The Bureau of Ocean Energy Management and Ocean Noise

Shane Guan, Jill Lewandowski, and Erica Staaterman

Introduction

In recent years, underwater anthropogenic sound impacts on marine life has become a well-recognized environmental issue among scientists, conservationists, regulators, and the general public. Many of these sounds could adversely affect marine life and fisheries (Erbe et al., 2018; Popper and Hawkins, 2019).

The US Bureau of Ocean Energy Management (BOEM; see www.boem.gov) and its predecessor agencies have a mission to manage the development of US Outer Continental Shelf (OCS) energy and mineral resources in an environmentally and economically responsible way. Thus, BOEM has been a pioneer in studying and mitigating the environmental effects of anthropogenic sound generated by the industrial activities that it regulates.

Founded in 1973, BOEM's Environmental Studies Program (ESP: see www.boem.gov/environmental-studies) helps to assess and understand how the Bureau's decision making impacts the environment. As such, it was the first US government entity to conduct studies on industrial noise impacts on marine life and provide the regulatory framework to monitor and mitigate such impacts. Today, the ESP is still one of the leading US government funders supporting scientific research in this field. Over the past three decades, BOEM has invested over $95 million on studies related to protected species and underwater noise through four general research themes: (1) empirical laboratory and field studies; (2) literature reviews, syntheses, and workshops; (3) sound source verification and modeling; and (4) impact monitoring.

To strengthen its role as a driving force within the regulatory community on sound in the marine environment, BOEM established the Center for Marine Acoustics (CMA: see www.boem.gov/center-marine-acoustics) in 2020 to integrate the Bureau's acoustic-related science and policy work. The functions of the CMA are to (1) build models that address current needs and drive improvements in the field; (2) track emerging science, fill data gaps, and apply new risk assessment methods; (3) address key policy and management improvements, both internal and external; (4) improve stakeholder understanding of actual risks; and (5) develop relationships with domestic and international organizations to advance shared goals. Staffed by acoustic-modeling experts and bioacousticians, the CMA is positioned to take the lead in assessing and addressing anthropogenic sound and its environmental impacts within the US federal government and internationally.

Early Research: Pioneer Studies on Noise Impacts from Oil and Gas Activities

In the 1980s, BOEM was the first US government agency to support and fund research that investigated industrial noise impacts on marine mammals. Most of these studies conducted aerial or vessel observations to document the behavioral responses and distributions of migrating or feeding mysticetes (i.e., baleen whales) and pinnipeds (i.e., seals and sea lions) when exposed to underwater noise from offshore oil and gas exploration and development. Anthropogenic sound sources examined included airguns for marine seismic surveys, drilling for oil and gas extraction and production, dredging and pile driving for industrial facility construction, and various vessels including icebreakers.

These pioneer studies established a conceptual acoustic source-path-receiver model that became widely used to assess the potential effects of anthropogenic noise on marine mammals based on various distances from the source. Following these initial studies, BOEM funded additional research on sperm and humpback whales' behavioral response to seismic airgun exposures in the Gulf of Mexico (2002–2005) and Australia (2011–2017), respectively.

https://doi.org/10.1121/AT.2022.18.4.63

Current Research: Comprehensive Studies on Ocean Noise and Impacts

Studies on Anthropogenic Sound Sources and Sound Propagation

Over the past decade or so, the United States has begun to develop offshore renewable energy in the OCS, and BOEM has invested heavily toward understanding underwater sounds from the construction and operations of offshore wind facilities.

One of the most notable studies is the Realtime Opportunity for Development Environmental Observations (RODEO: see www.boem.gov/rodeo), led by Dr. James Miller of the University of Rhode Island, Kingston, in collaboration with the Woods Hole Oceanographic Institution (WHOI), Woods Hole, Massachusetts, and Marine Acoustics, Inc., Middletown, Rhode Island. Acoustics research under RODEO included investigation of sound field characteristics of impact pile driving on large wind turbine installation. Both acoustic pressure and particle motion data were collected in the water column at various distances using mobile and stationary acoustic sensors. Studies also investigated sound levels and frequency contents from pile driving with and without air bubble curtains. After completing RODEO, BOEM initiated RODEO II to collect data on substrate-borne vibration, analyze interpulse sound intervals, and measure the impulsiveness of pile-driving sound as a function of distance.

