Maryland Offshore Wind Project Biological Assessment

For the National Marine Fisheries Service

Appendices

U.S. Department of the Interior
Bureau of Ocean Energy Management
Office of Renewable Energy Programs

BOEM
Bureau of Ocean Energy Management

UMCES TailWinds Fishery Resource Monitoring Program

Summary

The primary goal of the 8-yr University of Maryland Center for Environmental Science (UMCES) Fishery Resource Monitoring (FRM) program is to evaluate how Ocean City Maryland commercial and recreational fisheries for black sea bass (BSB) will adapt and be impacted by the US Wind Maryland Offshore Wind Project. Wind turbine foundations will add three-dimensional structure where very little currently exists. Under these new conditions, highly aggregated distributions of BSB centered on turbines are expected to result in increased catches by commercial and recreational fisheries. Additionally, BSB sensitivity to the percussive and vessel noises associated with turbine construction could cause dispersal from turbine and project regions resulting in short-term disruptions in catch. Commercial and recreational fishers are working with our team to evaluate changed BSB catch rates between 2-yr periods: before (2023-2024), during (2025-2026), and after (2027-2028) turbine construction within the project area. Monitoring designs utilize Before-After-Gradient and Before-After-Control-Impact procedures testing hypothesized changes in catch amplitude and variance. The commercial pot survey consists of rigs of 15 commercial pots each, with pots spaced proximate and distant to turbine structures to capture both turbine- and project-scaled changes in BSB catch rates. Monthly pot surveys (Mar-Nov) of six rigs, four in the project area and two in an adjacent control area, deploy ropeless EdgeTech devices to avoid whale and turtle entanglements. Statistical power analysis during an initial trial year (2022) showed that the sampling design supports detecting a >4-fold increase in catch rates. The recreational survey compares two existing well-fished artificial reef sites (control) to two turbine sites during monthly surveys (May-Oct) through standardized bottom drift and jig angling techniques. Both commercial and recreational surveys examine patterns of BSB colonization to new foundations as well as size, sex and diet metrics during all phases of the study.

The Fishery Resource Monitoring program is part of the UMCES overall monitoring program TailWinds: Team for Assessing Impacts to Living resources from offshore WIND turbineS, which bridges fisheries and marine mammal monitoring (https://tailwinds.umces.edu/). Leveraging hydrophone assets (Rockhoppers and F-PODs) deployed to passively monitor for cetaceans, six telemetry units are also deployed in a cross-shelf array to intercept electronically tagged fishes. A previous array in this region (funded by BOEM) over a 2-year period intercepted 1286 tagged fish including 315 striped bass, 352 Atlantic sturgeon, and >30 white sharks. A total of 20 species were detected including bluefin tuna; Atlantic cod; BSB; cownose rays; and blacktip, bull, dusky, sand tiger, and tiger sharks. Telemetry units are deployed during all periods of the Monitoring program within the project area (2023-2028) and maintained every 6 months. All telemetry data is shared and made available through the Mid-Atlantic Acoustic Telemetry Observation System online portal. TailWinds also engages fishery and conservation stakeholders and state, federal, and NGO advisory groups through PI membership on advisory panels, data sharing, social media, and cruise planning and reporting tools.

Abbreviations

BACI	Before-After-Control-Impact design
BAG	Before-After-Gradient design
BSB	black sea bass
BOEM	Bureau of Ocean Energy Management
CBL	Chesapeake Biological Laboratory
CPUE	Catch per unit effort
FRM	Fishery Resources Monitoring
F/V	Fishing Vessel
GARFO	NOAA Greater Atlantic Regional Office
GSI	Gonadosomatic Index
HSI	Hepatosomatic Index
IACUC	Institutional Animal Care and Use Committee
LOA	Letter of Authorization
MATOS	Mid-Atlantic AcousticTelemetry Observing System
MD DNR	Maryland Department of Natural Resources
MDWEA	Maryland Wind Energy Area
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
ROSA	Regional Offshore Science Alliance
s.d.	Standard deviation
UMCES	University of Maryland Center for Environmental Science

Objectives

The overall goal of this FRM program is to evaluate to what extent wind turbine tower foundations increase BSB availability to commercial fishers and charter anglers during 2-year CONSTRUCTION and AFTER periods in comparison to a 2-year BEFORE period. The pot survey investigates changes in BSB catch-per-unit-effort (CPUE) and demographics in the Ocean City MD commercial fishery and the recreational survey addresses these changes for the Ocean City charter fishery. Survey objectives were developed on the basis of expert consensus guidance, literature review, a trial-year of gear deployments, and statistical power analysis (see **Design Justification** below).

Pot Survey

Rigs of pots are deployed within the MarWin Project and control regions, during nine monthly surveys each year. The 6-year survey is divided into 2-year phases corresponding with BEFORE, CONSTRUCTION, and AFTER periods. Across these periods, we are testing the following expectations:

1. BSB catches will change with distance from turbine foundations. The BEFORE period will be quasi-uniform, the CONSTRUCTION Period will be high variance exponential, and the AFTER period will be moderate/low variance exponential (Figure 1).
2. The catches for traps spaced < 120 m from wind turbine sites will increase >10-fold between BEFORE and AFTER periods. During the CONSTRUCTION period, a significant 2-10 fold increase will be detected in comparison to the BEFORE period.
3. During the AFTER period, the catch rates within the MarWin project area will be >150% more than catch rates outside the influence of the project area (control sites).
4. May-August surveys will show greatest sensitivity to turbine and project area impacts. Fall storms (September-November surveys) will disrupt expected changes in catches.

Recreational Survey

Over 6 years, monthly angling surveys (May-October) occur at two reference artificial reef sites and two sites where turbines are to be sited. The 6-year survey is divided into 2-year phases corresponding with BEFORE, CONSTRUCTION, and AFTER periods. Using standard drift angling methods, we are testing the following expectations:

1. At turbine sites, BSB catches will be close to nil during the BEFORE period. Catches will increase >2-fold from the BEFORE to CONSTRUCTION periods, and >5-fold from the BEFORE to AFTER periods.
2. In comparison to reference artificial reef sites, BSB CPUE will be 2-fold higher during both the CONSTRUCTION and AFTER periods.
3. Colonizing BSB during the CONSTRUCTION period will be smaller and show a less-diverse diet than during the AFTER period and in comparison to the diets observed at the reference artificial reef sites.
4. Jigging off the bottom will be more effective at catching BSB at turbine sites than at reference artificial reef sites.

Design and Hypothesis Justification

FRM Expert Consensus Guidance

BSB is a key species in the Mid-Atlantic given priority by BOEM, the Mid-Atlantic Fishery Management Council, and state agencies in monitoring and assessing the impact of offshore wind energy (NEFSC 2017; Stanley et al. 2020; Wiernicki et al. 2020a). BOEM guidelines in developing renewable energy in WEAs recommend the development of surveys on key commercial and recreational fished species (BOEM 2023). Survey design and protocols of the FRM Program are consistent with BOEM and Responsible Offshore Science Alliance (ROSA 2021) guidance and include,

(1) A hypothesis-driven, integrated survey design
(2) At least 2 years each of pre-, construction, and post-construction data
(3) Use of BACI and BAG design principles
(4) Careful selection of control sites
(5) Survey stratification across key habitat features where feasible
(6) Survey sample size supported by power analysis
(7) Seasonal survey duration during periods of occurrence but also during periods that confirm absence
(8) Surveys should capture local (turbine) and regional (farm, shelf region) impacts
(9) Reporting of key metrics including CPUE, length, biomass, other demographic information, and diet data for key species
(10) Employment of fishing vessel platforms, trapping operations, and fishers in surveys
(11) Provision of data and data sharing
(12) Surveys must be compliant with the National Environmental Policy Act and Marine Mammal Protection Act; trap deployments should adopt best practices for avoiding protected species interactions (BOEM 2023).

Hypothesis Justification – Pot Survey

Pot surveys are a standard approach for estimating abundance trends for BSB throughout their range and have been calibrated against assumptions of trap retention and other measures of relative abundance (Bacheler et al. 2015; Shertzer et al. 2016; Cullen and Guida 2021). Specific hypotheses were informed by BSB studies, a meta-analysis (Methratta and Dardick 2019) and observations at the Block Island Wind Farm (see Wilber et al. 2018). During the BEFORE period, lack of substantial artificial and biogenic structure in the MarWin project area will be associated with low catch rates of this highly structured species (Fabrizio et al. 2014; Secor et al. 2019; Wiernicki et al. 2020a). During the CONSTRUCTION period, we predict negative effects as BSB will be sensitive to pile-driving percussive strikes and increased vessel noise (Stanley et al. 2020; Wiernicki et al. 2020b; Secor et al. 2021), but these may be offset by aggregation to newly emplaced turbine structures. During the AFTER period, higher densities are predicted. Methratta and Dardick (2019) found higher fish densities associated with turbines in soft sediments (such as those occurring in the MarWin project area) than in complex bottom types. In soft sediments, significant positive effects were seen 0-3 years after construction and within 0-140 m (but not >140 m) from turbine structures. In otter trawl surveys proximate to turbine jacket foundations at Block Island, >10 fold increased densities of BSB were observed (D. Wilbur, INSPIRE Environmental, pers. comm.).

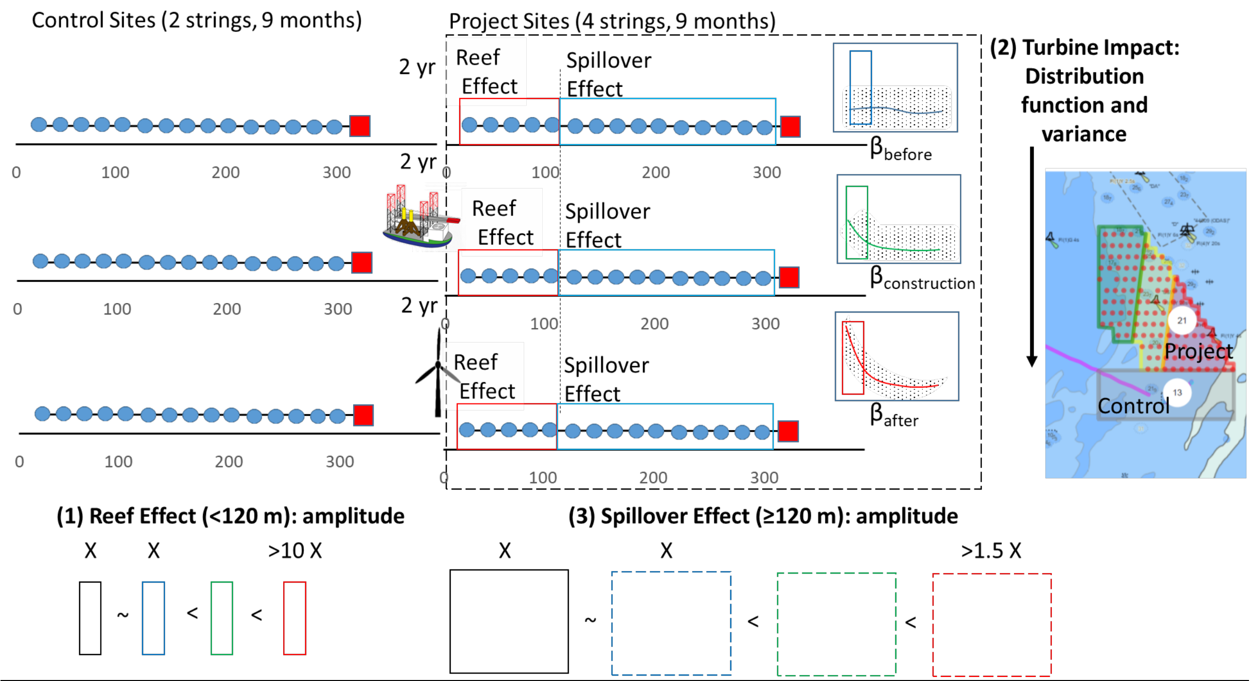


Figure 1. Pot survey Before After Gradient and Before After Control Impact concepts and hypotheses on (1) changes of turbine catch amplitude; (2) changes in turbine catch skewness; and (3) changes in project catch amplitude. Hypotheses are depicted as rig sets (each line with 15 pots) in control and farm sites during BEFORE (blue lines and boxes), CONSTRUCTION (green lines and boxes) and AFTER (red lines and boxes) periods. Control sites outside the influence of the wind farm are depicted as black lines and boxes.

We address turbine-scale influences through a BAG design and project-scale influences through a BACI design (see Methratta 2020a; 2021). In assessing turbine impacts, we investigate changes in both the amplitude and variance of abundance (Figure 1). In the BEFORE period, we predict low catches and an over-dispersed, quasi-uniform distribution. Turbine foundations will add three-dimensional structure within the MarWin project area where very little currently exists. Under these new conditions (AFTER period), we expect highly aggregated, under-dispersed distributions centered on turbines. During the CONSTRUCTION period, simultaneous avoidance (during turbine construction) and colonization (shortly after turbine construction) will contribute higher variance to distributions. To address the amplitude of turbine and project-scale influences, we subset rig catches for those pots as those <120 m (turbine) and those ≥120 m (project) distant from the foundation (Figures 1,4). Control sites will occur at > 3 km outside of the wind project area footprint. In all survey periods, we expect higher and more stable catch rates during May-August than during the spring period of immigration (March-April) and during late summer and fall months (September-November) when destratification will disrupt BSB movements followed by fall emigration (Secor et al. 2019; Wiernicki et al. 2020a).

Hypothesis Justification-Recreational Survey

The "Rigs to Reef" program epitomizes both scientific understanding and public perception on the perceived benefits of operating and retired petrochemical platforms and other artificial structures as fish habitat (Baine 2002; Bulleri 2005; Cowan et al. 2011). Rig foundations and towers result in rapid seabed and vertical colonization of benthic fouling communities (Grove et al. 1989; Lindquist et al. 2005), providing both refuge and forage benefits to reef associated fishes and their young (Figure 2). We do not seek to address the fundamental production v. attraction debate (Brickhill et al. 2005; Cowan et al. 2011; Reubens et al. 2014), but rather assess whether tower sub-foundations provide comparable fish attraction and fishing catch rates as nearby established wreck structures.

The study's premise is that recreational fisheries now occur at established reef sites that are separated by miles of un-fished, "feature-less" sand and sediment (Stumpf and Biggs 1988; Poppe et al. 1991). Ridges, riffles and other seabed features (e.g., shell hash, gravel) do occur, yet reefs with relief > 1 m are quite limited in the Mid-Atlantic Bight south of Hudson Canyon (Guida et al. 2015). Thus, fishing for reef-associated species in a BACI comparison of turbine sites is not meaningful as catch rates are expected to be nil or quite low at pre-construction turbine sites. Here, key comparisons are fishing rates between two established wreck sites and newly emplaced towers. We minimize confounding variables by 2-day and same-crew fishing (Figure 2) and by selecting established reefs that are at similar depths and distance from shore. On new turbine structures, we hypothesize that smaller and younger individuals will have opportunities to colonize these habitats, based on the general premise of higher juvenile dispersal in reef fishes. Recent studies in the project area show that BSB exhibit diel vertical behaviors throughout spring and summer months (Secor et al. 2021). Such behaviors could allow greater efficiency of fishing techniques (jigging) that target pelagic fishes.

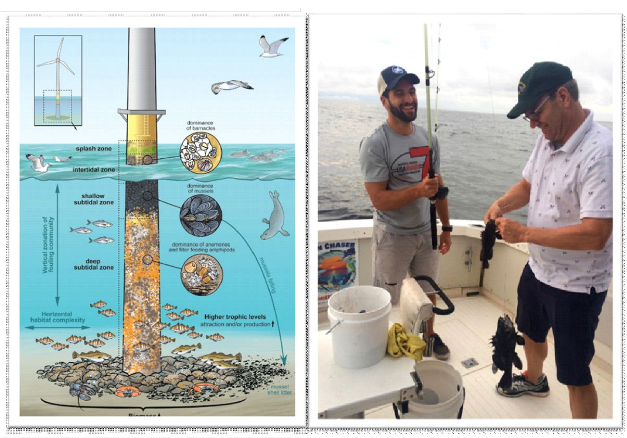


Figure 2. Left panel: changes in vertical and seabed food webs associated with a turbine reef effect, supporting hypothesis development for the recreational survey. From Degraer et al. (2020). Right panel: Charter recreational vessel fishing for BSB with standard 2-hook rig.

Trial year of deployments

During May-October 2022, trial deployments occurred during four two-day commercial pot fishing trips and two single-day recreational fishing trips. These trips tested the efficiency and safety of gear deployments and provided initial data in support of our survey designs. For the pot surveys, we determined that 6 rigs of 15 pots was a maximum safe load for the F/V Integrity and that single-day baitless soaks were sufficient to obtain catch rates (~1 fish per pot) that supported hypothesized effect size (see ***Power analysis*** below). For the recreational survey aboard the F/V Fin Chaser, we validated our assumption that turbine sites produced nil catch rates for BSB and developed consistent drop fishing methods. The trial year also allowed us to develop protocols and initial data associated with fish condition and diet estimates.

Power analysis: pot survey

Power analysis of catches from our trial year produced a global mean catch ± standard deviation of 1.02 ± 2.4 for 405 pot deployments across 24 sites. Catch variance was applied to the following allocation of sampling effort:

- Period: 3 periods: Before, During, and After construction
  - 2 years of observation in each period
  - 5 monthly samples per year *
- Treatment: 4 Project sites and 2 Control sites
- Distance: 2 sets nested within sites: Near (pots 1-6) and Far (pots 7-15).

*Note that this design is conservative as we will be sampling for 9 rather than 5 months; the latter was used because this was the frame of TRIAL year sampling.

An Analysis of Variance F-test for power using these values supported high power (>0.95) in detecting a hypothesized 10-fold effect size between periods and sites for the near pots (reef effect). Power remained high (>0.95), regardless of the number of sites chosen (2, 3, 4, 5, or 6). This means that the design should be robust to lost pots and the inability to go out on occasional months owing to weather.

