RWSC
Regional Wildlife Science Collaborative for Offshore Wind

RWSC RESEARCH SUMMARY:
Power Analysis for the Optimal Design of a Passive Acoustic Monitoring Network for US East Coast Offshore Wind

MAIN TAKEAWAYS

- The RWSC Marine Mammal Subcommittee conducted a simulation study to assess the statistical power of a regional scale passive acoustic monitoring (PAM) network to detect potential changes in baleen whale distribution or acoustic behavior associated with wind farm construction and operation. Statistical power is the probability of detecting a change if one occurs.

- Power to detect changes caused by offshore wind development was dependent on PAM sensor layout (“design”) and species:
    - A design with a 40 x 40 km regional grid of sensors supplemented by T-shaped arrays centered on the wind energy areas (WEAs) had highest power. Power was high to detect construction and operation effects for minke whales at all WEAs, high for sei and North Atlantic right whales (NARWs) where the species were relatively more abundant, but low everywhere for fin whales.
    - A design with the same 40 x 40 km grid supplemented by local 20 x 20 km arrays centered on the WEAs had low power.
    - In general, a more powerful design is one that concentrates sensors within and close to WEAs where responses may occur, supplemented by a regional grid to detect any large-scale trends not associated with wind development (e.g., due to climate change).
    - One factor limiting power is that the absolute size of the effect is small because the most potentially impactful construction activities (e.g., piledriving) were limited to times of year when whale densities are expected to be low.
    - With the regional grid, power was high to detect long-term declines.

- There were several assumptions and limitations involved in the analysis that could be addressed with additional data, if collected in the future, including:
    - Due to lack of comprehensive whale acoustic data in the study area, monthly density model outputs were used to simulate daily acoustic detections
    - Lack of baseline whale vocalization behavior in the study area
    - Lack of whale behavioral/vocalization response(s) to offshore wind sounds (pile driving, operational noise)
    - Unknown precise timing and sequencing of offshore wind project construction, as well as the duration of construction activities

- The RWSC and partners will consider these results and limitations as they coordinate deployment of PAM in U.S. Atlantic waters. Approaches may differ depending on the densities of whales and mixes of whale species in each subregion.

- The power analysis should be re-run every few years to adjust assumptions by incorporating new data and information and to confirm that the monitoring approaches being used will be able to answer the desired scientific questions.

- One strong result of the analysis—that collecting more data will result in higher statistical power—underscores the need for RWSC to continue facilitating the use of consistent data collection and management protocols across partners and funders so that eventually data can be pooled for analyses that test regional-scale hypotheses.

Funding to the RWSC for this project was provided by BOEM under Contract Number 140M0122P0011 and by the Virginia Coastal Zone Management Program under the project “Developing a Baleen Whale Monitoring Plan for Virginia's Wind Energy Area”

WHY DID RWSC COMPLETE THIS STUDY?

Passive acoustic monitoring (PAM) is one of several tools that can be used to detect baleen whales and other species that produce sounds ("vocalizations") underwater. Studies using PAM in U.S. Atlantic waters are being funded by NOAA, BOEM, DOE, the states, and offshore wind developers.

These groups and marine mammal experts along the Atlantic coast have been coordinating and discussing options for how to implement a regional-scale passive acoustic monitoring network to detect and monitor baleen whales. The purpose of the network would be to determine if there is a measurable change in baleen whale distributions over time, and if so, where are they going, and was the change caused by offshore wind development or some other stressor(s)?

BOEM convened two recent workshops on the topic in **June 2021** and **March 2022**. NOAA and BOEM also published a paper "NOAA and BOEM Minimum Recommendations for Use of Passive Acoustic Listening Systems in Offshore Wind Energy Development Monitoring and Mitigation Programs" **(https://doi.org/10.3389/fmars.2021760840)** that, among other recommendations, suggested a gridded design for a regional-scale network. Since then, the **discussions and coordination around PAM** continued via the **RWSC Marine Mammal Subcommittee**. The Subcommittee is interested in testing eight different hypotheses using PAM. Many of these hypotheses require the use of additional methods to fully test them.