Additionally, BOEM funded a study to develop a methodology for computing the received sound field as a function of range, bearing, and depth from nonpoint sources, such as impact pile driving in a range-dependent environment. The method incorporates the newly established damped cylindrical spreading model, which includes sediment type and bathymetry information. The study created an Excel spreadsheet-based acoustic prediction tool (see www.boem.gov/environment/dcs-v3) to allow regulators to predict more accurate and robust acoustic impact zones for wind farm construction-related impact pile driving.

Studies on Animal Psychoacoustics and Effects of Sound on Marine Life

BOEM has also undertaken several cutting-edge research to understand auditory perception and behavioral responses of animals when exposed to underwater sound. One of the critical information gaps in assessing marine mammal noise effects is the lack of sufficient understanding of low-frequency cetacean (i.e., baleen whales) auditory capabilities and sensitivities. To address this data gap, BOEM is jointly funding two studies with the Office of Naval Research, the Marine Mammal Commission (MMC), and National Oceanic and Atmospheric Administration (NOAA). These studies will collect auditory evoked potential hearing thresholds from temporarily restrained minke whales (led by Dr. Dorian Houser of the National Marine Mammal Foundation) and investigate bone conduction in baleen whales using finite-element modeling (led by Dr. Ted Cranford of San Diego State University [SDSU], San Diego, California).

Until recently, relatively few studies had been performed to establish audiograms and examine noise effects in marine reptiles, fishes, and invertebrates. To address this information need, BOEM has funded research investigating hearing sensitivity in leatherback sea turtles and behavioral responses of black sea bass and longfin squid exposed to pile-driving sound pressure and particle motion. In the latter study, BOEM sponsored Dr. Aran Mooney at WHOI to conduct lab-based and field experiments before, during, and after exposure to pile-driving playback sounds in a tank and in situ pile driving in a mesocosm.

In 2014, BOEM helped fund a panel led by Dr. Arthur N. Popper and Dr. Richard R. Fay to develop a set of criteria for fish and sea turtle noise exposure. The outcome was the publication of the Acoustical Society of America (ASA) S3/SC1 Standards titled *Sound Exposure Guidelines for Fishes and Sea Turtles*, registered with the American National Standards Institute (Popper et al., 2014).

Studies on Acoustic Habitat

The acoustic environment is one of the essential ecological elements for marine animals that are primarily acoustically oriented. The soundscape within the aquatic environment is filled with sound from geophysical sources, biological sources, and anthropogenic sources. A good understanding of the temporal, spatial, and spectral dynamics of these sound sources is critical for BOEM to plan its OCS activities and assess potential impacts. Through the National Oceanographic Partnership Program, BOEM co-funded Dr. Jennifer Miksis-Olds of the University of New Hampshire, Durham, to establish the

Atlantic Deepwater Ecosystem Observatory Network (ADEON; see adeon.unh.edu) to collect and analyze large soundscape datasets across the deepwater regions of the Atlantic OCS. The baseline data collected from ADEON are being used for BOEM to assess its Atlantic OCS energy and minerals activities in the region.

Underwater Noise Monitoring, Mitigation, and Risk Assessment

In addition to conducting underwater noise- and impact-related research, BOEM contributes a large portion of its efforts toward monitoring and mitigating underwater noise from its regulated OCS activities. For example, for over 10 years, BOEM has collaborated with NOAA's Marine Mammal Laboratory to conduct passive acoustic monitoring (PAM) during offshore oil and gas development for impact monitoring in the Arctic (see bit.ly/3Td0FxA).

BOEM is currently working with stakeholders through the Regional Wildlife Science Collaborative (see rwsc.org) to develop a regional PAM network in the Atlantic to monitor for the presence of marine mammals in relation to offshore wind development. Additionally, BOEM has supported the improvement of PAMGuard, a widely used open-source software developed by Dr. Douglas Gillespie of the University of Saint Andrews, Saint Andrews, Scotland, United Kingdom, as well as the Tethys metadata system developed by Dr. Marie Roch of SDSU for analyzing and organizing marine mammal detections from PAM.

Although behavioral responses and auditory impairments from noise exposure provide certain benchmarks to gauge the effects on individual animals, these parameters often cannot assess the population-level effects to predict the significance of biological impacts. Under the auspices of the National Academies of Sciences, a scientific committee was formed to propose a conceptual model of Population Consequences of Disturbance (PCoD). In 2015, BOEM funded a study to review ways to quantify exposure-related changes in marine mammal behavior, health, or body condition of individual from multiple stressors, including loss of habitat, pollution, anthropogenic noise, and fisheries bycatch, and to make recommendations for future research initiatives.