In contrast to the reef effect, the hypothesized spillover effect of 1.5-fold at the far pots could not be detected with sufficient power. Sampling intensity to achieve this effect size would need to increase 10-100 times and are not feasible within fiscal and logistical constraints. Still, we retain the far pot comparison in our design to support gradient and variance analyses (i.e., how rapidly do densities fall off with distance from the turbine foundation?) and test for an impact that could exceed our initial expectation of 1.5-fold.

Power analysis: recreational survey

As turbine site catches during the Before period are nil, trial-year data could not support a direct power analysis. Power analysis for the recreational survey was instead conducted using variance estimates reported in Cullen and Stevens (2020) in their comparison of BSB hook-and-line and video CPUEs at similar depths in a region south but adjacent to the MarWin Project area off Assateague Island. Under the ratio of expected differences in periods (0, 2 and 5 times the control site), the calculated F-test power is close to 100% (high probability of detecting the expected effects, using confidence level for the test of 95%). A separate trial using 1000 independent Monte Carlo simulations confirmed this high level of power.

Approach

Study Site

Site characteristics of the project and control sites for the pot survey are similar in bathymetry and soft sediment bottom type (Figure 3). The >20 m depths mean that all study sites will be thermally stratified (i.e., subjected to the "Cold Pool") during late spring to late summer months, and then become mixed following early fall storms (Wiernicki et al. 2020a). For the recreational survey, the two reference artificial reef sites include the southern Site 1: the sunken freighter, the *USS Saetia* (1918), a 98 m vessel of mostly <2 m hull relief; and the northern Site 2: the "Great Eastern Reef," a deposition area of opportunistic materials (primarily concrete units and cable mounds) with < 2 m relief. These two sites comprise the only fishable artificial reef structures near the MarWin Project area (Secor et al. 2019; 2021).

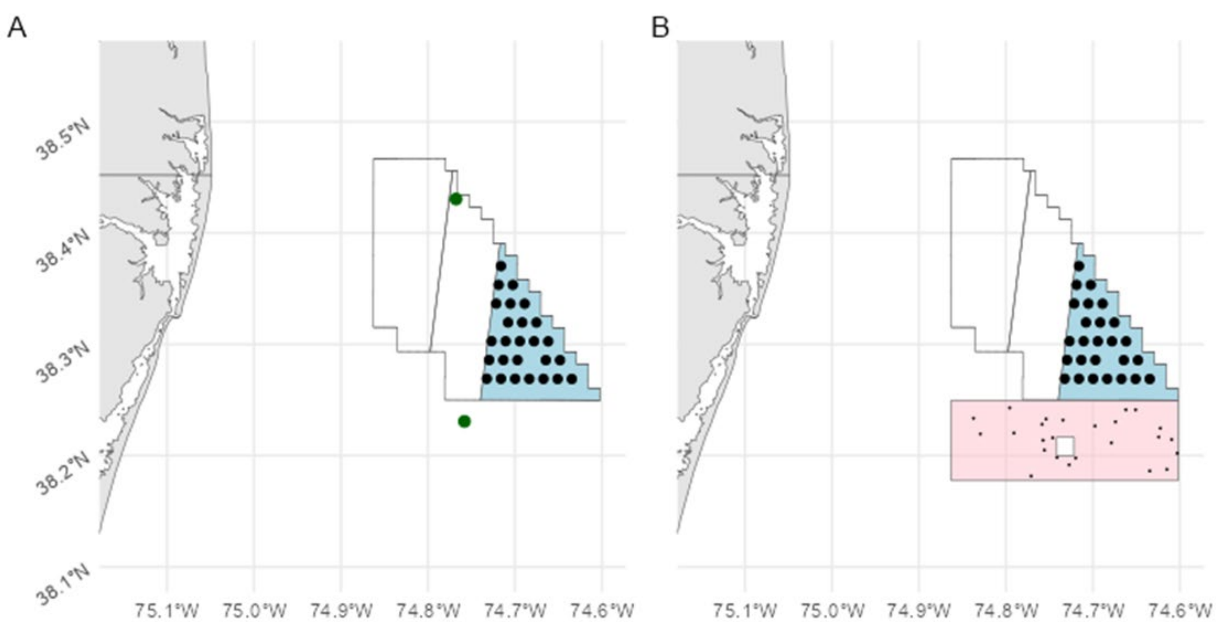


Figure 3. Study site for recreational (A) and commercial (B) surveys. For each commercial survey, four turbine and two control sites are randomly selected from within the MarWin (blue) and control (red) regions. Turbine locations are shown as large black points and example control site selections are represented by small black points. [Note recent changes from the initial COP from 26 turbines – shown above to – to 21 turbines are noted and the plan will be accordingly adjusted]. For the recreational survey, reference artificial reef sites (green points) and two turbine sites are selected per survey.

Pot survey

Ventless commercial fishing pots are similar to those used for commercial fishing and used successfully in past survey research (DeCelles et al. 2014). Sampling units are 40" pots, which are spaced, as in commercial rigs, at 10 fathoms (~20 m) apart on a rig of 15 pots (Figure 4). The 6 pots most-proximate to the turbine are subset as reef effect (near) pots and those 9 pots more distant are subset as spillover effect (far) pots. Each of the 6 rigs (4 project rigs and 2 control rigs) are "ropeless" and terminate in an EdgeTech retrieval cage. Pots are soaked without bait for a single night; Batcheler et al. (2013) showed that pot catchabilities declined at >48 hours. The EdgeTech ropeless device includes a retrieval cage that contains buoys and a coiled line and the lid of the cage is released upon acoustic signaling from a deck box. The goal of ropeless gear is to avoid entanglements with marine mammals and turtles and to test this new technology for broader application in commercial fisheries and monitoring programs (Anon. 2019). Our survey represents an initial test of this gear within the southern Mid-Atlantic, but the PI and the commercial operators at SeaBorn LLC (*FV Integrity*, Captain K. Harrington, Vessel ID MD9128BD) have substantial experience with recovering seabed-moored gear from vessel-based acoustic-transponder signals (Secor et al. 2020). Surveys will include at least four crew: the Captain, mate, and two UMCES scientists.

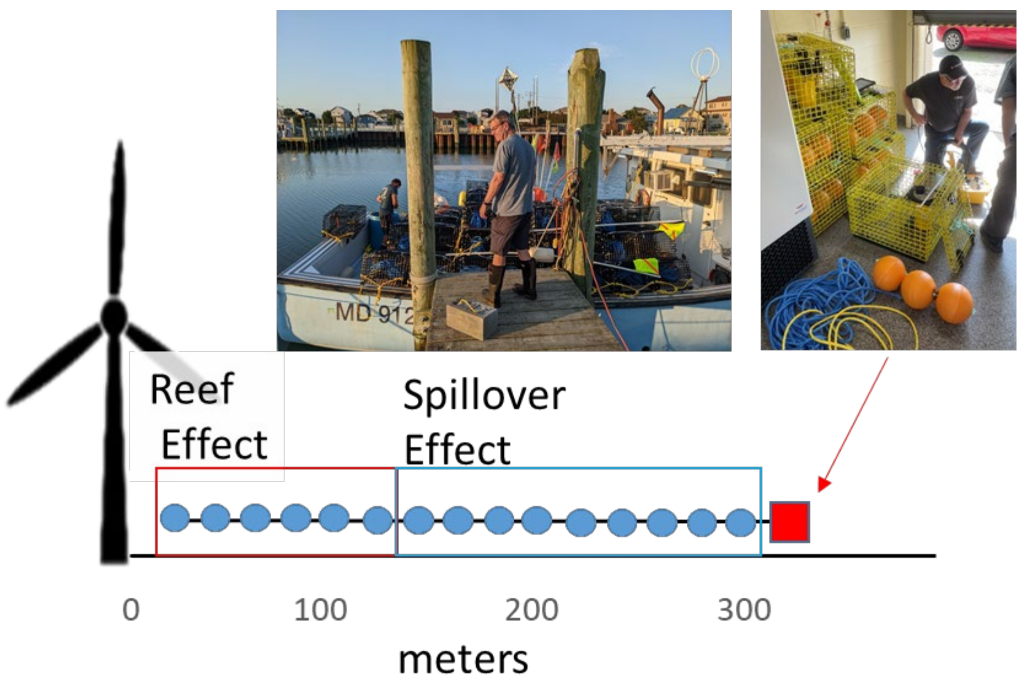


Figure 4. Commercial pots (blue circles, 10 fathom spacing) and an Edgetech ropeless device (shown and in red square) will be designated as reef effect and spillover effect segments to test for effect sizes associated with distance from turbine foundations.

Prior to each monthly survey, a subset of 4 project and 2 control sites are randomly selected from all possible turbine and control sites (Figure 3B). While turbine sites are selected from those turbines within the MarWin Project area, control sites are randomly selected from an area half the height and the same width as the BOEM lease area. The total number of surveys and deployments is summarized in Table 1.

Table 1. Pot survey periods, months, and gear deployments.

Period	Years	Monthly Surveys	Total Surveys	Vessel Days/yr	Total Vessel Days/Period
TRIAL (BEFORE)	2022	May-Aug	4	8	8
BEFORE	2023-2024	Mar-Nov	18	18	36
CONSTRUCTION	2025-2026	Mar-Nov	18	18	36
AFTER	2027-2028	Mar-Nov	18	18	36
Total	2022-2028	Mar-Nov	58		116

Sites	Rigs	Pots/ rig	Total Pots	Ropeless Devices
Project	4	15	60	4
Control	2	15	30	2
Total	6	15	90	6

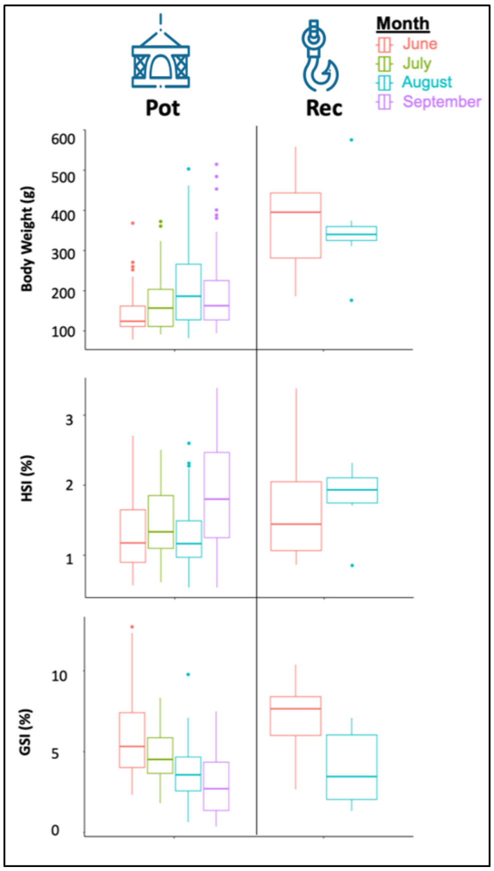
During each survey, wind speed and direction, wave height, ranked classes of cloud cover, bottom temperatures, and exact soak time are recorded and used as possible covariates in analysis of catch rates. Pots are soaked for a single night (~24 hr) and retrieved. Upon pot retrieval, BSB are counted and measured for total length and weight and, for a retained subsample of fish. A maximum of five individuals are selected from Near and Far pots on each rig. Depending on catch, a maximum of 60 is retained per survey). All other species are identified to the lowest taxon possible and enumerated. Frozen (dry ice) BSB samples are transported to the laboratory for later processing, which involves taking measurements of length, body weight, gonad type and weight, liver weight, total stomach weight, and stomach lining weight. Individual prey items are identified to the lowest taxa possible, enumerated, and weighed for a subsample of 40 fish per survey. These measures support indices of physiological condition including condition factor, gonadosomatic index, and hepatosomatic index; and diet metrics of percent number and frequency of occurrence (Figures 5, 6).

Complying with best practices to avoid protected species (BOEM 2023), we employ the following procedures:

- The F/V Integrity operates at < 10 knots.
- Prior to gear deployment surrounding waters are observed and should a whale be sighted within 1 nautical mile; an alternate survey site is fished.
- Float lines (used during trial year and during first BEFORE year (2023) when testing ropeless gear) are marked according to GARFO guidance. Floatlines contain weak inserts.
- Single day soaks are used to minimize interactions.
- Ropeless EdgeTech gear is used beginning 2023 to eliminate floatline deployments.

Recreational Survey

In each year, six monthly surveys (May-October) deploy standard angling techniques to obtain catch rates at two reference artificial reef sites and at two sites where turbine foundations will be constructed. For each month, one control and one turbine site are visited per day across two days, with the order of site visits randomized within a day and all sites visited within a 2-day window to limit bias owing to sea conditions and time of day. Using an experienced charter vessel captain (Captain Dan Stauffer, F/V Fin Chaser) and three anglers, we employ drift and jigging methods commonly used for BSB angling including clam/squid bait, 2-hook rig, 3/0 J-hooks, barrel swivels, and lead sinkers (Figure 2); the effort unit is a 3-minute drop (Cullen and Stevens 2020), with each site fished for 45 minutes (15 drops/angler). Anglers include the mate, a scientific crew, and a volunteer. At each site, a jigging trial is conducted by the mate upon arrival for a 15-minute period prior to the onset of the drift, near-bottom angling. During each survey, wind speed and direction, wave height, ranked classes of cloud cover, and bottom temperatures are recorded and used as possible covariates in analysis of catch rates. Angler type is recorded and evaluated for possible confounding effects (mate: high experience; scientist: moderate experience; volunteer: variable experience).



Fish are measured for condition on deck (stage of barotrauma, hooking injuries), length and weight, and, for a retained subsample of fish (10 per site and survey, preserved on dry ice), data is collected in the laboratory for sex, diet, and condition index (Figures 5,6). Fish not retained and showing signs of barotrauma are vented and returned to the water (Ruderhausen et al. 2020). The total number of surveys and deployments is summarized in Table 2.

Figure 5. Body size and condition data across all 170 fish collected during pot and recreational surveys.

Table 2. Recreational survey periods, months, and related deployments.

BACI Period	Years	Monthly Surveys	Total Surveys	Vessel Days/yr	Total Vessel Days	Fishing Sites
TRIAL (BEFORE)	2022	May, Aug	2	2	2	2
BEFORE	2023-2024	May-Oct	6	12	24	4
CONSTRUCTION	2025-2026	May-Oct	6	12	24	4
AFTER	2027-2028	May-Oct	6	12	24	4
Total	2022-2028	May-Oct	20		74	4

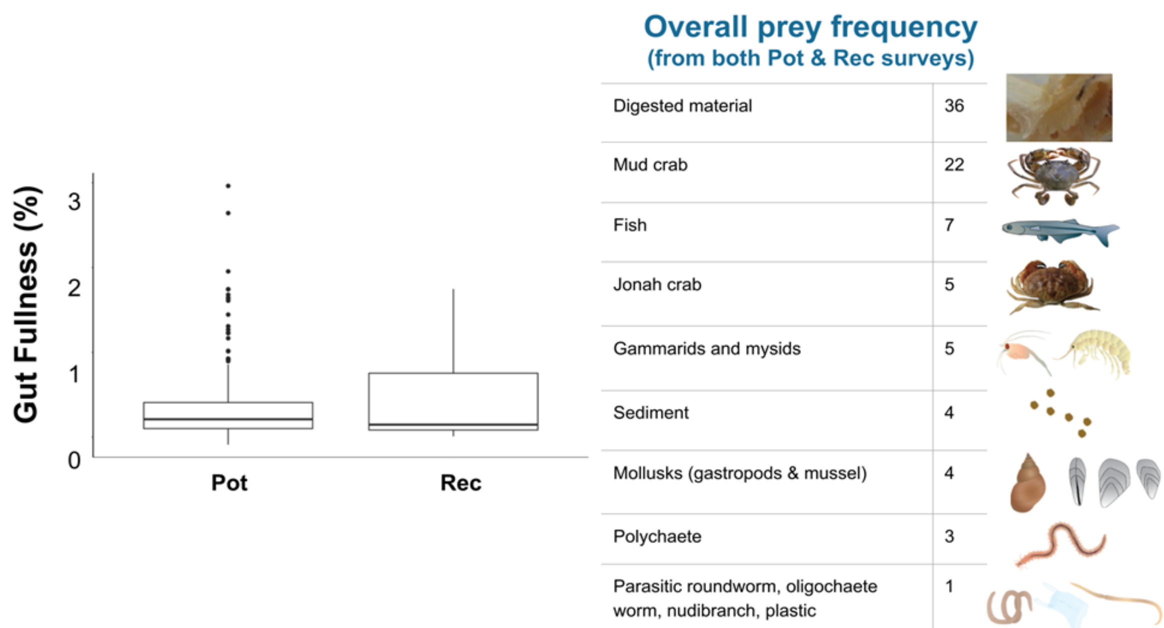


Figure 6. Diet data from pot and recreational fish surveys. Left: Gut fullness (%) with one outlier removed (7.49% from June 2022 pot cruise). Gut fullness was calculated by subtracting the weight of an individual's stomach lining from the total weight of their stomach, dividing by the individual's body weight, and then multiplying by 100. Right: Most common prey items (n) found within sampled fish stomachs during processing.

Other Activities

Permitting

The Federal Animal Welfare Act requires that all research and teaching activities carried out at university and other government programs are approved for safe and humane practices. This requirement is met through an institutional permitting program overseen by an Institutional

Animal Care and Use Committee (IACUC). The UMCES IACUC is comprised of six members including an outside veterinarian; the group has reviewed and approved FRM methodology through the BEFORE phase of construction (Protocol F-CBL-2022-01). Approval will be sought for the DURING phase in late 2024.

PI Secor received a NMFS GARFO Letter of Authorization for the 2022 and 2023 pot surveys which permits the commercial vessel platform (Captain Harrington, the FV Integrity and FV Sea Born) to land BSB outside their quota and other federal restrictions. PI Secor is also issued a state permit for capture of marine fishes that will allow landed fish in the recreational survey. Submission and approval for Exempted Fishing Permits must be repeated each year.

