Environmental Studies Program: Ongoing Study

Field	Study Information
Title	Feel the Vibrations: Behavioral Response by Fishes and Invertebrates to Particle Motion and Substrate Vibration from Offshore Renewable Energy Development (NT-23-10)
Administered by	Office of Environmental Programs
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Procurement Type(s)	Inter-Agency Agreement, Cooperative Agreement
Conducting Organization(s)	Pacific Northwest National Laboratory, Cooperative Agreement TDB
Total BOEM Cost	$750,000
Performance Period	FY 2023–2024
Final Report Due	August 31, 2025
Date Revised	October 10, 2023
Problem	Offshore renewable energy construction and operations introduce vibroacoustic energy into the substrate, which has the potential to negatively impact benthic organisms that spend their lives on, in, or near the seafloor. Chronic exposure to long-term substrate vibration could also affect the benthic community and ecosystem.
Intervention	Provide strategic insight into the magnitude and scope of the potential behavioral and physiological effects of substrate-borne vibration on susceptible species by examining 1) multiple fish and invertebrate species, 2) a suite of behavioral and physiological responses—acute, chronic, and/or biologically meaningful, and 3) behavioral and physiological responses in large tank environment with realistic vibroacoustic wave generator.
Comparison	There are few studies that have examined impacts of water-borne particle motion on demersal species, and even fewer studies focusing on substrate-borne vibration. A selection of species representing a range of sensory and/or mobility abilities will be tested in order to broaden the applicability of the results of this work.
Outcome	The knowledge gained from this study will be used by several BOEM program and regional offices in assessing impacts of BOEM activities. The Center for Marine Acoustics (CMA) will use the results to help inform their 1) vibroacoustic impact model, 2) technical papers provided to regional offices on acoustic issues, and 3) recommendations made to regulators on acoustic issues. The results will also be used in specific BOEM regulatory documents, such as environmental impact statements and Construction and Operations Plans.
Context	Nation-wide relevance for activities involving marine energy construction and operations.

BOEM Information Need(s): Construction and operations of marine energy facilities such as offshore wind turbines, wave energy converters, and tidal energy converters are known to generate substantial vibroacoustic energy into the water column and substrate. Little is known about the effects of particle motion and substrate-borne waves on marine life living on, in, or near the seafloor. The behavioral response information expected from this proposed study will be used by BOEM to make more informed assessments of the impacts of these activities, which will include species of ecological and commercial importance. The results will directly inform the animal behavior and physiology components of the CMA's acoustic impact model, as well as technical papers the CMA writes on acoustic issues, made available to other offices within BOEM to better inform environmental impact assessments, biological assessments, and inform decisions related to the National Environmental Policy Act and Endangered Species Act processes. Finally, the information will be used by the CMA to make recommendations to regulators responsible for updating vibroacoustic impact thresholds with the best available science.

Background: Offshore renewable energy construction and operations routinely and consistently emit vibroacoustic disturbances that propagates into the marine environment, including the surrounding water column and seafloor on which the structures are attached. Substantial progress has been made in understanding the extent and magnitude of the effect that acoustic pressure waves in the water column have on marine life, especially on marine mammals. Vibroacoustic energy also includes water-borne particle motion and substrate-borne vibration which are much less understood (Potty *et al*. 2020), especially their potential effects on fishes and marine invertebrates (Popper and Hawkins 2018; Hawkins *et al.* 2021). Results from the recent BOEM-funded Block Island Wind Farm study and the Realtime Opportunity for Development Environmental Observations (RODEO) showed 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). In FY2022, BOEM is funding another study to conduct in-depth study substrate-borne mechanical wave data collected during RODEO and CVOW projects (AT-2022-08).

The scientific community has become increasingly aware that most fish and all marine invertebrates sense acoustic waves in the form of particle motion (Hawkins *et al.* 2021). For benthic organisms, substrate-borne vibroacoustic waves are likely the main, if not the only, modality of the animals' sensory mechanism. Although researchers have begun to look into the potential effects on fishes and marine invertebrates from these forms of vibroacoustic disturbances (Miller *et al*. 2016), very little research has focused on behavioral and physiological responses of these species exposed to these disturbances. Therefore, there is an explicit need for a study of demersal fish and invertebrate species to particle motion and substrate-borne vibration to fill this knowledge gap. In fact, at the 2020 workshop on the state of the science related to wildlife and offshore wind energy development, the expert working group identified behavioral response studies of priority taxa to particle motion and substrate vibration as a key research priority for the next five years (Popper *et al.* 2022). The fishing community has also raised concerns on this topic.

