Field	Study Information
Title	Vibroacoustic Sensitivity and Subacute Biological Effects of Economically Important Fishes and Shellfishes from Marine Renewable Energy Development (NT-25-03)
Administered by	Office of Environmental Programs
BOEM Contact(s)	Shane Guan (shane.guan@boem.gov)
Procurement Type(s)	Interagency Agreement
Performance Period	FY 2025–2027
Final Report Due	TBD
Date Revised	May 29, 2024
Problem	Behavioral and physiological effects on economically important fishes and invertebrates (e.g., crabs, scallops) from particle motion and substrate-borne vibration in relation to marine renewable energy development have not been well studied. Knowledge in these areas is critically needed for BOEM's environmental impact assessments.
Intervention	Conduct controlled exposure studies in field experimental settings to investigate various behavioral and physiological effects of selected fish and invertebrate species. The sources used would be those that are representative of particle motion and substrate vibration from marine renewable energy development.
Comparison	Results would be compared among treatments vs. control in various sound and substrate-borne vibration exposure experiments. Comparisons would also be made from studies conducted in laboratory tank environments vs. in field mesocosm settings.
Outcome	Results would be directly used by BOEM for environmental impact assessments on the effects of offshore renewable energy development. Results can also be used to interpret biological effects of fishes and aquatic invertebrates from other anthropogenic sources from BOEM regulated activities (e.g., seismic surveys, marine mineral extraction). Results can be used to support the fish acoustics exposure criteria BOEM is working on.
Context	Nation-wide relevance for activities involving marine energy construction, operations, and decommissioning including species found in all BOEM Outer Continental Shelf (OCS) regions that could be exposed to marine energy construction and operations.

BOEM Information Need(s): Sensitivity and subacute effects, such as those leading to behavioral and/or physiological responses on fishes and aquatic invertebrates from sound and substrate-borne vibration sound and substrate-borne vibration waves in relation to marine renewable energy development have not been well studied. Most of our understanding on anthropogenic noise effects on aquatic species has been done on marine mammals that are exposed to acoustic pressure. Far fewer studies have been conducted on noise exposure to fishes and even fewer on aquatic invertebrates. Good understanding and knowledge in this area is critically needed for BOEM's environmental impact assessments.

Background: Although much attention has been focused on addressing anthropogenic underwater noise on marine life in recent decades, most of the studies to-date have been conducted on marine mammals and their responses to acoustic pressure (e.g., Southall et al. 2019; 2021). In comparison, very limited funding has been devoted to address noise effects on fishes and aquatic invertebrates (Williams et al. 2015), which has resulted in considerable gaps in our understanding of the biological effects of these species vs. marine mammals in noise impact assessments (Hawkins et al. 2015; Normandeau 2013).

Over the past decade, BOEM has supported a series of efforts to investigate the effects of anthropogenic sounds on fishes and marine invertebrates (e.g., M08PC20010, M11PC00031, M20AC10009, M17PG00029). These studies have gained valuable knowledge in our understanding on physical injury (e.g., Halvorsen et al. 2012; Casper et al. 2013; Popper et al. 2013) and behavioral responses (e.g., Jézéquel et al. 2022; 2023a; 2023b; Jones et al. 2023) on fishes and aquatic invertebrates from noise exposure associated with BOEM-regulated activities. Currently, BOEM is supporting two additional studies through FY2024 via an interagency agreement with the Pacific Northwest National Laboratory (PNNL; M23PG00011), and a cooperative agreement with the Woods Hole Oceanographic Institution (WHOI; M23AS00363) to further our understanding of the effects of sound and substrate-borne vibration disturbances from offshore renewable energy development on these species.

Unlike marine mammals whose auditory organ primarily responds to acoustic pressure, fishes and aquatic invertebrates sense acoustic energy in the form of particle motion and/or substrate-borne vibration (Mooney et al. 2010; Nedelec et al. 2016; Popper and Hawkins 2018; Hawkins et al. 2021). As such, careful considerations must be given regarding experimental designs that involve boundary conditions, sediment types and thickness, and measurements of animals' audiometric and physiological response. To address these issues, BOEM convened a workshop, Research Methodologies to Study Biological Effects from Particle Motion and Substrate-borne Vibration (140M0123D0001).

However, despite these investments, the overall research funding in this field remains low nationwide when compared to resources available for marine mammal studies. Given that the diversities of fish and aquatic invertebrate species are far greater than that of marine mammals (34,000 extant fish species, 17,500 decapod crustacean species, and 43,600 marine mollusk species vs. 140 marine mammal species), many of which are economically important and, if their stocks become depleted, could affect the livelihood of fishing communities. Expanded research efforts are needed to better understand the acoustic effects on these species. Furthermore, the rapid growth of offshore renewable energy development in the U.S. OCS makes it imperative that we must continue funding such studies (Popper et al. 2022, 2023).

Objective(s): The main objective of this study is to continue collaborating with DOE/PNNL to investigate the effects of sound and substrate-borne vibration disturbance from offshore renewable energy development on fishes and aquatic species, with a renewed approach based on recommendations from BOEM's recent workshop, Research Methodologies to Study Biological Effects from Particle Motion and Substrate-borne Vibration, and a focus on economically important marine species. An additional objective of this study is to gain empirical knowledge that can be used to improve the current fish acoustic exposure criteria, which are critically need for BOEM's environmental impact assessments.

Methods: The proposed study is for a behavioral/physiological assessment of fishes and invertebrates exposed to particle motion and substrate-borne vibration from sound and substrate-borne vibration stimuli in field-based mesocosm settings. The experiments will include controls to assess baseline behavior and physiology status without sound and substrate-borne vibration disturbances. The study

will design and construct sound source(s) that can generate substrate-borne vibration and water-borne particle motion similar to those from construction and operations of offshore energy devices (e.g., offshore wind turbine, wave energy converter, tidal energy converter). Measurements will be made of the sound and substrate-borne vibration field (must include well controlled wave disturbances such as compressional, sheer, and Scholte waves), using appropriate tools for each type of sound and substrate-borne vibration 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.

Specific Research Question(s):

1. Does the activity elicit any short-term behavioral responses 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 sound and substrate-borne vibration 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: N/A

Publications Completed: N/A

Affiliated WWW Sites: N/A

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