Hypotheses to be tested using a regional long-term/archival passive acoustic monitoring network

1. Construction and operation activities have no effect on baleen whale distribution or behavior, meaning that the number of detected vocalizations would not change during wind farm construction
2. Construction activities have no effect on baleen whale distribution but do affect their behavior by reducing cue (vocalization) production (detectability), meaning that the number of detected vocalizations would be lower during construction, but the number of whales would not change
3. Construction activities cause displacement of whales equally in all directions
4. Construction activities cause displacement of whales towards higher density areas outside of wind energy lease areas
5. Construction activities cause displacement of whales towards areas with less anthropogenic activity
6. Operating wind farms attract whales
7. Construction and operation leads to long-term displacement of whales
8. Changes in distribution and behavior occur but are due to large-scale global changes rather than OSW development

The purpose of this study was to determine the most effective sampling design for a regional PAM network that would be capable of testing these hypotheses and to maximize the chances that the data would help confirm or reject the hypotheses.

METHODOLOGY

The statistical power to effectively detect changes in baleen whale distribution and behavior associated with OSW development was calculated for three candidate PAM designs at both local and regional scales. For the local analyses three offshore wind lease areas (Vineyard Wind 1, Empire Wind, Maryland Offshore Wind) were selected as example activity sources, while the regional analyses assumed all 27 active Atlantic leases were constructed and in operation. The first candidate design was based on the recommended regional PAM monitoring design in Van Parijs et al. (2021) which suggested a 20 x 20 km grid of sensors in areas containing leases with a 40 x 40 km regional grid in the surrounding areas. The second design used a tighter 10 x 10 km grid covering the leases, and the third design used a linear array to create a T-configuration over the leases; both of these also keep the 40 x 40 km grid in surrounding areas (see figures below).

Several data sets were used to simulate all the above tested scenarios including monthly baleen whale density surfaces from surveys, estimated construction timelines, and information on vocalization rates and detection distances. To allow for the statistical power calculations, these data were then transformed into the estimated number of vocalizations (cues) detected by each PAM sensor.

