Environmental Studies Program: Ongoing Study

Field	Study Information
Title	Sediment-borne Wave Disturbances and Propagation and Potential Effects on Benthic Fauna (AT-22-08)
Administered by	Office of Renewable Energy Programs
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Procurement Type(s)	Cooperative Agreement
Conducting Organization(s)	University of Rhode Island
Total BOEM Cost	$500,000
Performance Period	FY 2022–2025
Final Report Due	December 31, 2024
Date Revised	July 5, 2024
Problem	Marine engineering activities (e.g., offshore wind farm construction, subsea drilling and dredging, and structure removal) generate intense and/or long-lasting vibroacoustic disturbances that could affect marine life. While many studies have been conducted on the free-field water-borne acoustic waves from impact pile driving, very little is known about the characteristics and propagation of substrate-borne vibroacoustic disturbances from these activities. Without such knowledge, we will not be able to address the potential physical, physiological, and behavioral effects of many ecologically and commercially important benthic species.
Intervention	This study would gain theoretical perspectives of substrate-borne vibroacoustic (including interface and compressional waves) characteristics and propagation on seabed through comprehensive data analyses and numerical modeling. The results would be applied to current knowledge in sensory biology of various benthic species to provide valid basis for impact assessment.
Comparison	The proposed study would build on Real-time Opportunity for Development Environmental Observations (RODEO) research at the Block Island Wind Farm (BIWF) and Coastal Virginia Offshore Wind Project (CVOW) to conduct comprehensive data analysis on substrate-borne particle velocity measurements. The study would also compare seafloor and sediment ambient vibroacoustic dynamics during pile driving and non-activity time periods.
Outcome	The proposed study would provide theoretical understanding of substrate-borne vibroacoustic characteristics from impact pile driving, with the acquired knowledge to be used to develop numerical models for predicting disturbances and propagation.
Context	Atlantic Seaboard, and potentially nation-wide

BOEM Information Need(s): BOEM is responsible for conducting thorough and scientifically sound environmental impact assessments on living marine resources that could be affected by its regulated activities. Marine engineering activities (e.g., offshore wind farm construction, subsea drilling and dredging, structure removal, and unexploded ordinance [UXO] detonation) on OCS waters have the potential of adversely impact marine life in the affected areas. Although BOEM has funded several studies in the past to obtain knowledge on underwater sound field from in-water pile driving, information remains scarce in terms of substrate-borne vibroacoustic disturbances, especially concerning the propagation of interface and compressional wave on seabed and in sediment.

Background: Pile driving for offshore wind farm construction produces high-intensity underwater acoustic disturbances that are known to have adverse effects to marine life (Casper et al., 2013; Branstetter et al.; 2018; Kastelein et al., 2018). Over the years, many studies have been carried out to understand pile driving sound field characteristics and sound propagation to address these environmental concerns and to assess the impacts. However, most of these studies to-date were focused on acoustic pressure waves in the water column (e.g., Reinhall and Dahl, 2011; Lippert et al., 2016; 2018; Martin and Barclay, 2019; Heaney et al., 2020).

Apart from the high acoustic pressure field being generated in the water column, these disturbances also include water-borne particle disturbances, compressional and shear waves in the sediment, as well as interface (Scholte) waves on the seabed. These non-pressure wave phenomena are generally known as particle motion (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 also increasing evidence that fishes and marine invertebrates primarily sense sound as a form of particle motion (Nedelec et al., 2016; Popper and Hawkins, 2018). 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).

Notwithstanding such relevance of particle motion detection by fish and invertebrates in relation to noise impacts from marine engineering activities, these types of vibroacoustic disturbances have largely been overlooked and rarely monitored. A few studies that investigated particle motion from in-water pile driving or offshore wind farm operations were only limited to describing the amplitudes and frequency contents of such disturbances being at measurement locations (MacGillivray and Racca, 2005; Sigray and Andersson, 2011; Yang et al., 2018; HDR, 2019; Potty et al., 2020). Results from recent BOEM funded studies show that at ranges of 500 m and 1,500 m, particle acceleration levels measured on seabed were well above the behavioral sensitivity for the Atlantic salmon, plaice, dab, and Atlantic cod up to a frequency of approximately 300 Hz (HRD, 2019; 2020). However, in comparison to acoustic pressure wave propagation, there are very few studies on the propagation or modeling of sediment-borne particle motion that can be used to assess the range to impact (e.g., Miller et al., 2016; Hazelwood and Macey, 2016; Hazelwood et al., 2018).

Objective(s): The objectives of this study are to obtain theoretical understanding substrate-borne vibroacoustic disturbances from impact pile driving activities and to acquire essential knowledge that can be used to develop numerical models to predict substrate-borne vibroacoustic propagation for impact assessments.

Although environmental impacts from substrate-borne particle motion from pile driving have been widely recognized as potential major effects on marine benthic organisms, very little research has been conducted to address these types of vibroacoustic disturbances (Popper & Hawkins, 2018). Therefore, the proposed study reflects ESP's vision statement to be "first in class" in being the best research program possible in the context of BOEM's mission and constraints.

In addition, though this study is proposed to address substrate-borne vibroacoustic characteristics and propagation from offshore wind farm construction (pile driving), results from this study have wide application for many marine engineering activities that are coupled with seabed, such as subsea drilling and dredging, offshore structure removal, and UXO detonation.

Methods: The study would build on RODEO I & II research at the BIWF and CVOW wind farm constructions by conducting comprehensive data analyses on substrate-borne particle motion data that have been previously collected to understand the detailed characteristics the vibroacoustic disturbances using advanced signal processing. In addition, a Finite Element Method would be used to understand the attenuation of the particle velocity field as a function of range.

Specific Research Question(s):

1. What are the main parameters to consider when estimate impact ranges from various substrate-borne vibroacoustic disturbances?
2. Does the model(s) developed accurately reflect empirical measurements collected? If so, can the range to effect of particle motion on seabed and in substrate in general be predicted using the model(s) developed?
3. If the model(s) developed do(es) not provide a generic prediction of range to effect of particle motion on seabed and in substrate at any sites, what are the factors that likely drive the model(s), and can any interaction relationship among these factors be qualitatively identified?
4. Can the values derived from the model(s) be used in the future to assess potential environmental impacts to benthic organisms and EFH from offshore wind farm construction activities involving pile driving?
5. Do some of the current approaches of using water column pressure gradients to estimate particle motion levels underestimate the measurements by accelerometers (e.g., Ocean Bottom Recorders Geophone and Hydrophone Sensor System, or OBX), thus underestimate the potential effects?
6. Would the model(s) developed from pile driving datasets on substrate-borne vibroacoustic disturbance and propagation be suitable to use for long-term effects from wind farm operations?

Current Status: URI is using the CVOW pilot geotechnical data as well as a simpler model using primarily sand to analyze particle movement near the sediment-water interface at various distances from pile driving. The plan to compare model results with field measurements made from installation of the Block Island Wind Farm and other recent installations.

Publications Completed: None

Affiliated WWW Sites: None

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