However, implementation of a PCoD model for regulatory process is not straightforward due to the lack of specific and detailed data required to carry out the analyses. In 2019, BOEM convened a group of experts led by Dr. Brandon Southall to create an analytical risk assessment framework that specifically focuses on geological and geophysical surveys in the Gulf of Mexico. This novel framework incorporates key information about a population's status, the behavioral context in which it encounters sound sources, and the spectral overlap between the sound source and the species' hearing capabilities. This framework is currently being applied to evaluate the risks of staggered versus simultaneous construction of several offshore wind farms in the New England area.

Working with Partners and Looking Forward

BOEM's work on acoustics as well as on a host of other physical, biological, and sociological issues is wholly dependent on partnerships. BOEM is a small agency with just under 600 full-time employees and limited research funding, so we rely heavily on partners, both domestic and international, to achieve our mission goals. Whenever possible, BOEM seeks partnerships to maximize the utility of results and extend limited budgets by leveraging funds with other interested federal, state, and private stakeholders. We conduct many of our studies through collaboration and cost sharing with other organizations, such as the Navy, Department of Energy, NOAA, MMC, and the Joint Industry Programme on Sound and Marine Life (JIP).

Because the United States strives to reduce its reliance on fossil fuels, BOEM is increasingly involved in the development of offshore renewable energy. At the same time, BOEM's environmental long-term vision of elevating the ESP to become "First in Class" is actively pushing the boundary to understand ocean noise and its effects on marine life. Some of the cutting edge/pioneer studies we are developing include looking into substrate-borne vibroacoustic disturbances from offshore renewable energy structure construction and operations and their potential effects to the benthic ecosystem; investigating marine mammal noise-induced hearing threshold shifts from exposure to complex noise (noise that includes both impulsive and nonimpulsive components); and developing synergetic models to assess cumulative effects from multiple stressors. Additionally, BOEM is working on developing a multiyear national acoustic science strategy to prioritize research and assessments needs to support BOEM's mission.

BOEM is also exploring ways to incentivize the use of noise abatement methods that reduce the levels of noise that are introduced into the marine environment, which could serve as a primary mitigation approach. For example, in 2013, BOEM hosted the Quieting Technologies workshop with acoustics experts to investigate technologies that could reduce underwater noise from marine seismic surveys, pile driving, and associated vessel activities. Since then, BOEM has worked with the JIP on Marine Vibroseis to support development of alternatives to airguns and is currently working with other federal agencies to establish performance targets and incentives for noise reduction during wind farm construction.

Finally, BOEM recognizes the interrelationships between many environmental issues (such as climate change and acoustics) with vulnerable communities (i.e., low-income, minority, and indigenous and tribal communities). BOEM is stepping up its efforts to understand how offshore energy activities may impact vulnerable communities to determine whether federal activities may have disproportionately high and/or adverse impacts on certain communities. The ESP and CMA will be working with BOEM's environmental justice team to increase engagement with, identify, and study topics that involve vulnerable communities.

Acknowledgments

We thank Arthur N. Popper for inviting us to write this essay and for his guidance in the process. We are also grateful to Paulina Chen, Rodney Cluck, and Yoko Furukawa for reviewing the manuscript.

References

Erbe, C., Dunlop, R., and Dolman, S. (2018). Effects of noise on marine mammals. In Slabbekoorn, H., Dooling, R. J., Popper, A. N., and Fay, R. R. (Eds.), *Effects of Anthropogenic Noise on Animals*. Springer, New York, NY, pp. 277-309.

Popper, A. N., and Hawkins, A. D. (2019). An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes. *Journal of Fish Biology* 94, 692-713.

Popper, A. N., Hawkins, A. D., Fay, R. R., Mann, D. A., Bartol, S., Carlson, T. J., Coombs, S., Ellison, W. T., Gentry, R. L., Halvorsen, M. B., Lokkeborg, S., Rogers, P. H., Southall, B. L., Zeddies, D. G., and Tavolga, W. N. (2014). *Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report*. Prepared by the American National Standards Institute (ANSI)-Accredited Standards Committee S3/SC1 and registered with ANSI. Springer, New York, NY.

Contact Information

Shane Guan
shane.guan@boem.gov
guan@cua.edu

Environmental Studies Program
Bureau of Ocean Energy Management
Sterling, Virginia 20164, USA
and
Department of Mechanical Engineering
The Catholic University of America
Washington, DC 20064, USA

Jill Lewandowski Jill.Lewandowski@boem.gov

Erica Staaterman erica.staaterman@boem.gov

Center for Marine Acoustics
Bureau of Ocean Energy Management
Sterling, Virginia 20164, USA