Biotelemetry

Biotelemetry receivers are deployed and are maintained as part of the larger US Wind-funded TailWinds project (tailwinds.umces.edu), which also deploys hydrophone devices for recording cetacean vocalizations. InnovaSea VR2W and VR2AR units are deployed as a cross-shelf array designed to intercept electronically tagged fishes through the MarWin Project and adjacent areas (Figure 7). A previous array in this region (funded by BOEM over a 2-year period) intercepted 1286 tagged fish including 315 striped bass, 352 Atlantic sturgeon, and >30 white sharks. A total of 20 species were detected including bluefin tuna; Atlantic cod; BSB; cownose rays; and blacktip, bull, dusky, sand tiger, and tiger sharks. Telemetry units are deployed during all periods of the monitoring program within the project area (2023-2028) and maintained every 6 months. All telemetry data is shared and made available through the Mid-Atlantic Acoustic Telemetry Observation System online portal, project URL https://matos.asascience.com/project/detail/240. TailWinds staff will also assist Ocean Tech Services in analysis and data sharing from the telemetry unit deployed with the US Wind MetOcean Buoy.

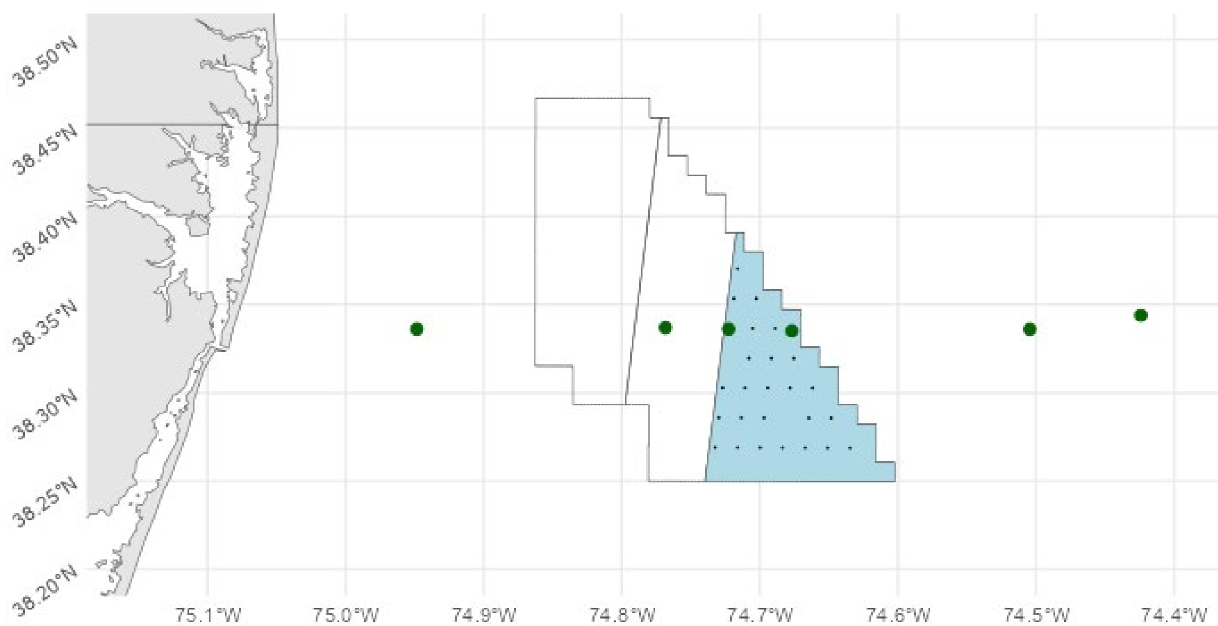


Figure 7. Cross-shelf locations of deployed biotelemetry devices (green). BOEM lease area with MarWin energy area (blue) and turbine location (black points) are shown for reference.

Milestone Schedule

The 8-year project's duration is 1 November 2021 to 30 October 2029. The project's annual schedule will be similar in all years except for the planning and preparation period, 1 November 2021 - 30 October 2022, and the wrap-up data analysis and reporting period, 1 December 2028 - 30 October 2029.

Project Schedule

January 2022-February 2023: Start-up period

- UMCES Animal Care and Use, NOAA LOA Permit, MDDNR consultation
- Supply, equipment and contractor (F/V Integrity, F/V Fin Chaser) procurements and scheduling
- Shake down deployments of experimental potting gear
- Shake down deployments of recreational gear
- Collection of initial pot survey baseline data for power analysis

March-November, 2023-2024: Monthly pot surveys, BEFORE Period
May-October, 2023-2024: Monthly recreational surveys, BEFORE Period
April 2024: BEFORE Period Report
March-November, 2025-2026: Monthly pot surveys, CONSTRUCTION Period
May-October, 2025-2026: Monthly recreational surveys, CONSTRUCTION Period
April 2027: CONSTRUCTION Period Report
March-November, 2027-2028, Monthly pot surveys, AFTER Period
May-October, 2027-2028, Monthly recreational surveys, AFTER Period
April 2029: AFTER Period Report
Dec-October 2028-2029: Wrap-up including, database compilation, data sharing, compiled data analysis of pot and recreational surveys, finalized BACI and BAG analyses, Draft Report deliverable, Final Report deliverable, and peer-reviewed paper preparation
October 2029: Final Report

Yearly Field Schedule (full design: 2023-2028)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pot Survey			x	x	x	x	x	x	x	x	x	
Recreational Survey					x	x	x	x	x	x		
Field Prep	x	x	x									x
Lab work	x	x	x	x	x	x	x	x	x	x	x	x
Data analysis	x	x	x							x	x	x
Semi-annual report					x						x	

Deliverables

1) During 12-month TRIAL year, biweekly meetings with US Wind were conducted to discuss progress on project logistics, findings, and continuing developments.
2) Semi-annual progress reports containing cruise reports, preliminary findings, and a list of project products (data sharing, outreach activities, publications, and presentations).
3) Semi-annual meetings with US Wind representatives to follow up on progress reports and coordinate surveys with US Wind actions.
4) Biennial Period Reports for BEFORE, CONSTRUCTION, and AFTER construction phases.
5) Draft final report for preliminary review by US Wind for the presence of any commercially sensitive information in the materials.
6) Final report to US Wind containing complete reporting on study findings, analyses of BACI and BAG designs, recommendations, and project products.
7) Data archiving and sharing of FRM database and biotelemetry data collected in the MarWin Project area.
8) Peer-reviewed publications on study design and findings.

Project Management

Dr. David Secor is responsible for managing the FRM project, as well as the entire TailWinds program. He will participate, plan, and oversee data analysis for pot and recreational surveys. Data scientist and field technician Mr. Michael O'Brien is responsible for cruise planning and reporting, biotelemetry deployments, and data analysis and management. Dr. Slava Lyubchich, a biostatistician, serves as Co-PI and oversees study design refinement and statistical analysis on BACI and BAG procedures. A laboratory technician assists during cruises and in analyzing BSB diet and condition analyses.

Data Management

Field data will be collected by Secor and his assistant M. O'Brien, who is responsible for entry and QA/QC of field and fish relocation data. A database will be assembled along with access scripts in the R programming language. Data is stored on the TailWinds server *delphinus*, housed at Chesapeake Biological Laboratory. Field data, model outputs, and research products are made available to US Wind. Spatial data will be formatted according to BOEM guidelines (BOEM 2023). Telemetry detections derived from transmitters and fish released by external investigators will be distributed promptly by email with information on the location of the detecting receiver(s). Investigators will be identified through the Mid-Atlantic Acoustic Telemetry Observation System, Florida Atlantic Coastal Telemetry Network, and Ocean Tracking Network. Since 2014, the Secor lab has provided >2 million biotelemetry records to 143 investigators on 60 different species. These records of location and time from our deployed receivers were provided promptly and freely without obligation. Further, telemetry data management R packages (matos, https://matos.obrien.page; otndo, https://otndo.obrien.page) were developed by M. O'Brien to ease data distribution, which have been provided to others to promote data sharing within the telemetry community. All published data and research products will include attribution and citation information to US Wind. To the extent possible, we will publish in open-source journals and deposit related data in online data repositories.

Bibliography

Anonymous, 2019. Ropeless fishing to prevent large whale entanglements: Ropeless Consortium Report. Marine Policy, 107: 103587.

Bacheler, N.M. et al., 2013. When a trap is not a trap: converging entry and exit rates and their effect on trap saturation of black sea bass (*Centropristis striata*). ICES Journal of Marine Science, 70(4): 873-882.

Baine, M. 2002. The North Sea rigs-to-reefs debate. ICES Journal of Marine Science 59:S277-S280.

Bergström, L., and 6 coauthors. 2014. Effects of offshore wind farms on marine wildlife-a generalized impact assessment. Environmental Research Letters 9(3).

BOEM (U.S. Department of the Interior, Bureau of Ocean Energy Management). 2023. Guidelines for Providing Information on Fisheries for Renewable Energy Development on the Atlantic Outer Continental Shelf Pursuant to 30 CFR Part 585

Brickhill, M. J., S. Y. Lee, and R. M. Connolly. 2005. Fishes associated with artificial reefs: attributing changes to attraction or production using novel approaches. Journal of Fish Biology 67:53-71.

Bulleri, F. 2005. The introduction of artificial structures on marine soft- and hard-bottoms: ecological implications of epibiota. Environmental Conservation 32(2):101-102.

Carey, D.A. et al., 2020. Effects of the Block Island Wind Farm on Coastal resources lessons learned. Oceanography, 33(4): 70-81.

Carr-Harris, A. and C. Lang. 2018. Sustainability and tourism: A case study of the United States' first offshore wind farm. https://works.bepress.com/corey_lang/29/ 35 p.

Cowan, J. H., and 14 coauthors. 2011. Red snapper management in the Gulf of Mexico: science- or faith-based? Reviews in Fish Biology and Fisheries 21(2):187-204.

Cullen, D.W., Guida, V., 2021. Use of geographically weighted regression to investigate spatial non-stationary environmental effects on the distributions of black sea bass (*Centropristis striata*) and scup (*Stenotomus chrysops*) in the Mid-Atlantic Bight, USA. Fisheries Research, 234.

Cullen, D.W., Stevens, B.G., 2017. Use of an underwater video system to record observations of black sea bass (*Centropristis striata*) in waters off the coast of Maryland. Fishery Bulletin, 115(3): 408-418.

DeCelles, G., Barkley, A., Cadrin, S., 2014. Mid-Atlantic Research Set Asice Report: Industry Based Survey on Black Sea Bass Utilizing Ventless Traps.

Degraer, S. et al., 2020. Offshore wind farm artificial reefs affect ecosystem structure and functioning A Synthesis. Oceanography, 33(4): 48-57.

Gill, A.B. et al., 2020. Setting the context for offshore wind development effects on fish and fisheries. Oceanography, 33(4): 118-127.

Fabrizio, M. C., J. P. Manderson, and J. P. Pessutti. 2013. Habitat associations and dispersal of black sea bass from a mid-Atlantic Bight reef. Marine Ecology Progress Series 482:241-253.

Fabrizio, M. C., J. P. Manderson, and J. P. Pessutti. 2014. Home range and seasonal movements of Black Sea Bass (*Centropristis striata*) during their inshore residency at a reef in the mid-Atlantic Bight. Fishery Bulletin 112(1):82-97.

Grove, R. S., C. J. Sonu, and M. Nakamura. 1989. Recent Japanese trends in fishing reef design and planning. Bulletin of Marine Science 44(2):984-996.

Guida, V., A. Drohan , D. Johnson, J. Pessutti, S. Fromm, and J. McHenry. 2015. Report on Benthic Habiats in the Maryland Wind Energy Area. NOAA/NEFSC/MD Interim Report to BOEM.

Hammar, L., S. Andersson, and R. Rosenberg. 2010. Adapting offshore wind power foundations to local environment. Vindval Report 6367. Swedish Environmental Protection Agency. 87 p.

Hutchison, Z.L. et al., 2020. Offshore wind energy and benthic habitat changes: Lessons from Block Island Wind Farm. Oceanography, 33(4): 58-69.

Langhamer, O. 2012. Artificial Reef Effect in relation to Offshore Renewable Energy Conversion: State of the Art. Scientific World Journal.

Lindquist, D. C., R. F. Shaw, and F. J. Hernandez. 2005. Distribution patterns of larval and juvenile fishes at offshore petroleum platforms in the north-central Gulf of Mexico. Estuarine Coastal and Shelf Science 62(4):655-665.

Methratta, E.T., 2020. Monitoring fisheries resources at offshore wind farms: BACI vs. BAG designs. ICES Journal of Marine Science, 77(3): 890-900.

Methratta, E.T., Hawkins, A., Hooker, B.R., Lipsky, A., Hare, J.A., 2020. Offshore Wind Development in the Northeast US Shelf Large Marine Ecosystem Ecological, Human, and Fishery Management Dimensions. Oceanography, 33(4): 16-27.

Methratta, E.T., Dardick, W.R., 2019. Meta-Analysis of Finfish Abundance at Offshore Wind Farms. Reviews in Fisheries Science & Aquaculture, 27(2): 242-260.

Mills, K. A., P. A. Hamer, and G. P. Quinn. 2017. Artificial reefs create distinct fish assemblages. Marine Ecology Progress Series 585:155-173.

Monti, D. 2018. "Fishing Report: Wind Farms Prove Beneficial for Fishermen." *Providence Journal*, June 8, 2018.

NEFSC (Northeast Fisheries Science Center). 2017. Stock Assessment for Black Sea Bass. 62nd Northeast Regional Stock Assessment Workshop (62nd SAW) Assessment Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 17-03; 822 p

Poppe, L. J., J. A. Commeau, and P. C. Valentine. 1991. Mineralogy of the silt fraction in surficial sediments from the outer continental-shelf off Southeastern New England. Journal of Sedimentary Petrology 61(1):54-64.

Reubens, J. T., S. Degraer, and M. Vincx. 2014. The ecology of benthopelagic fishes at offshore wind farms: a synthesis of 4 years of research. Hydrobiologia 727(1):121-136.

Rooker, J. R., Q. R. Dokken, C. V. Pattengill, and G. J. Holt. 1997. Fish assemblages on artificial and natural reefs in the Flower Garden Banks National Marine Sanctuary, USA. Coral Reefs 16(2):83-92.

ROSA (Responsible Offshore Science Alliance). 2021. ROSA Offshore Wind Project Monitoring Framework and Guidelines. https://www.rosascience.org/resources

Rothermel, E.R. et al., 2020. Comparative migration ecology of striped bass and Atlantic sturgeon in the US Southern mid-Atlantic bight flyway. Plos One, 15(6).

Rudershausen, P.J., Runde, B.J., Buckel, J.A., 2020. Effectiveness of venting and descender devices at increasing rates of postrelease survival of black sea bass. North American Journal of Fisheries Management, 40(1): 125-132.

Secor, D.H., H. Bailey, A. Carroll, V. Lyubchich, M.H.P. O'Brien and C.J. Wiernicki. 2021. Diurnal vertical movements in black sea bass (*Centropristis striata*): Endogenous, facultative, or something else? Ecosphere 12(6):e03616.10.1002/ecs2.3616

Secor, D.H., Zhang, F., O'Brien, M.H.P., Li, M., 2019. Ocean destratification and fish evacuation caused by a Mid-Atlantic tropical storm. Ices Journal of Marine Science, 76(2): 573-584.

Shertzer, K.W., Bacheler, N.M., Coggins, L.G., Fieberg, J., 2016. Relating trap capture to abundance: a hierarchical state-space model applied to black sea bass (*Centropristis striata*). ICES Journal of Marine Science, 73(2): 512-519.

Stanley, D. R., and C. A. Wilson. 1997. Seasonal and spatial variation in the abundance and size distribution of fishes associated with a petroleum platform in the northern Gulf of Mexico. Canadian Journal of Fisheries and Aquatic Sciences 54(5):1166-1176.

Stanley, J.A. et al., 2020. Ontogenetic variation in the hearing sensitivity of black sea bass (*Centropristis striata*) and the implications of anthropogenic sound on behavior and communication. Journal of Experimental Biology.

Stumpf, R.P.; Biggs, R.B. 1988. Surficial morphology and sediments of the continental shelf of the Middle Atlantic Bight. In: Pacheco, A.L., ed. Characterization of the Middle Atlantic water management unit of the Northeast regional action plan. NOAA Tech. Memo. NMFS-F/NEC-56:51-72. Theroux, R.B.; Grosslein, M.D. 19

Wiernicki, C.J. et al., 2020a. The recurring impact of storm disturbance on black sea bass (*Centropristis striata*) movement behaviors in the Mid-Atlantic Bight. Plos One, 15(12).

Wiernicki, C.J., Liang, D., Bailey, H., Secor, D.H., 2020b. The effect of swim bladder presence and morphology on sound frequency detection for fishes. Reviews in Fisheries Science & Aquaculture, 28(4): 459-477.

Wilber, D.H., Carey, D.A., Griffin, M., 2018. Flatfish habitat use near North America's first offshore wind farm. Journal of Sea Research, 139: 24-32.

UMCES TailWinds Marine Mammal Monitoring Program

Summary

In a before-during-after-gradient impact design framework, the goal of this project is to conduct a passive acoustic monitoring (PAM) study within the area of potential effect for the Maryland Lease Area to determine the response of marine mammals to the construction (DURING) and operation (AFTER) of an offshore wind facility by comparing it to pre-construction data (BEFORE). We are analyzing the hydrophone data from the US Wind metocean buoy at the start of the project (Years 1 and 2) for dolphins and porpoises. We will then utilize a 10-hydrophone array (Years 2-8) similar to that deployed in our earlier baseline study (Bailey et al. 2018) to detect and localize low-frequency whale calls and mid-frequency dolphin calls with 6 of the hydrophone moorings including additional devices to detect high frequency porpoise calls. This array will encompass a range of distances (ranging up to approximately 30 km distance) from the potential wind turbine locations as part of the gradient design to determine the impact distance (Bailey *et al.* 2018).

