Environmental Studies Program: Ongoing Study

Title	Substrate-Borne Vibroacoustic Disturbances from Offshore Wind Construction: Measurements, Physical Characteristics, and Propagation (NT-23-11)
Administered by	Office of Environmental Programs
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Procurement Type(s)	Cooperative Agreement and Interagency Agreement
Conducting Organization(s)	Woods Hole Oceanographic Institution (WHOI) and Pacific Northwest National Laboratory (PNNL)
Total BOEM Cost	$1,500,000
Performance Period	FY 2023–2026
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Date Revised	August 29, 2024
PICOC Summary	
Problem	Offshore construction activities, such as installation of large wind turbine structures, generate high levels of vibration on the seabed and in the substrate, in addition to intense water-borne sound, that could impact aquatic organisms and their environment. While there have been numerous studies on characterization and propagation of water-borne noise from these activities, there is virtually no dedicated research on characterization and propagation of substrate-borne vibroacoustic waves. Without the understanding of physical characteristics and propagation of substrate-borne vibrations, BOEM will not be able to address the potential effects of these disturbances on marine life, especially the benthic ecological communities, from offshore wind construction.
Intervention	This proposed study would gain valuable insights on the physical characteristics and propagation of various substrate-borne vibroacoustic disturbances through field measurements and numerical modeling during wind turbine pile driving.
Comparison	Currently, there are almost no studies investigating substrate-borne vibration and its potential environmental effects. BOEM has funded a study to analyze some of the sediment-borne vibroacoustic data that were collected during pile driving for the Real-time Opportunity for Development Environmental Observations [RODEO]) and Coastal Virginia Offshore Wind (CVOW) projects (AT-2022-08). However, those datasets were limited and focused on water-borne particle motion measurements. This study would focus on substrate-borne vibration using sensors dedicated to collect such data.
Outcome	The study would establish methodologies for substrate-borne vibroacoustic disturbance data collection and provide physical characteristics of these mechanical waves. The knowledge gained from the study is needed to accurately assess potential impacts on benthic organisms and their environment from wind project construction.
Context	Nation-wide relevance for activities involving wind turbine pile driving, and potentially for other marine engineering activities that cause disturbances to the

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BOEM Information Need(s): Offshore construction activities, including installation of large wind turbine structure during in-water pile driving, generate intense vibroacoustic disturbances that propagate both through the water column and in the substrate. While there have been numerous studies addressing water-borne acoustic disturbances and particle motion, there is essentially no information on the types and characteristics of these substrate-borne vibroacoustic disturbances. Without such knowledge, it would be difficult for BOEM to accurately assess potential impacts on marine life due to exposure to these disturbances, in particular the benthic organisms, many of which are commercially important species. The results will directly feed into the Center for Marine Acoustics impact models, as well as being used for impact assessments. Therefore, this information will benefit multiple BOEM programs for required decision-making related to National Environmental Policy Act and Endangered Species Act processes and in Office of Renewable Program's Construction and Operations Plan development.

Background: Pile driving for offshore wind farm construction generates various substrate-borne vibroacoustic disturbances, including compressional and shear waves that propagate within the sediment, as well as interface (Scholte) waves along the seabed (Miller et al. 2016). Some of these wave disturbances could contain high energy that, in cases of land-based impact pile driving, could cause structure damage to nearby buildings (Whyley and Sarsby 1992). There is increasing realization that fishes and marine invertebrates primarily sense sound as a form of particle motion (Popper and Hawkins 2018; Hawkins et al. 2021). Benthic-dwelling species are particularly sensitive to, and could potentially be impacted by, substrate-borne particle motion (Roberts and Breithaupt 2016; Roberts et al. 2016a; 2016b; Roberts and Elliott 2017).