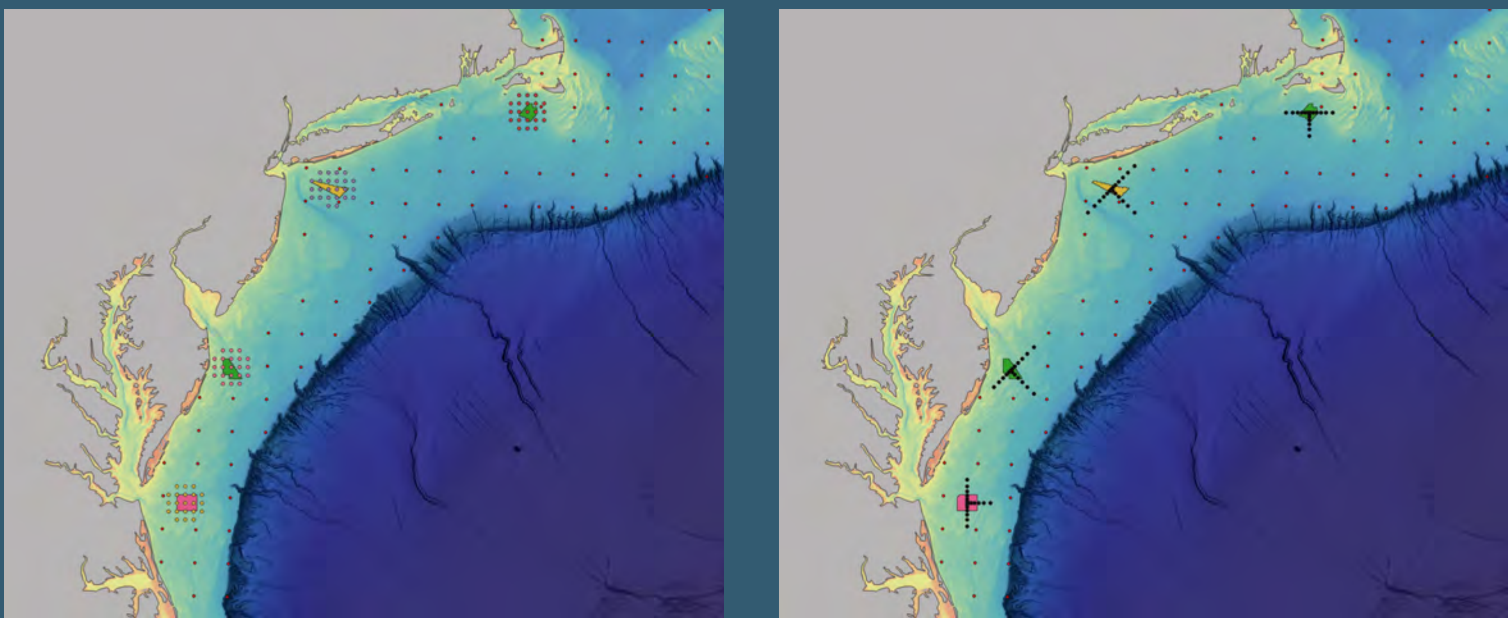

Figure 9A & 9B. The regional PAM design suggested in Van Parijs et al. 2021 with a 20 X 20 km sensor grid close to lease areas and a 40 X 40 km grid across the rest of the region. B. An alternative T-configuration design with sensors spaced closer over the leases and a 40 X 40 km grid across the rest of the region. In both maps each dot represents a single PAM sensor.

Acoustic Ecology

Statistical power was calculated using simulated vocalization (cue) detection scenarios based on the predicted number of vocalizations and their ability to be detected by PAM sensors. Those values were estimated for each species, region and month using known acoustic ecology and other properties of the whales and their environments:
Cue production rate is a measure of how often whales produce vocalizations. This varies from species to species and is often related to the animal's behavior (e.g., feeding, migrating, socializing). The **effective detection range** is a measure of how far away a vocalization be detected by an acoustic sensor and is affected by how loudly the sound is produced, its' acoustic frequency, and other environmental factors (e.g., water depth, temperature, ambient noise).

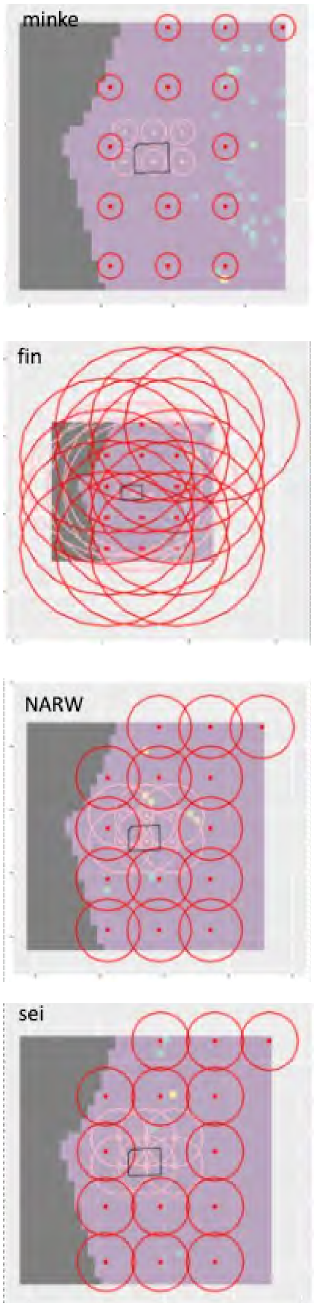

Figure 2. Detection areas for each of the four whale species included in the study are shown as red and pink circles surrounding each proposed PAM sensor (red and pink dots) in an equally spaced grid configuration near the Coastal Virginia Offshore Wind Commercial (CVOW-C) lease area.

Key Species

Four baleen whale species were selected to be test species for the analyses. These species were selected to provide variety in conservation status, distribution patterns and acoustic ecology:

Minke whales are the most abundant of the four whale species in the area and are commonly observed between April and October. Although they have the lowest cue production rate, their small effective detection range and high relative abundance resulted in the highest power to detect change.

Fin whales are the second most abundant species tested and can be observed in the study area throughout the year especially in the New York Bight. In addition to their higher densities, fin whales have the largest detection ranges and highest cue production rates making them the most detected species in the analysis. However, because of their large detection ranges, PAM sensors close to WEAs would detect both nearby responding whales and far-away non-responding animals (see Figure 2), so any effect of WEA activity on animal distribution or behavior would be diluted. This resulted in low power to detect change. An alternative approach for this species would be to try to localize and track individual animals using multiple PAM stations to detect their vocalizations and responses.