Abbreviations

AMAPPS	Atlantic Marine Assessment Program for Protected Species
BACI	Before-After-Control-Impact design
BAG	Before-After Gradient design
BANTER	Bioacoustic Event Classifier
BOEM	Bureau of Ocean Energy Management
CBL	Chesapeake Biological Laboratory
LFDCS	Low Frequency Detections and Classification System
MD DNR	Maryland Department of Natural Resources
MDWEA	Maryland Wind Energy Area
MMM	Marine Mammal Monitoring
NARW	North Atlantic Right whale
NB	Narrow Band
NOAA	National Oceanographic and Atmospheric Administration
PSO	Protected Species Observers
ROCCA	Real-time Odontocete Call Classification Algorithm
RTWB	Real-time Whale Buoy
s.d.	Standard deviation
UMCES	University of Maryland Center for Environmental Science
UMD-CP	University of Maryland College Park
URL	Uniform Resource Locator
WHOI	Woods Hole Oceanographic Institution

Objectives

The specific objectives of this project are to:

1. Identify detections of dolphins and porpoises from the data provided by US Wind from their acoustic devices (F-POD and LS1X) on the metocean buoy.
2. Characterize the temporal occurrence and spatial distributions of vocalizing marine mammals (baleen whales, dolphins and porpoises) identified using a combination of automated call detection software and expert human validation for each of the 2-year BEFORE, DURING, and AFTER periods (6 years total).
3. Compare the occurrence of marine mammals (baleen whales, dolphins and porpoises) in the BEFORE, DURING, and AFTER periods in combination with our previously collected data to determine whether a response to the construction or operation of a wind facility is observed.
4. Estimate specific spatial locations of North Atlantic right whales, humpback whales and dolphins (most prevalent are bottlenose dolphins) within the Maryland Lease Area using an acoustic localization array to examine if there is any change (avoidance or attraction) DURING and AFTER the wind facility construction.
5. Measure underwater sound levels BEFORE, DURING, and AFTER the wind facility construction and its propagation throughout the Maryland Lease Area and surrounding area, and compare with baseline ambient sound levels to determine marine mammal exposure levels.

Design and Hypothesis Justification

European studies on the impacts of offshore wind facility development have focused on harbor porpoises and pinnipeds, and the response of dolphins and whales that occur in U.S. waters is less well understood (Bailey *et al.* 2014). Previous studies in the Maryland Lease Area (OCS-A 0490) have focused on collecting baseline data on the occurrence of marine mammals to determine the seasonal occurrence of species and the potential impacts of offshore wind energy development. Previously, we performed passive acoustic monitoring (PAM) with an array of hydrophones to monitor for marine mammal calls. Regular occurrence of North Atlantic right whales, fin whales, humpback whales, bottlenose dolphins, common dolphins, and harbor porpoises was detected in the Maryland Lease Area (Bailey *et al.* 2018). Baleen whales tended to occur most frequently in the winter and spring whilst bottlenose dolphins were most common within and inshore of the Maryland Lease Area in the summer. We also characterized the ambient noise environment, which is important for determining how additional noise caused by an offshore wind facility will propagate and contribute to the underwater soundscape, an important component of marine mammals' habitat.

In the Marine Mammal Monitoring (MMM) program, we will collect and analyze passive acoustic recording data from the Maryland Lease Area. Additionally, US Wind (or their affiliates) will provide UMCES with the acoustic data from their hydrophones connected to the metocean buoy. We will use two types of archival sound recording devices, the Rockhopper designed by Cornell University that will sample at 200 kHz for baleen whales and dolphins (n=10) and the F-POD, which is a tonal click detector for small cetaceans including porpoises (n=6). The Rockhopper recorders are designed to include a localization array within the Maryland Lease Area that will allow us to determine the positions of calling critically endangered North Atlantic right whales, humpback whales, and dolphins. Using the data from this project, and the previously collected acoustic data in the study area, we will determine the marine mammal response to the wind turbine installation and operation, including changes in occurrence, calling behavior, and/or patterns of spatial habitat use. By leveraging this extensive survey effort across many years, we will be able to distinguish changes in marine mammal behavior due to natural inter-annual variation versus behaviors influenced by wind facility operations.

The expectation is that marine mammals will avoid areas in the vicinity of high noise exposure during and within a few days after the pile-driving activity in the construction phase (DURING period) resulting in reduced occurrence and there will be corresponding increases in occurrence at farther distances away (>15-20 km) from the noise source (Dähne *et al.* 2013, Bailey *et al.* 2014, Brandt *et al.* 2018). This displacement distance is expected to be reduced later in the construction process as the scale of response has previously been found to decline over time (Graham *et al.* 2019). These expectations are based on the response of harbor porpoises, which have less sensitive hearing to low frequency sounds, such as pile-driving, than baleen whales. The response of baleen whales to pile-driving is unknown, but avoidance behaviors and changes in call rates have been observed in response to seismic airgun surveys which are similarly low-frequency, impulsive sounds (Gordon *et al.* 2003, Castellote *et al.* 2012, Blackwell *et al.* 2013).

Given their hearing sensitivity, we would expect the shortest displacement distances and durations for porpoises (with higher frequency hearing sensitivity), then dolphins and baleen whales (which are more sensitive to lower frequency sounds). To avoid the critically endangered North Atlantic right whale migration through the area, pile-driving (the loudest activity during construction) of the wind turbine foundations will likely occur during May-October, when baleen whale and harbor porpoise occurrence is expected to be relatively low. This reduces the risk of disturbance to these species, but means our ability to detect a behavioral change is reduced as their occurrence is naturally relatively rare and more difficult to distinguish from avoidance during that time. Our extended time series of previously collected data from November 2014-2017 in the study area (Bailey *et al.* 2018) will aid in identifying any changes in occurrence or distribution related to the construction activities, particularly for smaller effect sizes.

Bottlenose dolphins are the most common marine mammal species during the summer period and we expect to detect increased movement (based on localized positions) and an increased proportion of their time foraging (based on detected feeding buzzes, which are echolocation clicks at short intervals while they are hunting prey) at farther distances from the pile-driving where there is lower sound exposure (Pirotta *et al.* 2014).

We predict that there will be no evident change in bottlenose dolphin movements or occurrence because of higher ambient noise levels during increased vessel activity associated with construction or operation of the wind facility based on our previous research in the study area (Fandel *et al.* in preparation). Behavioral reactions of harbor porpoises to the operation of a wind facility are also unlikely (Tougaard *et al.* 2009), although it is possible a reaction may be observed in baleen whales because of their greater hearing sensitivity to the low frequency sound produced during the normal operation of wind turbines. It is possible that increases in prey abundance associated with the wind turbine structures could lead to increased foraging of marine mammals at the site (Russell *et al.* 2014).

While the efforts here focus on protected species monitoring, the results from this study can also contribute to mitigation efforts. The pre-construction data can help to identify construction time periods that may have a reduced level of risk due to patterns of whale occurrence. Additionally, the data can help to identify the requirements (sensitivity, spacing, operating frequency) should additional (and real-time) PAM be used for mitigation efforts for marine mammals during construction.

Approach

We use two types of PAM devices so that we are able to encompass the frequency range of vocalizations from baleen whales to small cetaceans and record continuously for 6 months at a time. This will maximize use of data storage and battery power capabilities and significantly reduce costs associated with recovery and re-deployments at sea. The PAM deployments and recovery are conducted from the University of Delaware vessel R/V Daiber, the UMCES vessel the R/V Rachel Carson or from a fishing vessel in Ocean City, MD (previously chartered the F/V Seaborn and F/V Integrity).

The first PAM device is the Rockhopper Marine Passive Acoustic Recording Unit designed by the Center for Conservation Bioacoustics at Cornell University (https://www.birds.cornell.edu/ccb/rockhopper-unit, Figure 1). The Rockhopper's predecessor, the MARU (Marine Autonomous Recording Unit), were used in our previous PAM array (Bailey *et al.* 2018). This new model has an increased memory capacity and ability to record at significantly higher sampling rates so we can detect both baleen whales and dolphins with the Rockhopper (Klinck *et al.* 2020). Rockhoppers have undergone three years of field testing in the Gulf of Mexico for a Bureau of Ocean Energy Management (BOEM) funded project, and are now ready for industry-scale monitoring applications. This archival underwater acoustic recorder is bottom-mounted on the sea floor and have a satellite tracker attached to aid with recovery if the unit prematurely surfaces (e.g., due to trawling) to reduce the risk of data loss. The hydrophone in each Rockhopper is calibrated to allow assessment of absolute ambient sound levels. The Rockhopper units are programmed to record continuously at a sampling rate of 200 kHz (effective bandwidth is half the sample rate and hence up to approximately 100 kHz). Baleen whales produce species-specific vocalizations, and have been the subject of intensive study through passive acoustic monitoring by the Center for Conservation Bioacoustics (previously named the Bioacoustics Research Program) at Cornell University (Clark and Clapham 2004, Clark *et al.* 2010, Morano *et al.* 2012a, Morano *et al.* 2012b, Murray *et al.* 2013), with many automated data processing routines in place for the identification of their vocalizations (e.g. Urazghildiiev and Clark 2006, 2007, Urazghildiiev *et al.* 2009).

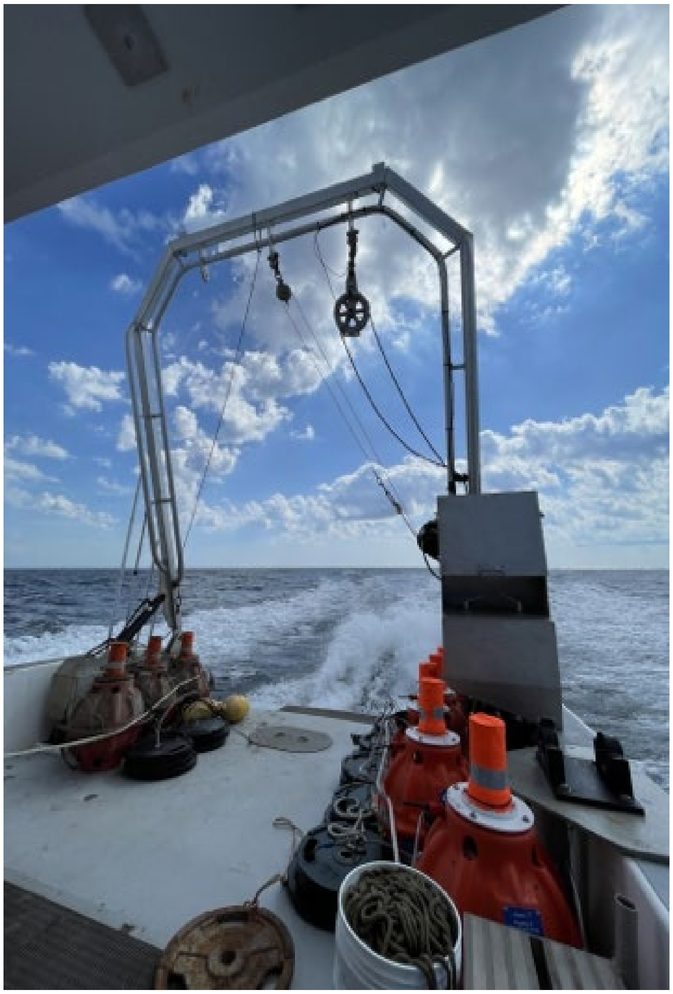


Figure 1: Recovered Rockhoppers (left) across from new Rockhoppers (right) ready to be deployed with their acoustic releases and sacrificial weights on the deck of the R/V Daiber on October 12, 2023.

As described in McCann (2012), recording raw digital sound data requires large amounts of data storage. The high frequencies produced by the smallest cetaceans, porpoises, use large amounts of memory that would require duty-cycling the devices or shorter deployments (and hence higher ship time and travel costs). We therefore use a second device called the F-POD to detect porpoises (Figure 2). Like its predecessor, the C-POD, which we used in our previous PAM array (Bailey *et al.* 2018), the F-POD uses digital waveform characterization to select cetacean echolocation clicks. It continuously monitors the 20-160 kHz frequency range and logs the time, full waveform, center frequency, sound pressure level, duration and bandwidth of each click (details at www.chelonia.co.uk), but in contrast to the Rockhopper does not record the complete soundstream. The F-POD is a relatively low-cost unit that contains a fully automated detection process for echolocation click trains produced by porpoises and dolphins. The unit is highly robust and the detection process has a very low false positive rate making it a very cost effective and time efficient device for detecting and analyzing the presence of small cetaceans (Brookes *et al.* 2013, Garrod *et al.* 2018).

The deployment of hydrophone assets will allow the marine mammal response to be evaluated in relation to distance from the wind turbines in a gradient design (Brandt *et al.* 2011, Bailey *et al.* 2014). In the study design we use a multi-scaled design with a large cross-shelf array within which there is a more focused localization array within the Lease Area. This satisfies the recommendation by BOEM in the Guidelines for Providing Information on Marine Mammals and Sea Turtles for Renewable Energy Development on the Atlantic Outer Continental Shelf (version June 2019, https://www.boem.gov/sites/default/files/renewable-energy-program/Regulatory-Information/BOEM-Marine-Mammals-and-Sea-Turtles-Guidelines.pdf). In Table 3 of this BOEM guidance it is stated "PAM methodologies that facilitate localization of vocalizing animals are highly encouraged." This localization array will allow us to identify the fine-scale locations of calling North Atlantic right whales, humpback whales, and whistling dolphins to determine if there is any change in distribution or movements BEFORE, DURING and AFTER the wind facility construction. The devices are also located at sites that included the area of potential effects (APE) as similarly covered in our previous PAM array (Award Ref. No. 14-14-1916 BOEM and 14-17-2241 BOEM) and recommended by BOEM in their survey guidelines.

Figure 2. UMCES and Cornell team members deploying an F-POD shown from the R/V Daiber and a photograph of an F-POD (right, from www.chelonia.co.uk).

Survey Design and Data collection

Ten Rockhopper units are deployed in a synchronized localization array within the Maryland Lease Area (n=7), and at three locations outside of the Lease Area sampling inshore (west) and offshore (east) within the APE. We are using similar locations to our previous PAM array to maintain consistency over time (Figure 3). This array configuration of the Rockhopper units will allow for understanding of spatial and temporal occurrence of baleen whale and dolphin species in and around the Lease Area. North Atlantic right whale, humpback whale, and dolphin calls that are detected on 3 or more Rockhoppers will be considered locatable and further analyzed to calculate a location estimate using the methodology applied in our previous project (Bailey *et al.* 2018).

The F-PODs are deployed at 6 sites to detect small cetacean (porpoise and dolphin) echolocation clicks. They are deployed within and outside the Lease Area at sites near where the C-PODs were previously deployed to encompass a range of distances and directions from the wind turbines (sites T-1M, A-1M, A-4M, A-5M, T-2M and T-3M, Figure 3). Two F-PODs are centered in the planned MarWin construction area in the southeast portion of the Lease Area to better capture expected avoidance behaviors during the CONSTRUCTION Period. Fewer sites are monitored with the F-PODs for porpoises than the other species because the harbor porpoise population has a relatively high abundance (estimated at 75,079 in the area central Virginia to Maine), is not listed as threatened or endangered under the Endangered Species Act, and this population is not considered strategic under the Marine Mammal Protection Act (MMPA) (Hayes *et al.* 2020). It should be noted that in contrast, the bottlenose dolphins present in the study area are from the Western North Atlantic Northern Migratory Coastal Stock, which is a strategic stock due to its designation as depleted under the MMPA. Hence, as a result of this designation and the prevalence of bottlenose dolphins within the study area, we are using a sufficiently high sampling rate to detect dolphin calls at all ten sites with the Rockhoppers.

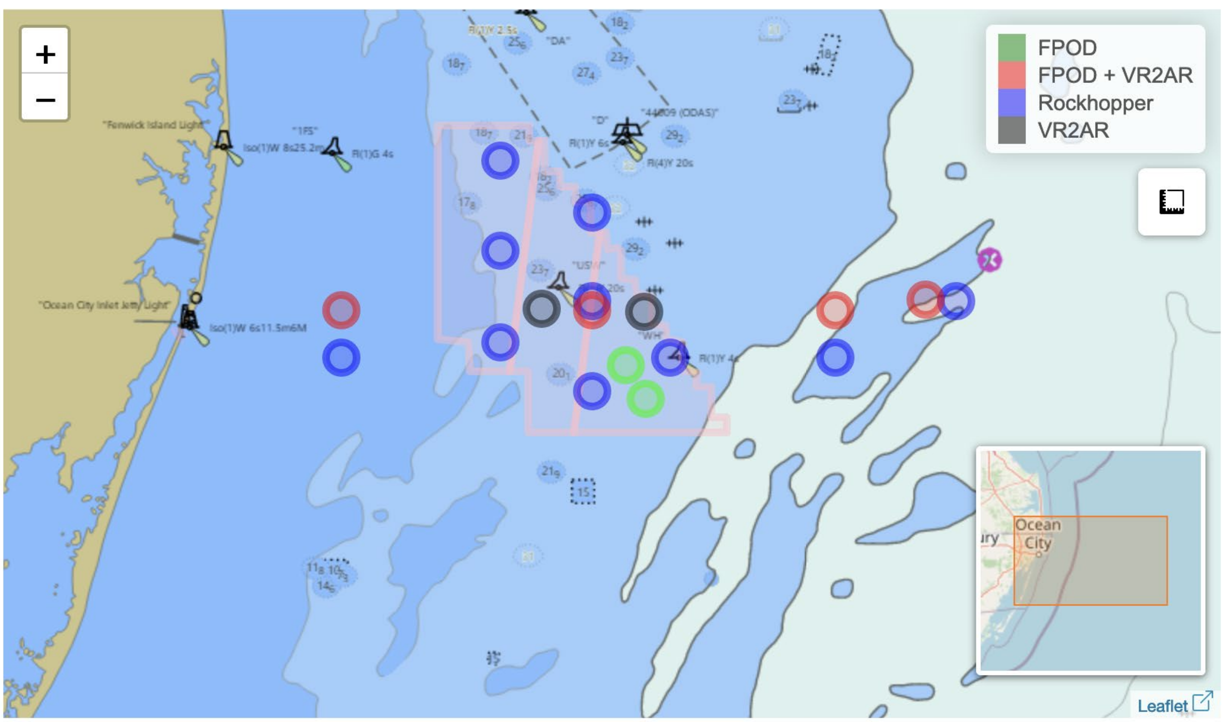


Figure 3. Map of the PAM recording devices (Rockhopper, blue; F-POD and VR2 units, red; F-PODs only, green; VR units only, gray) within and surrounding the Maryland Lease Area (faint pink lines).