Currently there is limited information on the physical characteristics and propagation of substrate-borne mechanical waves, and there is no dedicated and systematic study to address these topics (e.g., Miller et al. 2016; Hazelwood and Macey 2016; Hazelwood et al. 2018; Potty 2020). Results from the recent BOEM-funded Block Island Wind Farm study showed that at ranges of 500 m and 1,500 m, particle acceleration levels measured on the seabed were well above the behavioral sensitivity for the Atlantic salmon, plaice, dab, and Atlantic cod up to a frequency of approximately 300 Hz (HDR 2019). In FY 2022, BOEM is funding another study to conduct in-depth substrate-borne mechanical wave measurements during RODEO and CVOW projects (AT-2022-08). However, data collection from these studies are mainly focused on water-borne acoustic pressure and particle motion, with substrate-borne data only available from one geosled and one Ocean Bottom Recorder (OBX) at limited distances between 725 and 1,150 m. Without additional data collected at a wide range of distances, it is impossible to gain enough insight of wave propagation to be able to sufficiently model this complex phenomenon accurately.

This proposed study would contribute to knowledge on substrate-borne mechanical waves from marine engineering activities, including offshore wind construction. The information obtained from this study would greatly assist BOEM decision-making using scientific knowledge that is first in class. In addition, this study would explore additional data collection methods and identify the most appropriate geoacoustic sensor(s) to obtain substrate-borne vibroacoustic signals at different ranges and layers of the sediment.

Objectives: The objectives of this study are to:

- Establish appropriate methodologies to collect and analyze substrate-borne vibroacoustic disturbances from offshore wind construction activities that could potentially affect benthic ecological communities, and
- Obtain critical knowledge on the characteristics and propagation of different types of substrate-borne mechanical waves at various source ranges and at various sediment depths for impact assessment modeling.

Methods: The study would first develop an appropriate methodology for the collection and analysis of substrate-borne vibroacoustic disturbances based on preliminary study results from a currently BOEM-funded project (AT-2022-08). Then, using that methodology, additional substrate-borne mechanical wave measurements would be made on at least one newly approved offshore wind project (e.g., Vineyard Wind and/or South Fork Wind) during construction activities. Vibroacoustic data would be collected at various distances from the source and sediment depths using appropriate geoacoustic sensors. For field data collection, vessel(s) will be needed to deploy and retrieve acoustic sensors and recording equipment. Finally, the data will be analyzed to in a way that propagation models can be developed in the future for impact assessments.

Specific Research Question(s):

1. What are the appropriate methods to collect substrate-borne vibroacoustic disturbance data from an offshore wind construction project that are relevant to environmental impact assessment (including the suitable geoacoustic sensors, signal processing, and acoustic metrices)?
2. What are the types of substrate-borne vibroacoustic disturbances from offshore wind construction activities and how are they related (e.g., compressional, shear, and interface waves)?
3. What are the physical characteristics of substrate-borne mechanical waves from offshore wind construction activities (i.e., amplitude, frequency, directivity, propagation speed, duty cycle, etc.)?
4. What are the propagation characteristics of substrate-borne mechanical waves from offshore wind construction activities and how they relate to different types of sediments (i.e., decay rate over distance and depth, frequency-dependent propagation, etc.)?
5. How can substrate-borne mechanical waves be modeled for their physical characteristics and propagation so ranges to effects can be predicted for impact assessment?

Current Status: PNNL researchers have been working with BOEM experts on experimental design to investigate particle motion and substrate-borne vibration effects on fishes and aquatic invertebrates. Through our planning process, we have agreed on two species to be tested: chinook salmon and dungeness crab. PNNL and BOEM experts worked on modeling and measuring sound field of the tanks that would be used for the sound exposure experiments.

WHOI and BOEM experts had a kick-off meeting in March 2024. WHOI submitted a study plan, which BOEM reviewed and approved in July 2024. WHOI researchers and BOEM experts will have another meeting in September 2024 to discuss details of the experimental design.

Publications Completed: None

Affiliated WWW Sites: None

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