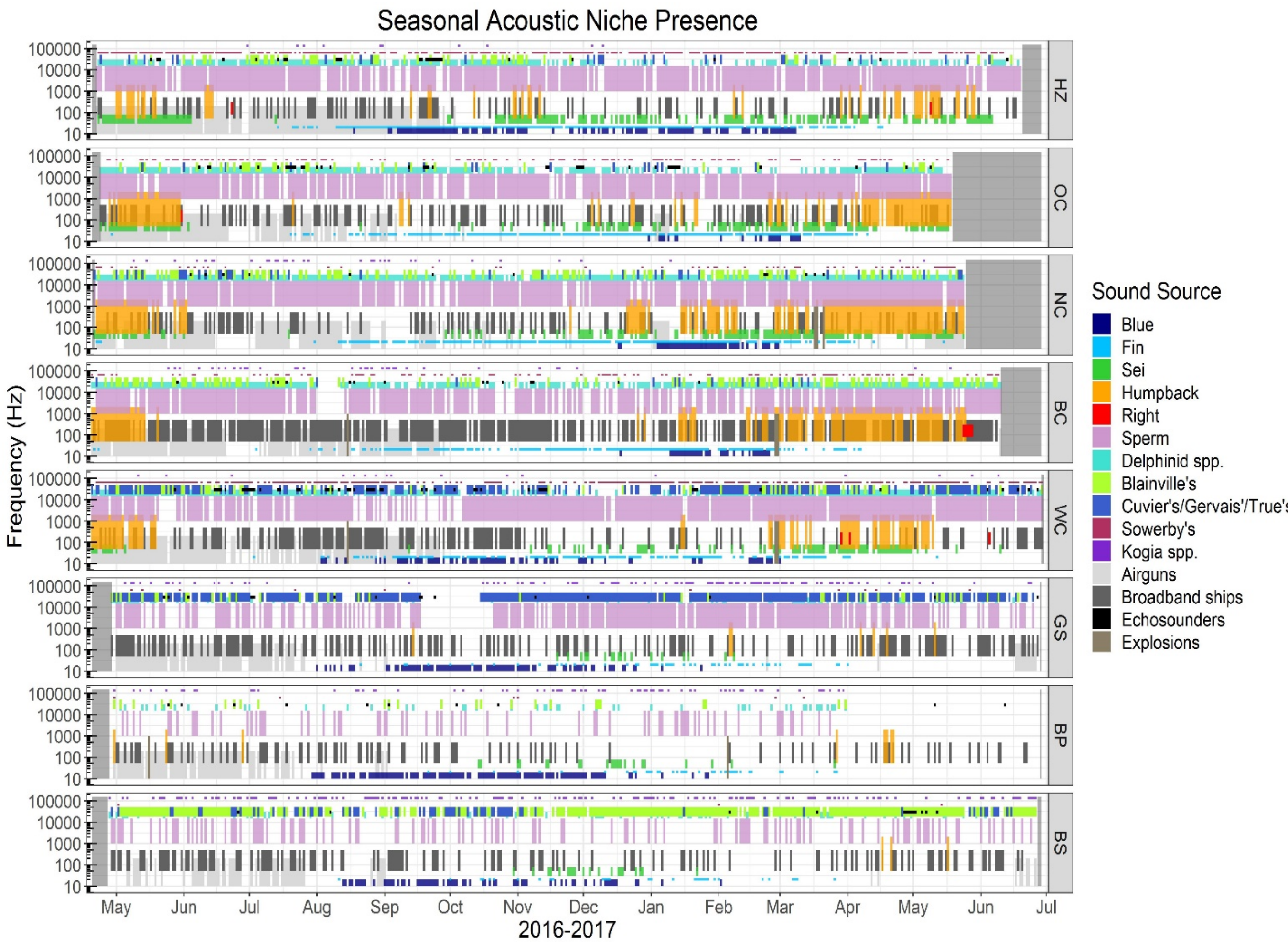

Figure 5. Spectrographic Box Display for all eight Sites. These are Heezen, Oceanographer, Nantucket, Babylon and Wilmington canyons. In addition to Gulf Stream, Blake Plateau and Blake Spur sites.

Next Steps:

The following analyses will include:

- Baseline analyses (see above) of additional years of HARP data from 2017 to 2019, which include eight additional HARPs for each year.
- The addition of the Navy HARPs to these baseline acoustic niche data.
- Cross checking and improving detector accuracy for beaked whales and delphinids if possible.
- Identifying and analyses of seismic and sonar activities on select recorders following further impact assessment analyses.
- Development of acoustic metrics and species composition analyses.

References

Baumann-Pickering, Simone, Mark A. McDonald, Anne E. Simonis, Alba Solsona Berga, Karlina PB Merkens, Erin M. Oleson, Marie A. Roch et al. "Species-specific beaked whale echolocation signals." *The Journal of the Acoustical Society of America* 134, no. 3 (2013): 2293-2301.

Davis, Genevieve E., Mark F. Baumgartner, Julianne M. Bonnell, Joel Bell, Catherine Berchok, Jacqueline Bort Thornton, Solange Brault et al. "Long-term passive acoustic recordings track the changing distribution of North Atlantic right whales (Eubalaena glacialis) from 2004 to 2014." *Scientific reports* 7, no. 1 (2017): 1-12.

Stanistreet, Joy E., Douglas P. Nowacek, Simone Baumann-Pickering, Joel T. Bell, Danielle M. Cholewiak, John A. Hildebrand, Lynne EW Hodge, Hilary B. Moors-Murphy, Sofie M. Van Parijs, and Andrew J. Read. "Using passive acoustic monitoring to document the distribution of beaked whale species in the western North Atlantic Ocean." *Canadian Journal of Fisheries and Aquatic Sciences* 74, no. 12 (2017): 2098-2109.

Stanistreet, J.E., Nowacek, D.P., Bell, J.T., Cholewiak, D.M., Hildebrand, J.A., Hodge, L.E., Van Parijs, S.M. and Read, A.J., 2018. Spatial and seasonal patterns in acoustic detections of sperm whales Physeter macrocephalus along the continental slope in the western North Atlantic Ocean. *Endangered Species Research*, *35*, pp.1-13.