As a complement to our marine mammal monitoring, Co-PI Secor is contributing Innovasea (previously known as VEMCO) receivers for acoustically tagged fish that are co-located at up to four of our mooring sites to provide additional information on the spatiotemporal pattern of tagged fish occurrence (such as endangered Atlantic sturgeon, white sharks and sand tiger sharks).

Data Analysis

Temporal patterns of marine mammal occurrence

Baleen whale species and dolphins are identified from the acoustic recordings using a combination of automated call detection software and expert human validation. We can then construct a time series of detections at each site for the baleen whale species North Atlantic right whales, fin whales, and humpback whales, and for dolphin species. Species occurrence will be described at daily, weekly, monthly, and seasonal scales across the duration of the survey.

Bottlenose dolphins produce individually distinctive signature whistles that can remain consistent throughout their lifetime (Sayigh *et al.* 1990, Janik and Sayigh 2013). The identity information is encoded within the shape of the contour of the whistle, establishing independent features (Janik *et al.* 2006). The concept of utilizing signature whistles to identify free-ranging bottlenose dolphins is a recent application (Janik *et al.* 2013, Gridley *et al.* 2014, Longden *et al.* 2020). A recent study by our team identified over 1,000 individual bottlenose dolphin signature whistles within and surrounding the Maryland Lease Area (Bailey *et al.* 2018, Bailey *et al.* 2021).

The process of identifying dolphin signature whistles is currently very time-consuming and labor intensive. We will develop an automated machine learning algorithm that will improve the time-efficiency and accuracy of processing the sounds recorded to identify and match signature whistles to track individual dolphins. Machine learning algorithms have achieved unprecedented accuracy in human speech recognition (Saon *et al.* 2017) and, being applied to acoustic recordings, can greatly advance capabilities and speed of acoustic analysis and increase autonomy of data processing by minimizing human input in the process. We will investigate the applicability of deep neural network architectures including long-short term memory (Yu and Kim 2018) and convolutional neural networks (CNN; e.g., de Benito-Gorron *et al.* 2019). We will train and evaluate these network models using available manually processed recordings. We will specifically test performance of CNNs with residual connections—a relatively new architecture that has proven to be effective in delivering high classification performance for time series (Fawaz *et al.* 2019, Zhong *et al.* 2020). Implementation of deep neural networks such as CNN and unbounded interleaved-state recurrent neural network (UIS-RNN; Zhang *et al.* 2019) will allow us to add new individuals in the classification results during the operation stage (i.e., expand the library of dolphin signature whistles). The use of signature whistles in our study will enable us to determine the abundance, density and site fidelity of dolphins (Longden *et al.* 2020) in relation to the periods BEFORE, DURING and AFTER. This is also important for identifying whether animals that return after the construction activities are those that were exposed to the sounds produced during construction or are new (naïve) animals that have moved from other areas.

Porpoise calls are automatically detected by the F-POD devices. Data are downloaded and processed using the custom F-POD software freely available from Chelonia Ltd. (details at www.chelonia.co.uk), and analyzed by the UMCES team to determine the time series of detection positive hours (DPH, hours in which at least one echolocation click train was detected). During the first and second years, we deployed mooringings with both an F-POD and C-POD device so that we can determine the comparability of detection rates at the hourly and daily scale.

In addition to the data collected during this project, the UMCES team are also analyzing and collating porpoise and dolphin detection data from the F-POD and LS1X acoustic recorder deployed in association with US Wind's metocean buoy that was deployed in May 2021 for one year. This information will be combined with our previously collected data and our BEFORE data from this project.

Temporal patterns of occurrence will be analyzed in relation to the pile-driving and other wind facility construction activities, the distance from the wind turbine structures and received sound level, in a similar approach to Brandt et al. (2011) (Figure 4). The analysis will include comparison with the pre-construction (BEFORE) data from this project, together with that from the acoustic recorders associated with the metocean buoy and our previously collected data in the study area, using generalized auto-regressive moving average models (or similar approach) to account for the correlation in time series data (Wingfield *et al.* 2017).

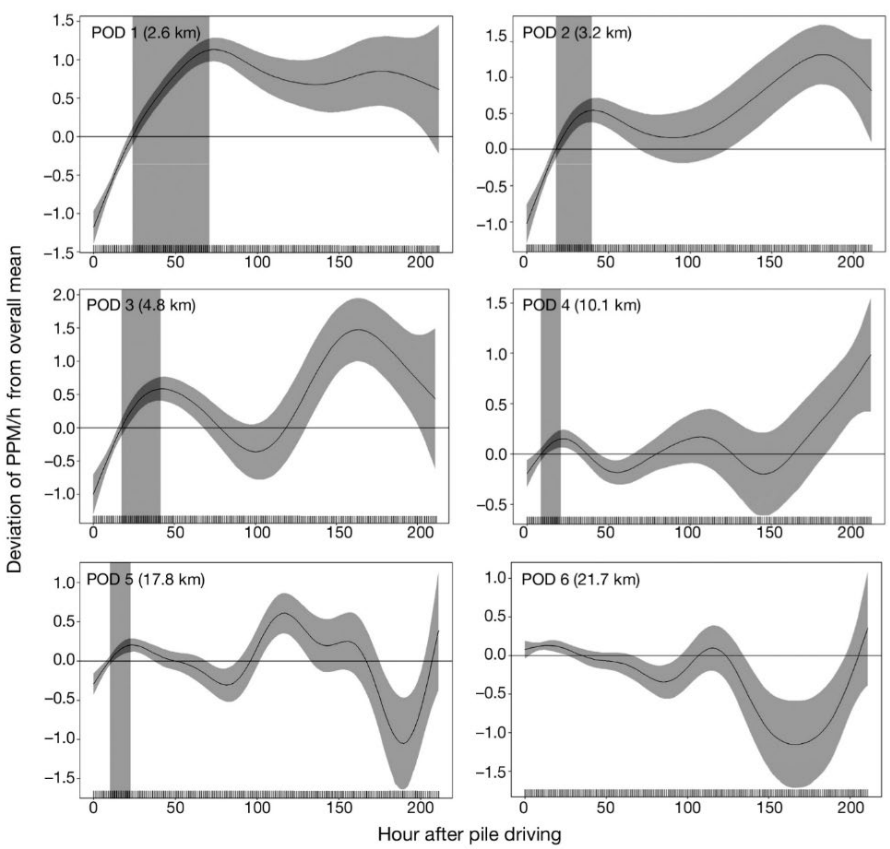


Figure 4: Example of approach to determine whether there is a response to the structure installation, its temporal extent and spatial gradient. These graphs show an analysis of porpoise detections from C-PODs

at a range of distances from the pile-driving of the Horns Rev II offshore wind farm in the Danish North Sea from Brandt et al. (2011). The lines show the deviation in occurrence from the overall mean at each site and how this changes with time after pile-driving at different distances away (gray areas around the line represent 95% confidence intervals). The gray shaded vertical boxes indicate the range of the possible duration of the effect.

Spatial distribution and movements of marine mammals

Using the approach in our earlier study (Bailey *et al.* 2018, Fandel *et al.* in preparation), we will estimate positions of North Atlantic right whales, humpback whales, and dolphins from localizing their calls. We will compare spatial distributions before, during and after construction activities and specifically pile-driving. Spatial distributions at different periods will be compared using the following statistical methods. First, traditional statistical metrics will be used such as area-weighted mean absolute deviation and standard deviation. These metrics quantify the overall average differences, however, do not necessarily inform how well the areas of occurrence overlap in different periods or if the differences are statistically significant. The spatial similarity test (Smith 2020) will be applied for determining statistical significance of the changes. Second, for binary-type area comparisons, we will use methods of spatial forecast verification based on contingency tables (aka confusion matrices), such as the threat score, which quantifies the proportion of the area that was correctly predicted (e.g., based on the observations in the previous period). Our third type of forecast evaluation, the intensity-scale verification approach (Casati *et al.* 2004, Yu *et al.* 2020) will consider both the spatial scale and the magnitude of differences. This method unites the first two approaches and compares the distributions on several spatial scales. By considering coarser spatial scales, an exact match of spatial occurrence in different periods is not required and a spatially close resemblance is acknowledged.

We will also use sequences of calls to form movement tracks, where possible, to determine how movement speeds and linearity vary in relation to the underwater sound levels before, during and after the wind turbines have been constructed (using the methods in Fandel *et al.* in preparation).

Ambient sounds levels and sound exposure levels

Ambient sound may be highly temporally variable as a result of the periodicity of physical processes, vocally active biological constituents, and the contribution of anthropogenic sounds to the environment. We will calculate the ambient sound levels and analyze variation over time displayed as spectrograms (frequency variations over time), and power spectra (power variations over time) (Clark *et al.* 2009, Hildebrand 2009, Rice *et al.* 2014, Estabrook *et al.* 2016). The received levels at our acoustic recorder sites at a range of distances from the wind turbine construction will allow us to estimate sound exposure levels by marine mammals. We will compare the temporal and spatial occurrence of marine mammal species with ambient sound levels to determine their reaction to changes in underwater noise levels, and particularly those associated with activities DURING construction (including pile-driving) and AFTER when the wind turbines are operational.

Milestone Schedule

Project schedule:

- November 2021 – UMCES prepare sub-award agreement with Cornell University.
- November 2021 to November 2023 – UMCES will analyze the dolphin and porpoise detections from the metocean buoy acoustic data and work with Cornell to create a data management system for all of the acoustic data and detections in the Maryland Lease Area.
- November 2022 to March 2023 – Cornell and UMCES order, prepare, and test the acoustic recorders, discuss with US Wind the device locations, and obtain any necessary permits. Cornell will provide training on their whale detection algorithms.
- April 2023 – UMCES and Cornell deploy the acoustic recorders (10 Rockhoppers and 6 F-PODs).
- October 2023 to April 2029 – UMCES and Cornell recover and re-deploy the acoustic recorders every 6 months (April/October of each year) for 6 years. UMCES team identify and analyze the marine mammal detections from the acoustic recorders.
- April 2029 – Cornell will recover the acoustic recorders.
- May to October 2029 –UMCES and Cornell complete the data archiving, final analyses and prepare the Final Report.

Period	**Month/Year**
BEFORE	April 2023 – April 2025
DURING CONSTRUCTION	April 2025 – April 2027
AFTER	April 2027 – April 2029

Details on our planned activities and milestones are given in Table 1.

Table 1: Summary of activities and milestones

Activity	Year							
	1	2	3	4	5	6	7	8
Refine detectors for marine mammal calls, particularly dolphin signature whistles	X	X						
Process dolphin and porpoise detections from the US Wind metocean buoy acoustic data	X	X						
Order and prepare acoustic monitoring equipment and moorings		X						
Obtain necessary permits and submit notice to mariners		X						
Deploy acoustic monitoring devices at ten sites in our PAM array		X	X	X	X	X	X	
Deploy and recover a mooring with a C-POD and F-POD to check the detection rates are comparable		X						
Recover and re-deploy acoustic monitoring devices		X	X	X	X	X	X	
Final recovery of the acoustic monitoring devices								X
Process acoustic data and identify species detected from PAM array		X	X	X	X	X	X	X
Assess ambient noise levels			X	X	X	X	X	X
Analyze temporal occurrence of marine mammals from processed acoustic data			X	X	X	X	X	X

Activity	Year							
	1	2	3	4	5	6	7	8
Calculate spatial locations, analyze spatial distributions, and characterize movements			X	X	X	X	X	X
Determine whether there is an observable response by marine mammals to the construction of the offshore wind facility				X	X	X	X	
Determine whether there is an observable response by marine mammals to the operation of the offshore wind facility							X	X
Presentations at relevant meetings and conferences		X	X	X	X	X	X	X
Preparation of scientific manuscripts			X	X	X	X	X	X
Semi-Annual Progress Reports		X	X	X	X	X	X	X
Final Report and 2-page summary sheet								X

Deliverables

1) Semi-annual progress reports containing cruise reports, summaries of daily marine mammal occurrence (specifically dolphins and porpoises in Years 1 and 2 with the addition of North Atlantic right whales, humpback whales and fin whales in Years 3 to 8), the temporal pattern and spatial distribution of vocalizing marine mammal species, positions of localized North Atlantic right whale, humpback whale and dolphin calls where possible (Years 3 to 8), and list of project products (data sharing, publications, presentations).
2) Final report containing complete reporting on study findings, analysis of any observed baleen whale, dolphin and porpoise response to the construction and operation of a wind facility in the Maryland Lease Area, recommendations, and project products.
3) Two-page summary sheet giving the project overview and key findings.

4) Results will be presented at meetings and in manuscripts that will be submitted to peer-reviewed scientific journals.
5) The raw acoustic data will be shared with NOAA's National Centers for Environmental Information (NCEI) and the Northeast Passive Acoustic Program after the acoustic recorders are recovered.

Project Management

Dr.s Helen Bailey and David Secor are responsible for managing the project. Dr. Bailey is responsible for providing the F-PODs to Cornell University for deployment, for the analysis of the acoustic recordings for vocalizing marine mammal species, the temporal variation and spatial distribution of detected species from the study, determining whether there is an observable marine mammal response to the construction or operation of an offshore wind facility, an analysis of the ambient sound levels, and report and manuscript writing. Dr. Secor manages personnel, contracts, budgets, and assists with deployment logistics.

Dr. Aaron Rice is the PI at Cornell University and is the Principal Ecologist at their Center for Conservation Bioacoustics. Dr. Rice is responsible for providing the Rockhopper units, their deployment and recovery, archiving the raw acoustic data, transferring a copy of the acoustic data to UMCES, and training the UMCES team on their procedure for identifying whale calls and calculating positions where localization is possible for whales and dolphins. He also contributes to project reports and scientific manuscripts.

Data Management

Our data management objectives are to protect the data while analysis is occurring at UMCES and Cornell, preserve data for future use, and provide the data to the broader community for expanded use. We will develop our data management program as a maturing component of the project to reflect improving data management methodologies or strategies.

Data Products

The data products to be managed under this plan include sound files, spatial and temporal metadata associated with sound files, sound files with identified species calls, and synthesized data products describing spatial and temporal patterns of identified species calls, such as geographical information system (GIS) map layers and summaries of acoustic occurrence data.

Excerpted original sound recordings and their associated metadata, along with annotations of species-specific vocalizations will be shared with the public and scientific community with unrestricted access through the website of Cornell's Macaulay Library of Natural Sounds (http://macaulaylibrary.org/), one of the world's largest online repositories of sounds. The Macaulay Library has currently applied for accreditation by the Center for Research Libraries for archiving of digital media. As such, we will make its audio standards follow those of Macaulay Library.

Content and Format

Sound recordings are recorded and stored as WAV formatted files. These audio files are annotated with temporal and spatial metadata, time of recording (GMT), latitude and longitude of recording location, water temperature, and salinity. Temporal and spatial metadata follows Federal Geospatial Metadata Standards (http://www.fgdc.gov/metadata/geospatial-metadata-standards). The Cornell University team at the Center for Conservation Bioacoustics has sound analysis tools for visualization and annotation of specific sound events. These data, including the temporal metadata, are exported to a database, and connected to the original sound file, for data summarization and reference. Acoustic data from the Rockhoppers and detection information from the F-PODs are stored by Cornell University with on-site, off-site, and cloud-based back-ups.

At UMCES, MMM project data are housed on the dedicated server, "*delphinus,"* built to meet the processing and storage needs of the program. An interactive map-based portal will allow data query by instrument deployment for the project period, but also include historical data from previous BOEM studies in the wind project area. The server's configuration is:

- AMD Ryzen Threadripper 3960X processor (24 cores @ 3.8GHz)
- 128GB of ECC DDR3 RAM
- 96TB storage
- Ubuntu 22.04 LTS
- 10GbE fiber connections to project workstations on the UMCES Chesapeake Biological Laboratory (CBL) network

Initial software installation and configuration:

- SAMBA Server for Windows interoperability
- NGINX web server for internal document storage
- PostgreSQL database
- Matlab (Pamguard, Raven-X, and other acoustic analysis packages)
- GIT repository for software source control
- Programming languages (Java, R, Julia, Python, C/C++)

Access

All acoustic data and resulting data products are stored on a centralized Cornell backup system with duplicate off-site backup. Representative sound files with identified species will be made available to the public within the timeline of this project and available after the completion of this project through the Macaulay Library website. Due to the immense size of the entire dataset (>500,000 hours of audio data), it is impractical to serve all of the data over the internet. At the conclusion of the project, acoustic records containing identified species' calls, in database form, will be made accessible through a Cornell data server for future, ongoing analysis. The raw acoustic data will be provided to the NOAA Northeast Passive Acoustic Program (Current Program Lead: Dr. Sofie Van Parijs) and archived at NOAA's NCEI, which is the repository BOEM requested for our previously collected passive acoustic data. In addition, spatially referenced synthesized data products can be shared through the Mid-Atlantic Ocean Data Portal and/or MarineCadastre.gov. The acoustic detection information will be shared publicly, including with the regulatory agencies BOEM and NOAA and any other groups US Wind requests. Co-authorship will be given to the project team on any publications that arise during this research project.

Any information collected from Dr. David Secor's Innovasea tag receivers will be shared through the Mid-Atlantic Acoustic Telemetry Observation System (MATOS).

Bibliography

Bailey, H., K. L. Brookes, and P. M. Thompson. 2014. Assessing environmental impacts of offshore wind farms: Lessons learned and recommendations for the future. Aquatic Biosystems 10: 8.

Bailey, H., A. Rice, J. E. Wingfield, K. B. Hodge, B. J. Estabrook, D. Hawthorne, A. Garrod, A. D. Fandel, L. Fouda, E. M. McDonald, E. Gryzb, W. Fletcher, and A. L. Hoover. 2018. Determining habitat use by marine mammals and ambient noise levels using passive acoustic monitoring offshore of Maryland., Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2019-018. 232 p., pp.

