

Technical Summary

Study Title	Sediment-borne Wave Disturbances and Propagation and Potential Effects on Benthic Fauna
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Project Manager(s)	Prof. James H. Miller
Affiliation of Project Manager(s)	University of Rhode Island
Address of Project Manager(s)	70 Lower College Road, Kingston, Rhode Island 02881-1967
Principal Investigator(s)	James H. Miller and Gopu R. Potty
Keywords	Pile driving impacts, particle motion, Scholte-wave, marine fishes and invertebrate impacts, modeling, Atlantic coast

ABSTRACT: The acoustical energy generated by impact pile driving creates Scholte waves which propagate along the water-seafloor interface. The objective of this study was to develop an understanding of Scholte wave particle motion produced during impact pile driving by conducting a transient finite element analysis using COMSOL Multiphysics (<https://www.comsol.com/>). The results from modeling an ideal scenario vs. a real-world environment provide insight into the potential for Scholte wave particle motion to impact benthic species in the vicinity pile driving activities. Results demonstrate that site specific conditions, such as seafloor stratification, can significantly influence the measured particle motion and pressure at various locations within the water and sediment. Future research on how marine organisms react to different types of wave propagation can be integrated with modeling methods in a study such as this to provide a more detailed understanding of the impacts of offshore pile driving to marine fishes and invertebrates.

BACKGROUND: Construction of fixed foundation offshore wind farms involves the installation of large diameter steel piles using high-energy hammers. These piles are installed via vibratory or impact pile driving or using a combination of these methods to drive the pile to its desired installation depth. This report focuses on impact pile driving, which is when the top of the pile is struck repeatedly by a hammer to force the pile into the sediment. The purpose of this study is to investigate, and demonstrate a method for describing, the physical properties of substrate-borne wave disturbances and propagation through the sediment from offshore wind turbine installation and operation. With site and species-specific data, this method can be used in the future to predict the potential effects on benthic fauna.

OBJECTIVES: The objectives of this study are to obtain a theoretical understanding of substrate-borne vibroacoustic disturbances from impact pile driving and from wind turbine operations and to acquire essential knowledge that can be used to develop numerical models to predict substrate-borne vibroacoustic propagation for impact assessment to benthic fauna.

METHODS: The study builds on Realtime Opportunity for Development Environmental Observations (RODEO I & II) research at the Block Island Wind Farm and Coastal Virginia Offshore Wind (CVOW) 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 is used to understand the attenuation of the particle velocity field as a function of range.

A transient analysis was conducted using COMSOL Multiphysics (COMSOL) to observe how the particle motion (acceleration, velocity, displacement) and pressure of the Scholte wave changes with time. COMSOL is software that enables users to construct finite element models with various physics interfaces such as Pressure Acoustics and Solid Mechanics. These physics interfaces contain governing equations for different media types (liquids and solids), with the benefit of describing material properties (density, sound speeds, etc.) as well as boundary and domain conditions which enhance model fidelity. First, an “ideal” case confirmed that COMSOL was appropriate for this study and provided a baseline of Scholte wave particle motion data. Next, a second case incorporated seafloor stratification based on sediment borings collected near the CVOW Research Lease Area (OCS A497) turbine locations to better predict behavior in the real world.

RESULTS: This study demonstrates a method for modeling impact pile driving as a sound source for both sound pressure and particle motion. Model results from the “ideal” model demonstrate the validity of COMSOL to illustrate Scholte wave propagation at and near the boundary between the seabed and water column. This ideal model is then enhanced by integrating field data from CVOW in the second model, which illustrates how different sediment layers can complicate wave propagation due to internal reflection of energy within and between the layers. Finally, results demonstrate that site specific conditions, such as seafloor stratification, can significantly influence the measured particle motion and pressure at various locations within the water and sediment.

CONCLUSIONS: The models developed in this study can be used to conduct sensitivity studies of anthropogenic activities. By varying one parameter at a time within the modeling scenario of the anthropogenic activity, the sensitivity of the acoustic field to that parameter could be determined, which could elucidate conditions that influence potential impacts for different species. Future research on how marine organisms react to different types of wave propagation can be integrated with modeling

methods in a study such as this to provide a more detailed understanding of the impacts of offshore pile driving to marine fishes and invertebrates.

STUDY PRODUCT(S):

- 1) BOEM Study Report: Giordano BJ, Amaral JL, Guan S, Lin Y-T, Miller JH, Mohajerin TJ, Popper AN, Potty GR, Vigness-Raposa KJ. 2025. Sediment-borne wave disturbances and propagation and potential effects on benthic fauna. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management. 60 p. Report No.: OCS Study BOEM 2025-028.
- 2) Abstract submitted for *The Effect of Noise on Aquatic Life* (AN2025) conference in Prague June 29 – July 4, 2025, in Prague: Modeling Scholte Waves Generated by Impact Pile Driving

MAP OF STUDY AREA:

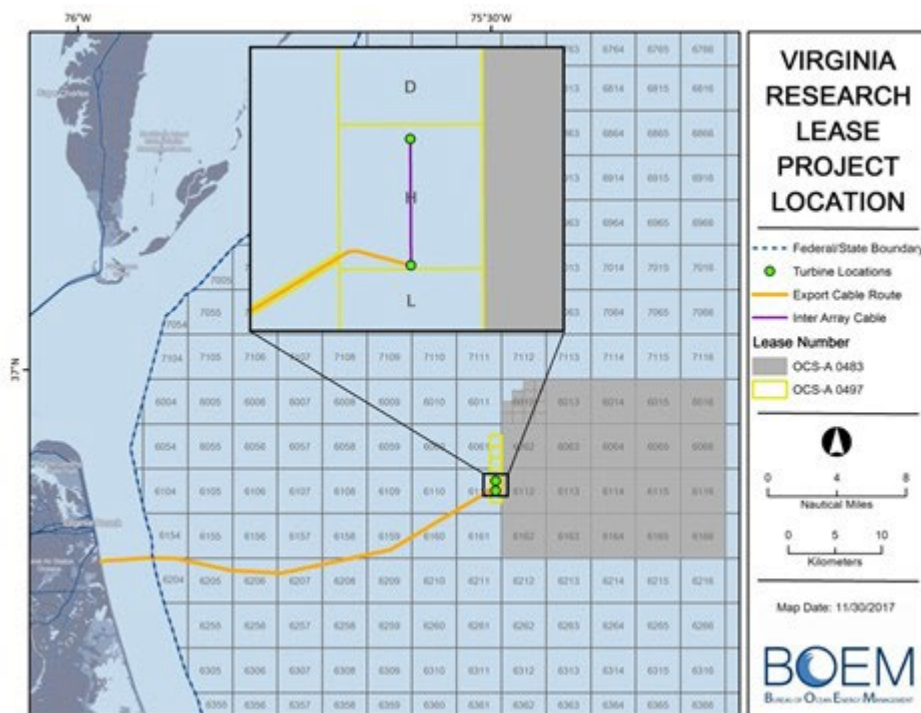


Figure of CVOW lease area: Geotechnical samples for the second model used in this study were obtained near the CVOW pilot research lease area turbine locations. Export cable shown is not relevant to this study.