North Atlantic Right Whales (NARW) are the second most abundant species tested and can be observed in the study area throughout the year especially in the New York Bight. In addition to their higher densities, fin whales have the largest detection ranges and highest cue production rates making them the most detected species in the analysis. However, because of their large detection ranges, PAM sensors close to WEAs would detect both nearby responding whales and far-away non-responding animals (see Figure 2), so any effect of WEA activity on animal distribution or behavior would be diluted. This resulted in low power to detect change. An alternative approach for this species would be to try to localize and track individual animals using multiple PAM stations to detect their vocalizations and responses.

Sei whales are also more commonly found north of the study area but have been seen more frequently in New York Bight and Southern New England waters between March and July. They have been listed as endangered since 2018. They were slightly more detectable than NARWs with only have marginally higher cue production rates, and detection ranges, and hence similar statistical power.

RESULTS

Statistical power varied between sampling designs, species and scenarios of change. Power was low for all species and scenarios under the Van Parijs et al. design. Power was high for minke whales everywhere using the T-design and was high for sei and North Atlantic right whales using the T-design in places whale densities were relatively higher (e.g., Southern New England). Power for the 10 x 10 km grid design was intermediate.
Given a design, the variability in power was mainly due to the estimated "effect size" – the proportion of animals monitored that would respond – which was a factor of the estimated effect range (number of animals affected), the estimated baseline species densities (number of animals available to react), and the concentration of the PAM sensors (number of sensors present to detect vocalizations).

In subregions within the study area where whale density was relatively low during the time periods of interest (e.g., south of Cape Hatteras), statistical power was also lower. False positive rates—the probability of detecting a statistical change that did not actually occur—were species-specific and decreased with a larger monitoring area and under the T-design or 10 x 10 km grid design.

Photo Credit: Andrew Bain
Photo Credit: Vivek Kumar

WHAT WILL RWSC DO WITH THESE RESULTS?

The RWSC and partners will consider these results and limitations as they coordinate deployment of PAM in U.S. Atlantic waters in each subregion through the RWSC Marine Mammal Subcommittee. This may require taking different approaches initially and over time depending on the densities of whales, mixes of whale species, and offshore wind development characteristics in each area.
The results also highlight data gaps and research needs that, if addressed, could increase statistical power. RWSC will highlight these needs in the RWSC Science Plan and track their progress:

- Increase acoustic monitoring in the study area in general to improve understanding of whale vocalization rates, detection ranges, and ambient ocean noise.
- Pair PAM with other methods (e.g., shipboard/aerial visual observations, tagging) to better understand acoustic behavior and detectability.
- Increase acoustic monitoring further offshore to help distinguish between global changes in whale distribution and those caused by offshore wind development.
- Repeat the power analysis every few years to incorporate the latest acoustic data, updated whale detection data and information, and specific offshore wind development information.

The most definitive result of the analysis – that collecting more data (both for longer periods of time and larger number of sensors) will result in higher statistical power – underscores the need for RWSC to continue facilitating the use of **consistent data collection and management protocols** across partners and funders so that eventually data can be pooled for analyses that test regional-scale hypotheses. In the absence of these efforts, it would be nearly impossible for any single PAM data collection effort to amass the data required to understand any potential regional-scale impacts to baleen whales from offshore wind development.

How to cite this document:
Regional Wildlife Science Collaborative for Offshore Wind (RWSC). 2023. RWSC Research Summary: Power analysis for the optimal design of a passive acoustic monitoring network for US east coast offshore wind. URL. Produced September 2023.

How to cite the full technical reports:
Chudzinska M, Thomas L. 2023 (CREEM, St Andrews, UK). Power analysis for optimal design of a passive acoustic monitoring network in the Atlantic Ocean. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management. 85 p. Report No.: OCS Study BOEM 2023-041. https://espis.boem.gov/final%20reports/BOEM_2023-041.pdf
Chudzinska M, Thomas, L, Wood, J (2023) Power analysis for optimal design of passive acoustic monitoring network in the Virginia offshore wind area. Report number SMRUC-RWS-2023-010 (unpublished).