Bailey, H., A. Fandel, K. Silva, K. B. Hodge, and A. N. Rice. 2019. Year 4/5 Marine Mammal Passive Acoustic Monitoring Study. Progress Report December 2019 to Maryland Department of Natural Resources, Grant Number 14-18-240 MEA. 14 p. , pp.

Bailey, H., A. D. Fandel, K. Silva, E. Gryzb, E. McDonald, A. L. Hoover, M. B. Ogburn, and A. N. Rice. 2021. Identifying and predicting occurrence and abundance of a vocal animal species based on individually specific calls. Ecosphere 12: e03685.

Blackwell, S. B., C. S. Nations, T. L. McDonald, C. R. Greene, A. M. Thode, M. Guerra, and A. M. Macrander. 2013. Effects of airgun sounds on bowhead whale calling rates in the Alaskan Beaufort Sea. Marine Mammal Science 29: E342-E365.

Brandt, M. J., A. Diederichs, K. Betke, and G. Nehls. 2011. Responses of harbour porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. Marine Ecology Progress Series 421: 205-216.

Brandt, M. J., A. C. Dragon, A. Diederichs, M. A. Bellmann, V. Wahl, W. Piper, J. Nabe-Nielsen, and G. Nehls. 2018. Disturbance of harbour porpoises during construction of the first seven offshore wind farms in Germany. Marine Ecology Progress Series 596: 213-232.

Brookes, K. L., H. Bailey, and P. M. Thompson. 2013. Predictions from harbor porpoise habitat association models are confirmed by long-term passive acoustic monitoring. Journal of the Acoustical Society of America 134: 2523-2533.

Casati, B., G. Ross, and D. B. Stephenson. 2004. A new intensity-scale approach for the verification of spatial precipitation forecasts. Meteorological Applications: A journal of forecasting, practical applications, training techniques and modelling 11: 141-154.

Castellote, M., C. W. Clark, and M. O. Lammers. 2012. Acoustic and behavioural changes by fin whales (*Balaenoptera physalus*) in response to shipping and airgun noise. Biological Conservation 147: 115-122.

Clark, C. W., and P. J. Clapham. 2004. Acoustic monitoring on a humpback whale (*Megaptera novaeangliae*) feeding ground shows continual singing into late spring. Proceedings of the Royal Society of London B: Biological Sciences 271: 1051-1057.

Clark, C. W., W. T. Ellison, B. L. Southall, L. Hatch, S. M. Van Parijs, A. Frankel, and D. Ponirakis. 2009. Acoustic masking in marine ecosystems: intuitions, analysis, and implication. Marine Ecology Progress Series 395: 201-222.

Clark, C. W., M. W. Brown, and P. Corkeron. 2010. Visual and acoustic surveys for North Atlantic right whales, *Eubalaena glacialis*, in Cape Cod Bay, Massachusetts, 2001-2005: Management implications. Marine Mammal Science 26: 837-854.

Dähne, M., A. Gilles, K. Lucke, V. Peschko, S. Adler, K. Krügel, J. Sundermeyer, and U. Siebert. 2013. Effects of pile-driving on harbour porpoises (*Phocoena phocoena*) at the first offshore wind farm in Germany. Environmental Research Letters 8: 025002.

de Benito-Gorron, D., A. Lozano-Diez, D. T. Toledano, and J. Gonzalez-Rodriguez. 2019. Exploring convolutional, recurrent, and hybrid deep neural networks for speech and music detection in a large audio dataset. EURASIP Journal on Audio, Speech, and Music Processing 2019: 9.

Estabrook, B. J., D. W. Ponirakis, C. W. Clark, and A. N. Rice. 2016. Widespread spatial and temporal extent of anthropogenic noise across the northeastern Gulf of Mexico shelf ecosystem. Endangered Species Research 30: 267-282.

Fandel, A. D., K. B. Hodge, A. N. Rice, and H. Bailey. in preparation. Bottlenose dolphin (Tursiops truncatus) movements under varied ambient sound conditions.

Fawaz, H. I., G. Forestier, J. Weber, L. Idoumghar, and P.-A. Muller. 2019. Deep learning for time series classification: A review. Data Mining and Knowledge Discovery 33: 917-963.

Garrod, A., A. D. Fandel, J. E. Wingfield, L. Fouda, A. N. Rice, and H. Bailey. 2018. Validating automated click detector dolphin detection rates and investigating factors affecting performance. The Journal of the Acoustical Society of America 144: 931-939.

Gordon, J., D. Gillespie, J. Potter, A. Frantzis, M. P. Simmonds, R. Swift, and D. Thompson. 2003. A review of the effects of seismic surveys on marine mammals. Marine Technology Society Journal 37: 16-34.

Graham, I. M., N. D. Merchant, A. Farcas, T. R. Barton, B. Cheney, S. Bono, and P. M. Thompson. 2019. Harbour porpoise responses to pile-driving diminish over time. Royal Society Open Science 6: 190335.

Gridley, T., V. G. Cockcroft, E. R. Hawkins, M. L. Blewitt, T. Morisaka, and V. M. Janik. 2014. Signature whistles in free-ranging populations of Indo-Pacific bottlenose dolphins, *Tursiops aduncus*. Marine Mammal Science 30: 512-527.

Hayes, S. A., E. Josephson, K. Maze-Foley, and P. E. Rosel. 2020. US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments - 2019. US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA. NOAA Technical Memorandum NMFS-NE-264., 479 pp.

Hildebrand, J. A. 2009. Anthropogenic and natural sources of ambient noise in the ocean. Marine Ecology Progress Series 395: 5-20.

Janik, V. M., L. S. Sayigh, and R. S. Wells. 2006. Signature whistle shape conveys identity information to bottlenose dolphins. Proceedings of the National Academy of Sciences 103: 8293-8297.

Janik, V. M., S. L. King, L. S. Sayigh, and R. S. Wells. 2013. Identifying signature whistles from recordings of groups of unrestrained bottlenose dolphins (*Tursiops truncatus*). Marine Mammal Science 29: 109-122.

Janik, V. M., and L. S. Sayigh. 2013. Communication in bottlenose dolphins: 50 years of signature whistle research. Journal of Comparative Physiology A 199: 479-489.

Klinck, H., D. Winiarski, R. C. Mack, C. T. Tessaglia-Hymes, D. W. Ponirakis, P. J. Dugan, C. Jones, and H. Matsumoto. 2020. The Rockhopper: a compact and extensible marine autonomous passive acoustic recording system. Pages 1-7 *in* Global Oceans 2020: Singapore-US Gulf Coast. IEEE.

Longden, E. G., S. H. Elwen, B. McGovern, B. S. James, C. B. Embling, and T. Gridley. 2020. Mark–recapture of individually distinctive calls—a case study with signature whistles of bottlenose dolphins (*Tursiops truncatus*). Journal of Mammalogy 101: 1289-1301.

McCann, J. 2012. Developing environmental protocols and modeling tools to support ocean renewable energy and stewardship. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs, Herndon, VA, OCS Study BOEM 2012-082, 626 pp.

Morano, J. L., A. N. Rice, J. T. Tielens, B. J. Estabrook, A. Murray, B. L. Roberts, and C. W. Clark. 2012a. Acoustically detected year-round presence of right whales in an urbanized migration corridor. Conservation Biology 26: 698-707.

Morano, J. L., D. P. Salisbury, A. N. Rice, K. L. Conklin, K. L. Falk, and C. W. Clark. 2012b. Seasonal and geographical patterns of fin whale song in the western North Atlantic Ocean. Journal of the Acoustical Society of America 132: 1207-1212.

Murray, A., A. N. Rice, and C. W. Clark. 2013. Extended seasonal occurrence of humpback whales in Massachusetts Bay. Journal of the Marine Biological Association of the United Kingdom doi: 10.1017/S0025315412001968.

Pace, R. M., P. J. Corkeron, and S. D. Kraus. 2017. State-space mark-recapture estimates reveal a recent decline in abundance of North Atlantic right whales. Ecology and Evolution doi: 10.1002/ece3.3406.

Pirotta, E., K. L. Brookes, I. M. Graham, and P. M. Thompson. 2014. Variation in harbour porpoise activity in response to seismic survey noise. Biology Letters 10: 20131090.

Rice, A. N., J. T. Tielens, B. J. Estabrook, C. A. Muirhead, A. Rahaman, M. Guerra, and C. W. Clark. 2014. Variation of ocean acoustic environments along the Western North Atlantic Coast: A case study in context of the right whale migration route. Ecological Informatics 21: 89-99.

Russell, D. J. F., S. M. J. M. Brasseur, D. Thompson, G. D. Hastie, V. M. Janik, G. Aarts, B. T. McClintock, J. Matthiopoulos, S. E. W. Moss, and B. McConnell. 2014. Marine mammals trace anthropogenic structures at sea. Current Biology 24: R638-R639.

Saon, G., G. Kurata, T. Sercu, K. Audhkhasi, S. Thomas, D. Dimitriadis, X. Cui, B. Ramabhadran, M. Picheny, L.-L. Lim, B. Roomi, and P. Hall. 2017. English Conversational Telephone Speech Recognition by Humans and Machines. arXiv 1703.02136.

Sayigh, L. S., P. L. Tyack, R. S. Wells, and M. D. Scott. 1990. Signature whistles of free-ranging bottlenose dolphins *Tursiops truncatus*: stability and mother-offspring comparisons. Behavioral Ecology and Sociobiology 26: 247-260.

Smith, T. E. 2020. Notebook on Spatial Data Analysis [online]. http://www.seas.upenn.edu/~ese502/ - notebook.

Tougaard, J., O. D. Henriksen, and L. A. Miller. 2009. Underwater noise from three types of offshore wind turbines: Estimation of impact zones for harbor porpoises and harbor seals. The Journal of the Acoustical Society of America 125: 3766-3773.

Urazghildiiev, I. R., and C. W. Clark. 2006. Acoustic detection of North Atlantic right whale contact calls using the generalized likelihood ratio test. Journal of the Acoustical Society of America 120: 1956-1963.

Urazghildiiev, I. R., and C. W. Clark. 2007. Acoustic detection of North Atlantic right whale contact calls using spectrogram-based statistics. Journal of the Acoustical Society of America 122: 769-776.

Urazghildiiev, I. R., C. W. Clark, T. P. Krein, and S. E. Parks. 2009. Detection and recognition of North Atlantic right whale contact calls in the presence of ambient noise. IEEE Journal of Oceanic Engineering 34: 358-368.

Wingfield, J. E., M. O'Brien, V. Lyubchich, J. J. Roberts, P. N. Halpin, A. N. Rice, and H. Bailey. 2017. Year-round spatiotemporal distribution of harbour porpoises within and around the Maryland Wind Energy Area. PLOS ONE 12: e0176653.

Yu, B., K. Zhu, M. Xue, and B. Zhou. 2020. Using new neighborhood-based intensity-scale verification metrics to evaluate WRF precipitation forecasts at 4 and 12 km grid spacings. Atmospheric Research 246: 105117.

Yu, Y., and Y.-J. Kim. 2018. A Voice Activity Detection Model Composed of Bidirectional LSTM and Attention Mechanism.*in* 2018 IEEE 10th International Conference on Humanoid, Nanotechnology, Information Technology,Communication and Control, Environment and Management (HNICEM), 1–5.

Zhang, A., Q. Wang, Z. Zhu, J. Paisley, and C. Wang. 2019. Fully Supervised Speaker Diarization.*in* ICASSP 2019 - 2019 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), 6301–6305. .

Zhong, M., M. Castellote, R. Dodhia, J. Lavista Ferres, M. Keogh, and A. Brewer. 2020. Beluga whale acoustic signal classification using deep learning neural network models. The Journal of the Acoustical Society of America 147: 1834-1841.

UMCES TailWinds Near Real-Time Whale Buoy Monitoring Program

Summary

Baleen whales – especially the critically-endangered North Atlantic Right Whale (NARW) – are sensitive to underwater noise and vulnerable to ship strikes. Near Real-Time Whale Buoys (RTWBs), developed by M. Baumgartner at WHOI, are key assets in the conservation of NARW and other baleen whales. This system collects data about baleen whale presence, supporting near real-time alerts and further insights about baleen whale occurrence relevant to offshore wind energy development and NOAA actions to curtail whale vessel strikes. The buoy relays whale detection information to shore via Iridium satellite communications every 2 hours where it is displayed in near real-time on a publically accessible website, mobile applications, and direct messaging to subscribers via email and text.

An RTWB unit has been continuously deployed from May 2021 at 38.303 N, 74.645 W within the MarWin project area. Funding has leveraged state, federal, university, and industry support. Deployment, maintenance and continuous data processing associated with the RTWB is expensive, and although long-term deployment is expected during future phases of the US Wind project, the current deployment is funded through 2024 (BEFORE construction period). To support early deployment and development stages of offshore wind and near real-time monitoring of whales in the Maryland Lease Area, Maryland DNR funded the construction, Year 1 (summer 2021-2022) deployment, and analysis of a RTWB by our team. This was followed by a second year of RTWB monitoring, Year 2 (summer 2022-2023), with a use agreement from Maryland DNR and funding support from the lessee US Wind Inc. In the current year (2023), continued RTWB monitoring is supported Maryland DNR and NOAA.

The raw acoustic data will be archived at NOAA's National Centers for Environmental Information and Northeast Fisheries Science Center's Passive Acoustic Program for wider dissemination by regulatory agencies, other stakeholders, and researchers with associated reports developed and provided to partners for dissemination.

Abbreviations

AIS	Automatic Identification System
BOEM	Bureau of Ocean Energy Management
DMON	Digital Acoustic Monitoring Instrument
DNR	Department of Natural Resources
LFDCS	Low-Frequency Detection and Classification System
MEA	Maryland Energy Administration
MFN	Multi-Function Node
NCEI	NOAA's National Centers for Environmental Information
NARW	North Atlantic Right Whale
NOAA	National Oceanic and Atmospheric Administration

RTWB	Near Real-Time Whale Detection Buoy
UMCES	University of Maryland Center for Environmental Science
WHOI	Woods Hole Oceanographic Institution

Objectives

1. Deploy the RTWB system: Annually refurbish and deploy a RTWB system consisting of a moored buoy with the capability to record and process audio in real-time using a published detection algorithm. Relay detection information to shore in near real-time via Iridium satellite communications.
2. Near real-time whale detections: Review and verify transmitted RTWB data in near real-time for detections of baleen whales (right, fin, humpback, and sei whales) from the low-frequency detection and classification system (LFDCS) software by trained analysts and evaluate system performance.
3. Comparison with whale sightings: Compare the near real-time whale detections with available visual sightings data of whale species in the study area.
4. Between-analyst variability: Evaluate between-analyst variability in detection classifications if and when changes to the analyst team occur. Update the protocol guide as needed to ensure consistency in whale classifications and based upon best available science on whale vocalizations.
5. Post-recovery audio analysis: Analyze logged audio data from the recovered RTWB to confirm whether days with missing transmissions or “Possibly detected” whale species were “Detected” or “Not Detected” to compile a final database of whale occurrence for each year.
6. Inter-annual comparison: Compare the near real-time whale detections with data from our previous RTWB and passive acoustic monitoring deployments to determine whether there are inter-annual changes in occurrence or any responses to vessel, site assessment, or development activities.
7. Display whale detection information: Display near real-time information on baleen whale presence on a public website (robots4whales.whoi.edu and https://tailwinds.umces.edu/rtwb), the Whale Alert (www.whalealert.org), Mysticetus and NOAA/BOEM’s Ocean Alert app (https://www.boem.gov/boem-harnessing-citizen-science-new-ocean-alert-mobile-app), and delivered to stakeholders via email and text messages.
8. Slow Zones: Report on Slow Zones established by NOAA for North Atlantic right whales based on the Maryland RTWB detections.

Design and Hypothesis Justification

The Maryland Lease Area (OCS-A 0490) is within an important migration route for the critically endangered North Atlantic right whale, fin whale, humpback whale, and sei whale. Whales are sensitive to elevated anthropogenic sound and vulnerable to ship strikes and entanglement in mooring lines, often associated with fishing gear. In partnership with Maryland Department of Natural Resources (DNR) and Woods Hole Oceanographic Institute (WHOI), UMCES has deployed a near real-time whale buoy (RTWB) and analyzed data since May 2021. RTWB monitoring for a second year was supported by US

Wind and in a continued collaboration with Maryland DNR and WHOI. In the current year, monitoring is supported principally by Maryland DNR. Whale presence continues to inform NOAA's right whale Slow zone and dynamic management areas, and is displayed on public websites, in apps, and delivered to stakeholders via text messages and email.

The current RTWB is owned by Maryland DNR with an anticipated lifespan of 15 years, and is an individual unit in a larger pool of RTWBs available for deployment. The UMCES/WHOI project team recovers the RTWB unit approximately annually, replacing the extant unit with a reconditioned one. The replacement RTWB allows minimal interruption in data collection. The servicing and testing of the RTWB is at the WHOI facility rather than at sea. At WHOI, unforeseen repairs can be conducted in a controlled environment.

The focus of the analysis is to identify the presence of four baleen whale species (right, humpback, fin, and sei whales) through a detection and classification system that is validated by trained analysts and displayed in near real-time on a public website and app, and distributed directly to stakeholders via email and text messages (after Baumgartner et al. 2019). The latter data sharing is important for NOAA's Dynamic Management through Right Whale Slow zones, where the "Ocean City" buoy is the only near-real-time unit between the NY Bight and mouth of the Chesapeake Bay. Near real-time detections are transmitted, analyzed, and added to our previous years' data collection. A suitable location for the RTWB was determined in consultation between UMCES, US Wind, and MD DNR (38.303 N, 74.645 W, Figure 1). The RTWB would be re-deployed at the same or similar location for future years unless activities in the area or sponsor needs indicate an alternative location would be preferable.