The proposed study builds on recent and current BOEM investments, such as RODEO, RODEO II, AT-22-08, and NT-22-11, which include physical measurements and analyses of particle motion and substrate-borne vibration, during construction of several offshore wind farms off the Atlantic seaboard (e.g., Amaral *et al.* 2018, OCS Study BOEM 2018-029). However, these studies were designed to investigate the physical characteristics of vibroacoustic disturbances from wind farm construction. They do not address the behavioral and physiological responses of benthic marine organisms exposed to these disturbances.

Objectives: The goal of this project is to provide insight about the potential effects of substrate-borne vibration from offshore renewable energy construction and operations on demersal fish and invertebrates through a dedicated empirical behavioral and physiological response studies. The results will provide sufficient empirical evidence—by considering a range of behaviors that are acute, chronic, and/or biologically significant. Insight will also be gained on the relationship between changes in the vibroacoustic field and behavioral/physiological responses.

Methods: The proposed study is for a behavioral/physiological assessment of demersal fish and/or invertebrates exposed to substrate-borne vibration from a vibroacoustic wave generator in large tanks and will include a control to assess baseline behavior and physiology status without vibroacoustic disturbances. The study will design and construct a vibroacoustic wave generator or a low frequency speaker that are capable of generating substrate-borne vibration and water-borne particle motion similar to those from construction and operations of at least two types of offshore energy devices (e.g., offshore wind turbine, wave energy converter, tidal energy converter). Measurements will be made of the vibroacoustic field (must include well controlled wave disturbances such as compressional, sheer, and Scholte waves), using appropriate tools for each type of vibroacoustic waves. The study output will provide appropriate context for assessing the cause of any observed changes in behavior and physiology by including measurements and/or documentation of other relevant disturbances and environmental factors. The objectives may be achieved through a well-controlled laboratory study in large tanks, with the intention of examining a vibroacoustic field that is representative of offshore renewable energy construction and operations.

Potential methods to investigate animals being exposed to substrate-borne vibration and water-borne particle motion may include, but are not limited to the following:

- Animal-mounted sensors (e.g., accelerometers) to measure fine-scale movements (e.g., startle responses, lateral movements, feeding behaviors).
- Underwater camera to detect animal group movement and behavior responses.
- Measure stress hormone levels of animals being exposed to various substrate-borne vibration and water-borne particle motion at different frequencies and durations.

Potential species may include (listed by approximate priority, preference to include multiple species):

- Flatfish (e.g., common sole, winter flounder)
- Bivalves (e.g., scallop, clam, mussels)
- Crustaceans (e.g., American lobster, crabs)
- If multiple species are examined, species should represent a range of life history strategies, mobility, and hearing abilities, and preference to species with commercial/conservation importance (Popper *et al.* 2022).

Specific Research Question(s):

Depending on the study design, possible research questions may include:

1) Does the activity elicit short-term behavioral response in the species (e.g., flee, startle, freeze)?
2) Does the activity interfere with food finding behaviors (e.g., foraging, filtering, scavenging)?
3) Does the activity elicit changes in the stress hormone levels of the animals (e.g., cortisol)?

4) What is the threshold for behavioral response, is it behavior-specific?
5) What is the threshold for physiological response?
6) Do individuals adapt, acclimate, or become sensitized to exposure and what are the characteristics that define those processes (e.g., onset, duration, etc.)?
7) Do any changes in behavior correlate with changes in the vibroacoustic sound field?
8) Do any changes in physiology correlate with changes in the vibroacoustic sound field?
9) If behavioral responses are detected are they likely to have population level impacts?

Current Status: The PNNL PIs and BOEM had a kick-off meeting on September 14, 2023 and will discuss detailed experiment design in the following weeks. The cooperative agreement is pending procurement.

Publications Completed: N/A

Affiliated WWW Sites: N/A

References:

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