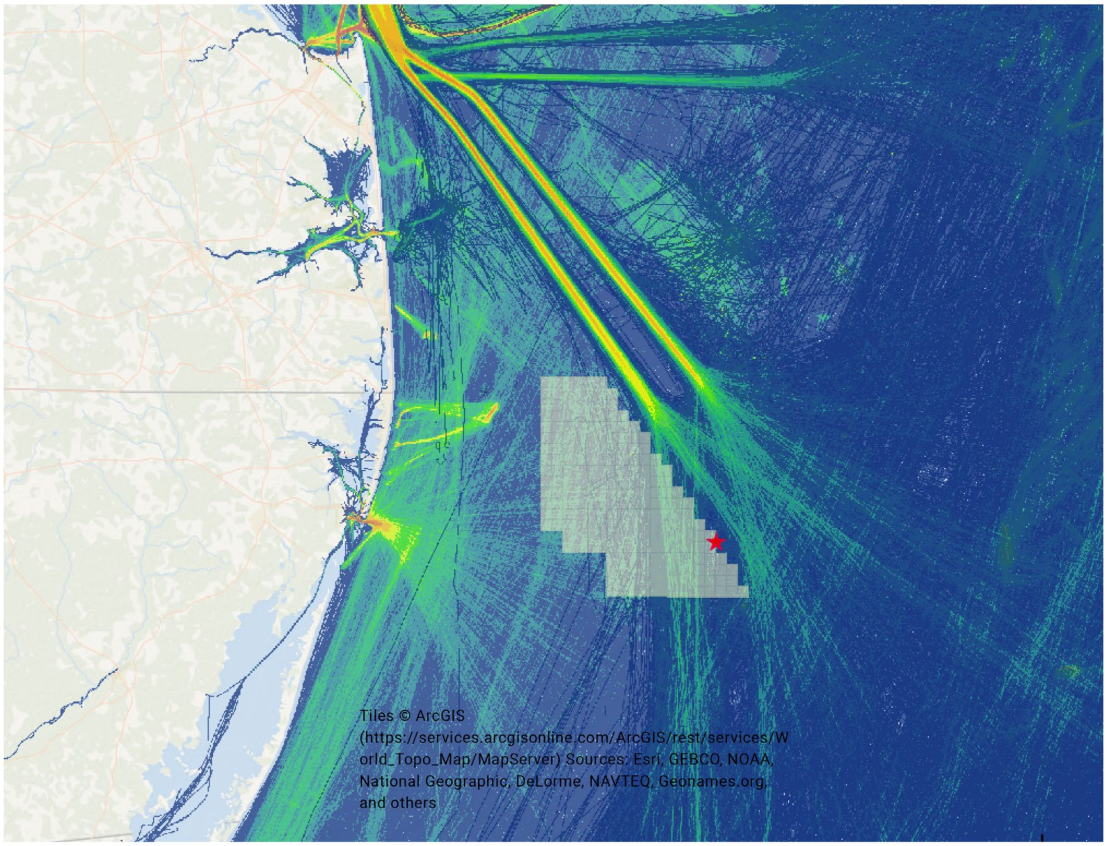


Figure 1: Location of the RTWB (red star, 38.303°N, 74.645°W) overlaid on the Maryland Lease Area (white shaded boxes) with the cargo vessel traffic density based on Automatic Identification System (AIS) data collected in 2021. Map exported from the MARCO Mid-Atlantic Ocean Data Portal.

Objective 1: Deploy the RTWB system

The RTWB system developed by WHOI (Figure 2) consists of three enabling technologies and is described in Baumgartner et al. (2019):

(1) **The digital acoustic monitoring (DMON) instrument.** The DMON is a passive acoustic recording and processing instrument (Johnson and Hurst 2007) that is capable of recording and processing audio in near real-time using custom detection algorithms (Baumgartner et al. 2013). It features a programmable digital signal processor, 32 GB of FLASH memory, and serial communications capabilities. The instrument operates at low power, making it ideal for use on power-limited autonomous platforms; when running the LFDCS software (described below), the instrument consumes just 130 mW of power. The DMON component is housed on the seabed in a faring and affixed to a bottom-mounted structure called the multi-function node (MFN; Figure 2).

(2) **The low-frequency detection and classification system (LFDCS) software.** The LFDCS software processes the detection algorithm within the DMON component and allows for detection, characterization, classification, and reporting of marine mammal tonal vocalizations (Baumgartner and Mussoline 2011). The software uses dynamic programming to estimate a pitch track for any type of tonal

marine mammal call (Baumgartner and Mussoline 2011, Baumgartner et al. 2013). A pitch track is a compact representation of a sound (analogous to a series of notes on a page of sheet music) derived from an audio spectrogram. Attributes of the pitch track are extracted and compared to the attributes of known call types in a call library using quadratic discriminant function analysis. The LFDCS call library can contain hundreds of these known call types, allowing the LFDCS to efficiently and simultaneously detect and classify many different calls produced by numerous species. To date, the LFDCS has been used to detect the calls of right, humpback, sei, fin, bowhead, beluga, killer and blue whales, as well as bearded seals (Baumgartner et al. 2013, Baumgartner et al. 2014). In addition to detecting tonal calls, the LFDCS regularly reports spectra of background noise, allowing near real-time monitoring of both biotic and abiotic sources of ambient noise (e.g., wind, ships).
(3) **An acoustically quiet mooring.** The mooring utilizes patented stretch hoses to dampen wave-induced motion and to deliver digital data from the bottom-mounted DMON to the surface buoy. The RTWB relies on a mature mooring design that allows both the delivery of digital data from a bottom-mounted acoustic monitor to the surface buoy as well as quiet operation that is essential for passive acoustic monitoring (Figure 2; Baumgartner et al. 2019). The MFN, containing the DMON component, is attached to the surface buoy by hoses that can stretch to nearly twice their relaxed length (Paul and Bocconcelli 1994); these hoses absorb the motion of the surface buoy in rough wave conditions and keep the MFN acoustically quiet. The hoses also contain helically wound conductors that allow data and power to be delivered between the MFN and the surface buoy. The surface buoy contains an electronics package that stores received DMON output data for 2 hours and then transmits those stored data to shore via an Iridium satellite modem.

The RTWB location should be in a water depth of at least 30 m to avoid surface noise masking whale calls. The current and proposed location for the RTWB was based on where the water depth was greatest in the Maryland Lease Area (approximately 35 m deep) and near the location of one of the archival acoustic monitoring devices (station A-7M) during our baseline data collection in November 2014 – November 2017 (Bailey et al. 2018). This location is contained within the US Wind “MarWin” project area, corresponding with the first phase of construction planned to start 2025-2026.

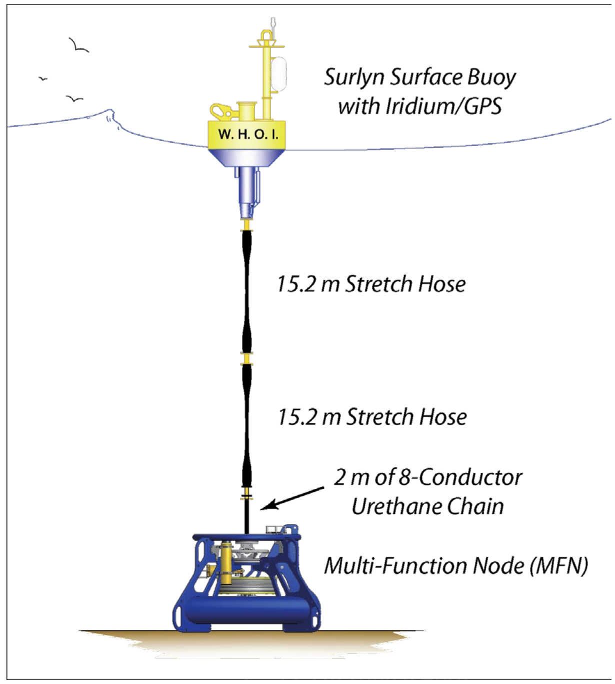


Figure 2: The Maryland RTWB constructed for the first year of monitoring and the mooring diagram featuring the bottom-mounted MFN, stretch hoses, and surface buoy.

Objective 2: Near real-time whale detections

For each 2 hourly data transmission, pitch tracks with an average amplitude of 11 dB above background sound levels are drawn and colored based on their amplitude at 15-minute intervals (periods). Higher amplitude sounds are in warmer colors and lower amplitude in colder colors (Figure 3). Up to 8Kb of detection data are transmitted per hour. Analysts from UMCES review the transmitted pitch tracks daily for the 3-year monitoring period to determine species occurrence. Each species receive a classification for each 15-minute period as “Detected”, “Possibly Detected”, or “Not Detected” based on a documented protocol for reviewing pitch tracks in near real-time (Wilder et al. 2023). Whale species presence is identified based on 4 criteria: amplitude, shape of the pitch tracks, isolation from other pitch tracks, and classification of species-specific calls by the LFDCS based on the frequency of the sound over time in relation to a reference library (see section 2 of Objective 1). Fin whales are identified by a 20Hz pulse train (call type 4) with a consistent inter-pulse interval that changed seasonally (Morano et al. 2012). North Atlantic right whales are identified by up-calls at 200Hz or just below (call types 5, 6, 7 and 8). Song patterns are used to identify humpback whales, and down-sweeps as singles, doublets, or triplets between 30 and 100Hz indicate sei whale presence (call types 1, 2, 3 and occasionally 17).

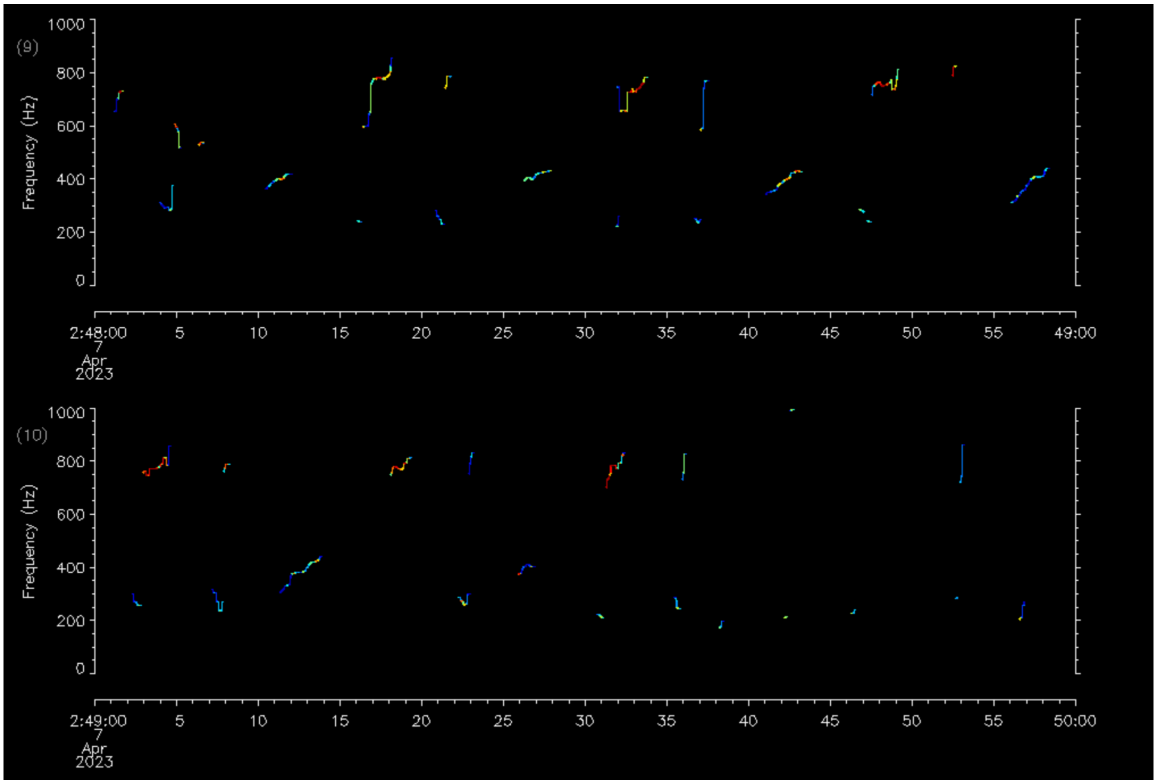


Figure 3: Pitch tracks of humpback whale calls on 7th April 2023 transmitted from the RTWB within the Maryland lease area. Warmer colored lines indicate louder sounds. The UMCES analyst classified this period as Humpback Whale Detected.

Objective 3: Comparison with whale sightings

Available visual sighting reports of whale species within the study area will be compared with near real-time RTWB data corresponding with that time period to compare occurrence by these two different survey methods. Visual sightings can also help to confirm whale presence if the acoustic classification was "Possibly Detected" for that day. Visual sightings come from varied sources including Protected Species Observers onboard US Wind's site assessment surveys and Normandeau Associates' seasonal aerial surveys (10 per year; https://remote.normandeau.com/uswind_home.php).

Objective 4: Between-analyst variability

Pitch track data from the RTWB is reviewed daily all year round, including weekends and holidays, which requires at least 2 analysts for scheduling. The number of periods, and the time required to review them, is highest during the late autumn to spring because of the increased whale occurrence during this timeframe. Prompt review is particularly important when there are automated right whale call detections because of this species' critically endangered status. An UMCES analyst will determine if the right whale detection is confirmed, enter it on the WHOI Robots4Whales website, and this information is then conveyed to NOAA, who issues a Slow zone alert. The UMCES team has developed a procedure whereby if there is a questionable right whale detection, a second analyst is immediately contacted via text message for a second review to reduce any delay between the data transmissions, verification of whale detections, and action by NOAA. Slow Zones have economic impacts for commercial businesses and consequently it is vitally important that analysts classify detections accurately and consistently. Between analyst agreement in whale occurrence estimates for this system has been reported to be very high (Baumgartner et al. 2020). Agreement was greater for right, sei and fin whales than for humpback whales, which have more variable call types (Baumgartner et al. 2020). All UMCES analysts go through a training program prior to commencing the daily review procedure on the near real-time data and upon commencement of these duties all daily pitch tracks are reviewed by a second analyst for at least a 1-month period whilst the novice analyst gains experience. As new analysts join the team, we will compare the classifications between the experienced and novice analysts to determine between-analyst variability and its effect on whale species occurrence.

Objective 5: Post-recovery audio analysis

"Possibly detected" (PD) periods submitted in near real-time during the previous year's monitoring for baleen whales are reviewed in the archived audio recordings from the recovered RTWB to confirm the presence of whale calls. The entire hour surrounding each 15-minute period in which a whale is PD are reviewed in the Interactive Sound Analysis Software Raven Pro 1.6 (Cornell Lab of Ornithology Bioacoustics Research Program, Ithaca, NY, U.S.A). Once the presence or absence of whale calls is determined within the audio recording, the PD periods are confirmed as species "Detected" or "Not Detected" in our database and for use in further analyses.

Objective 6: Inter-annual comparison

Data is summarized to determine daily detections for each whale species and the percentage of days present per month. Interannual comparisons will be important should RTWB deployments continue into future phases of CONSTRUCTION and AFTER-Construction.

Objective 7: Display whale detection information

The buoy relays detection information generated by the DMON to shore via Iridium satellite communications every 2 hours where it is displayed in near real time on a publicly accessible website and evaluated by a trained analyst. The presence of four baleen whale species, right, humpback, sei, and fin whales, is estimated by the analyst and those estimates are also displayed in near real-time on the WHOI website (robots4whales.whoi.edu) and UMCES Tailwinds website (tailwinds.umces.edu/rtwb), displayed on the Whale Alert, Mysticetus and NOAA/BOEM's Ocean Alert apps, and delivered to stakeholders and interested parties via email and text messages (Figure 4). When the RTWB is recovered each, the raw acoustic recordings are downloaded and WHOI will share a copy with UMCES. At the end of the project, all of the audio recordings will be shared with the NOAA Northeast Fisheries Science Center's Passive Acoustic Program, currently led by Dr. Sofie Van Parijs, and archived with NOAA's National Centers for Environmental Information (NCEI), which is where BOEM have requested our previous data be archived for use by other agencies, stakeholders and researchers.

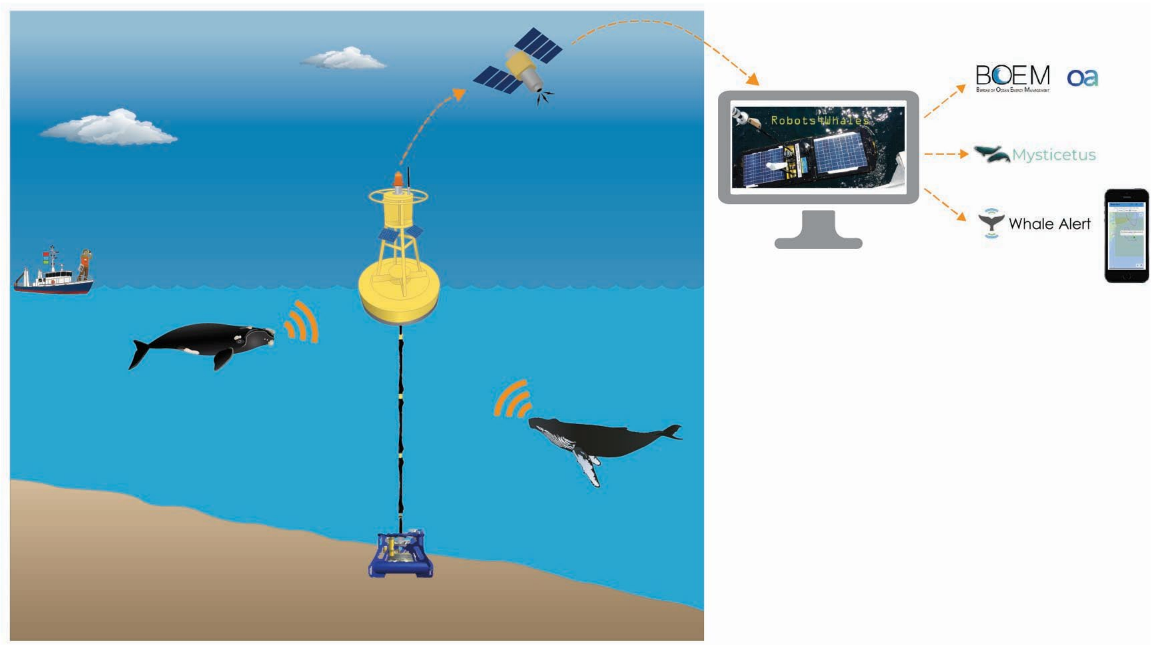


Figure 4: Diagram of the RTWB system and data dissemination. Sounds that whales make within the detection range of the RTWB recorder are transmitted from the buoy via iridium satellite communications to a computer where analysts can review the data for the presence of whales at the Robots4Whales website, dcs.whoi.edu. Any whales detected are shared with the public through the Robots4Whales and UMCES Tailwinds websites and apps (BOEM's Ocean Alert, Whale Alert, and Mysticetus).

Objective 8: Slow Zones
When North Atlantic right whales are deemed "Detected", this information is shared with the National Oceanic and Atmospheric Administration (NOAA) who notify all interested parties and recommend that all vessels travel at 10-knots or less in the vicinity by activating a Slow Zone (Figure 5). These slower speeds reduce the likelihood of a lethal ship strike with a whale (https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-vessel-strikes-north-atlantic-right-whales). The times of these recommended Slow Zones during the study period will be recorded.

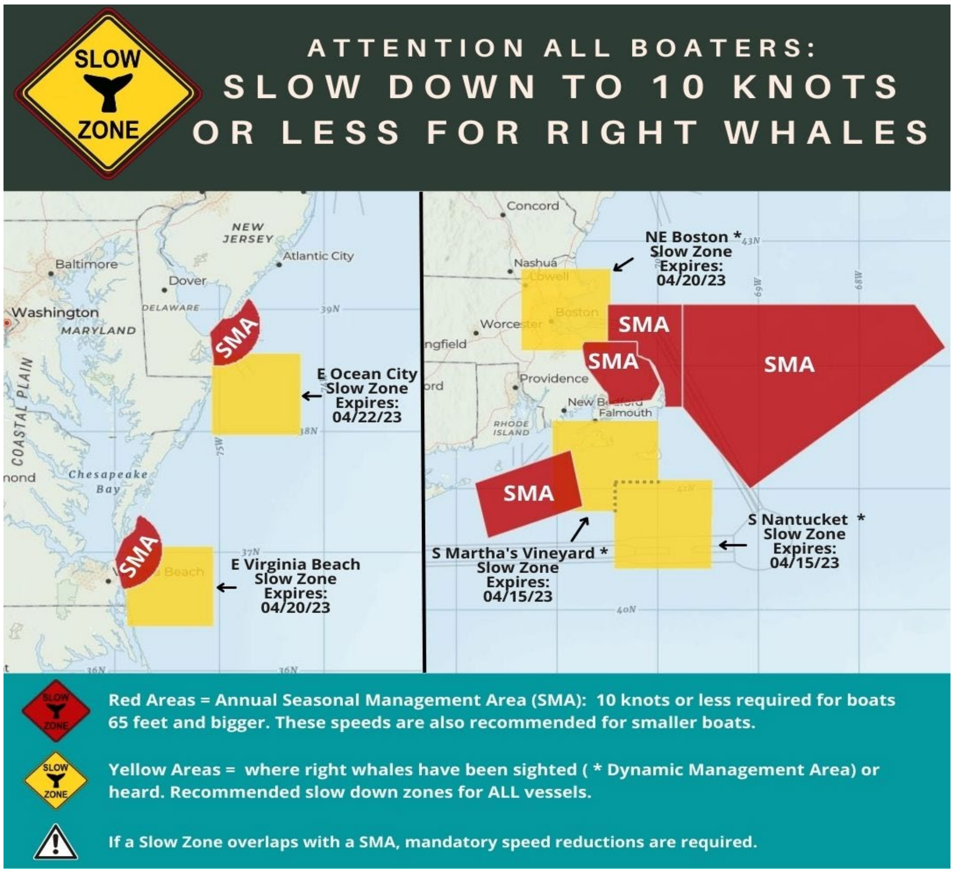


Figure 5: Map of Slow Zones for North Atlantic right whales established by NOAA. The map depicts the Slow Zone for our Ocean City, MD, study area that began on 7th April 2023.

Work Plan and Milestone Schedule

Although not yet funded, we present a four-year project workplan as an example. During the first 3 months of the project, an RTWB would be refurbished and prepared for deployment. The RTWB would be annually recovered and a replacement deployed each year for 3 years. Final recovery of the RTWB and wrap-up analysis would occur in Year 4. Details on planned activities and milestones are given in Table 1. Currently, the RTWB is supported by Maryland DNR and NOAA until 30 June 2024.

Table 1: Summary of activities and milestones. Semi-annual period 1 is 1 July – 31 December and period 2 is 1 January to 30 June of each year.

Activity	**Semi-annual period**							
	Year 1		**Year 2**		**Year 3**		**Year 4**	
	1	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Prepare RTWB	X							
WHOI submit any necessary permit applications and notice to mariners	X		X		X			
Deploy RTWB system	X							
Receive, verify, and display whale detections from RTWB	X	X	X	X	X	X	X	
Recover, re-furbish and re-deploy buoy platform			X		X			
Recover RTWB							X	
Analyze detections and compare to visual sightings and previously collected data		X	X	X	X	X	X	
Evaluate between analyst variability if there are any personnel changes		X	X	X	X	X	X	
Review recovered audio for whale detections			X	X	X	X	X	X
Presentations at relevant team, stakeholder, and scientific meetings	X	X		X		X		X
Preparation of manuscripts		X	X	X	X	X	X	X
Semi-annual progress reports		X		X		X		
Final report and 2-page summary sheet								X

Project Management

Dr. Secor (UMCES) is responsible for managing the project and supervising the UMCES analysts and completion of the reports. Dr. Bailey (Blue Wave Consulting, LLC) oversees all aspects of analysis, deployment coordination, and participates in verification and analysis of the data transmitted from the buoy platform, and contribute to manuscript and report writing. Dr. Mark Baumgartner (WHOI) is responsible for obtaining any necessary permits and the notice to mariners, and preparing, deploying and recovering the RTWB. Dr. Mark Baumgartner (WHOI) will be responsible for repairing any issues that arise with the RTWB and will display all RTWB data on the publicly accessible website robots4whales.whoi.edu (dcs.whoi.edu) and enable the data to be displayed in the Whale Alert app and other similar apps.

Data Management

Acoustic data from the RTWB is stored at WHOI and on the UMCES *delphinus* server and back-ups made on and off site. Data will be shared publicly and co-authorship given to the project team on any publications. The acoustic detection information will be shared with the regulatory agencies BOEM and NOAA and any other groups Maryland DNR requests. The raw acoustic data will be provided to the NOAA Northeast Fisheries Science Center's Passive Acoustic Program (Current Program Lead: Dr. Sofie Van Parijs) and archived at NOAA's NCEI.

Bibliography

Bailey, H., A. Rice, J. E. Wingfield, K. B. Hodge, B. J. Estabrook, D. Hawthorne, A. Garrod, A. D. Fandel, L. Fouda, E. M. McDonald, E. Gryzb, W. Fletcher, and A. L. Hoover. 2018. Determining habitat use by marine mammals and ambient noise levels using passive acoustic monitoring offshore of Maryland., Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2019-018. 232 p.

Baumgartner, M. F., J. Bonnell, P. J. Corkeron, S. M. Van Parijs, C. Hotchkin, B. A. Hodges, J. B. Thornton, B. L. Mensi, and S. M. Bruner. 2020. Slocum gliders provide accurate near real-time estimates of baleen whale presence from human-reviewed passive acoustic detection information. Frontiers in Marine Science **7**:100.

Baumgartner, M. F., J. Bonnell, S. M. Van Parijs, P. J. Corkeron, C. Hotchkin, K. R. Ball, L. P. Pelletier, J. Partan, D. Peters, J. Kemp, J. Pietro, K. Newhall, A. Stokes, T. V. N. Cole, E. Quintana, and S. D. Kraus. 2019. Persistent near real-time passive acoustic monitoring for baleen whales from a moored buoy: System description and evaluation. Methods in Ecology and Evolution **10**:1476-1489.

Baumgartner, M. F., D. M. Fratantoni, T. P. Hurst, M. W. Brown, T. V. N. Cole, S. M. Van Parijs, and M. Johnson. 2013. Real-time reporting of baleen whale passive acoustic detections from ocean gliders. The Journal of the Acoustical Society of America **134**:1814-1823.

Baumgartner, M. F., and S. E. Mussoline. 2011. A generalized baleen whale call detection and classification system. The Journal of the Acoustical Society of America **129**:2889-2902.

Baumgartner, M. F., K. M. Stafford, P. Winsor, H. Statscewich, and D. M. Fratantoni. 2014. Glider-based passive acoustic monitoring in the Arctic. Marine Technology Society Journal **48**:40-51.

Johnson, M., and T. Hurst. 2007. The DMON: an open-hardware/open-software passive acoustic detector.*in* 3rd International Workshop on the Detection and Classification of Marine Mammals using Passive Acoustics, Boston, Massachusetts, U.S.A.

Morano, J. L., D. P. Salisbury, A. N. Rice, K. L. Conklin, K. L. Falk, and C. W. Clark. 2012. Seasonal and geographical patterns of fin whale song in the western North Atlantic Ocean. The Journal of the Acoustical Society of America **132**:1207-1212.

Paul, W., and A. Bocconcelli. 1994. Drifting buoy systems using rubber stretch hose. Sea Technology **35**:37-44.

Wilder, J., G. Davis, A. DeAngelis, S. Van Parijs, and M. Baumgartner. 2023. Low-frequency detection and classification system (LFDCS) Reference Guide. US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA., NOAA Technical Memorandum NMFS-NE-295.

IMPACT PILE DRIVING REPORT

VERSION 1.2-Multi-Species: 2022

US Wind O&M FacilityProxy for proposed sheet piles

PRINT IN LANDSCAPE TO CAPTURE ENTIRE SCREEN

(if OTHER INFO or NOTES get cut-off, please include information elsewhere)

PROJECT INFORMATION	PEAK	SELss	RMS
Single strike level (dB)	204	161	170
Distance associated with single strike level (meters)	10	10	10
Transmission loss constant	15		
Number of piles per day	3		
Number of strikes per pile	975		
Number of strikes per day	2925		
Cumulative SEL at measured distance	196		

OTHER INFO Proxy Source levels from the "Impact Proxy Sound Levels" Tab

NOTES A strike rate for impact piling of the sheet piles was not provide

Attenuation 5

RESULTANT ISOPLETHS (Range to Effects)

FISHES

	ONSET OF PHYSICAL INJURY			BEHAVIOR	
	Peak Isopleth	SEL_{cum} Isopleth		RMS Isopleth	
		Fish ≥ 2 g	Fish < 2 g		
ISOPLETHS (meters)	7.4	37.8	54.1	215.4	Fishes present
Isopleth (feet)	24.1	124.0	177.5	706.8	

SEA TURTLES

	PTS ONSET		BEHAVIOR	
	Peak Isopleth	SEL_{cum} Isopleth	RMS Isopleth	
ISOPLETHS (meters)	0.1	2.8	4.6	Sea Turtles present
Isopleth (feet)	0.4	9.1	15.2	

MARINE MAMMALS

	LF Cetacean	MF Cetaceans	HF Cetaceans	PW Pinniped	OW Pinnipeds
PTS ONSET (Peak isopleth, meters)	1.0	0.2	13.6	1.2	0.1
PTS ONSET (Peak isopleth, feet)	3.3	0.6	44.6	3.8	0.4
PTS ONSET (SEL_{cum} isopleth, meters)	69.7	2.5	83.1	37.3	2.7
PTS ONSET (SEL_{cum} isopleth, feet)	228.8	8.1	272.5	122.4	8.9
	ALL MM	MF Cet. present	HF Cet. present	Phocids present	Otariids present
Behavior (RMS isopleth, meters)	46.4	LF Cet. present			
Behavior (RMS isopleth, feet)	152.3				

of this spreadsheet for 24" sheet piles in 2-6m water depth (Napa River Flood - Caltrans 2020), and strike rate/piles per day based on the schedule provided by Weston Solutions, Inc. (2023) [IHA application available

ed in the IHA application from the Naval Facilities Engineering Command Mid-Atlantic, just the duration per pile installation. Information available in Caltrans (2020) indicate sheet piles could be installed using an APE 7.

at: https://www.fisheries.noaa.gov/s3/2023-09/USCGPortAngeles-2023IHA-APP-508-OPR1.pd

.5 hammer which has a maximum blow rate capability of 75 blows per minute based on information from the manufacturer. Therefore, assuming 13-minutes for each pile installation at a max rate of 75 blows per m

IMPACT PILE DRIVING REPORT

VERSION 1.2-Multi-Species: 2022

US Wind O&M FacilityProxy for proposed 12- to 18-in steel piles

PRINT IN LANDSCAPE TO CAPTURE ENTIRE SCREEN

(if OTHER INFO or NOTES get cut-off, please include information elsewhere)

PROJECT INFORMATION	PEAK	SELss	RMS
Single strike level (dB)	199	146	156
Distance associated with single strike level (meters)	10	10	10
Transmission loss constant	15		
Number of piles per day	5		
Number of strikes per pile	100		
Number of strikes per day	500		
Cumulative SEL at measured distance	173		

OTHER INFO: Proxy Source levels from the "Impact Proxy Sound Levels" Tal

NOTES: 0

Attenuation: 5

RESULTANT ISOPLETHS (Range to Effects)

FISHES

	ONSET OF PHYSICAL INJURY: Peak Isopleth	ONSET OF PHYSICAL INJURY: SEL_{cum} Isopleth, Fish ≥ 2 g	ONSET OF PHYSICAL INJURY: SEL_{cum} Isopleth, Fish < 2 g	BEHAVIOR: RMS Isopleth	
ISOPLETHS (meters)	3.4	1.2	2.2	25.1	Fishes present
Isopleth (feet)	11.2	3.8	7.1	82.4	

SEA TURTLES

	PTS ONSET: Peak Isopleth	PTS ONSET: SEL_{cum} Isopleth	BEHAVIOR: RMS Isopleth	
ISOPLETHS (meters)	0.1	0.1	0.5	Sea Turtles present
Isopleth (feet)	0.2	0.3	1.8	

MARINE MAMMALS

	LF Cetacean	MF Cetaceans	HF Cetaceans	PW Pinniped	OW Pinnipeds
PTS ONSET (Peak isopleth, meters)	0.5	0.1	6.3	0.5	0.1
PTS ONSET (Peak isopleth, feet)	1.5	0.3	20.7	1.8	0.2
PTS ONSET (SEL_{cum} isopleth, meters)	2.1	0.1	2.6	1.1	0.1
PTS ONSET (SEL_{cum} isopleth, feet)	7.0	0.3	8.4	3.8	0.3
	ALL MM	MF Cet. present	HF Cet. present	Phocids present	Otariids present
Behavior (RMS isopleth, meters)	5.4	LF Cet. present			
Behavior (RMS isopleth, feet)	17.8				

b of this spreadsheet for 20" steel pipe in 3m water depth (generic example), and strike rate/piles per day based on the schedule provided by Weston Solutions, Inc. (2023) [IHA application available at: https://www.fishe eries.noaa.gov/s3/2023-09/USCGPortAngeles-2023IHA-APP-508-OPR1.pd

IMPACT PILE DRIVING REPORT

VERSION 1.2-Multi-Species: 2022

US Wind O&M FacilityProxy for proposed 12- to 18-in timber piles

PRINT IN LANDSCAPE TO CAPTURE ENTIRE SCREEN

(if OTHER INFO or NOTES get cut-off, please include information elsewhere)

PROJECT INFORMATION	PEAK	SELss	RMS
Single strike level (dB)	179	140	152
Distance associated with single strike level (meters)	10	10	10
Transmission loss constant	15		
Number of piles per day	5		
Number of strikes per pile	100		
Number of strikes per day	500		
Cumulative SEL at measured distance	167		

OTHER INFO Proxy Source levels from the "Impact Proxy Sound Levels" Tab

NOTES 0

Attenuation 5

RESULTANT ISOPLETHS

(Range to Effects)

FISHES

	ONSET OF PHYSICAL INJURY			BEHAVIOR	
	Peak Isopleth	SEL_{cum} Isopleth: Fish ≥ 2 g	SEL_{cum} Isopleth: Fish < 2 g	RMS Isopleth	
ISOPLETHS (meters)	0.2	0.5	0.9	13.6	Fishes present
Isopleth (feet)	0.5	1.5	2.8	44.6	

SEA TURTLES

	PTS ONSET		BEHAVIOR	
	Peak Isopleth	SEL_{cum} Isopleth	RMS Isopleth	
ISOPLETHS (meters)	0.0	0.0	0.3	Sea Turtles present
Isopleth (feet)	0.0	0.1	1.0	

MARINE MAMMALS

	LF Cetacean	MF Cetaceans	HF Cetaceans	PW Pinniped	OW Pinnipeds
PTS ONSET (Peak isopleth, meters)	0.0	0.0	0.3	0.0	0.0
PTS ONSET (Peak isopleth, feet)	0.1	0.0	1.0	0.1	0.0
PTS ONSET (SEL_{cum} isopleth, meters)	0.9	0.0	1.0	0.5	0.0
PTS ONSET (SEL_{cum} isopleth, feet)	2.8	0.1	3.3	1.5	0.1
	ALL MM	MF Cet. present	HF Cet. present	Phocids present	Otariids present
Behavior (RMS isopleth, meters)	2.9	LF Cet. present			
Behavior (RMS isopleth, feet)	9.6				

of this spreadsheet for 14" timber pile in 5m water depth (Pier 39), and strike rate/piles per day based on the schedule provided by Weston Solutions, Inc. (2023) [IHA application available at: https://www.fisheries.noaa.gov/s3/2023-09/USCGPortAngeles-2023IHA-APP-508-OPR1.pdf

minute, it was assumed for the purposes of this assessment that 975 blows would be required for each sheet p