BOEM OCEAN SCIENCE

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Acoustics at BOEM

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BOEM OCEAN SCIENCE is published by the Bureau of Ocean Energy Management to communicate recent ocean science, technological information, and issues of interest related to offshore energy recovery, marine minerals, and ocean stewardship.

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ON THE COVER
Artist's rendition of sperm whales communicating with each other in the Gulf of Mexico. Russell Yerkes, BOEM.

All photos courtesy of the Bureau of Ocean Energy Management unless otherwise noted.

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Frequently Used Abbreviations

ADEON	Atlantic Deepwater Ecosystem Observatory Network
CHAOZ	Chukchi Acoustic, Oceanography and Zooplankton Study
ESA	Endangered Species Act
G&G	Geological and Geophysical surveys
JIP	Joint Industry Programme (a consortium of oil and gas companies)
MMPA	Marine Mammal Protection Act
NEPA	National Environmental Policy Act
NMFS	NOAA Fisheries (previously known as National Marine Fisheries Service)
NOAA	National Oceanic and Atmospheric Administration
PAM	Passive Acoustic Monitoring
TSHD	Trailing Suction Hopper Dredge

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The Acting Director's Message

When scientists talk about impacts of noise on marine life, their frame of reference depends on questions such as: what animals are there and what can they hear; what is the frequency and loudness of the noise from the sound source; and can this noise interrupt important biological behaviors and communication between these animals?

One thing is certain—whether above or below the ocean's surface, the soundscape is inundated with a cacophony of sounds that occur naturally and those that are anthropogenic, or human-induced. It's these anthropogenic sounds—or noise—that can become bothersome, especially to marine animals. As human presence in the offshore environment has increased, so have the anthropogenic noise levels. Current science indicates that noise can adversely impact marine species' abilities to communicate, navigate, and reproduce.

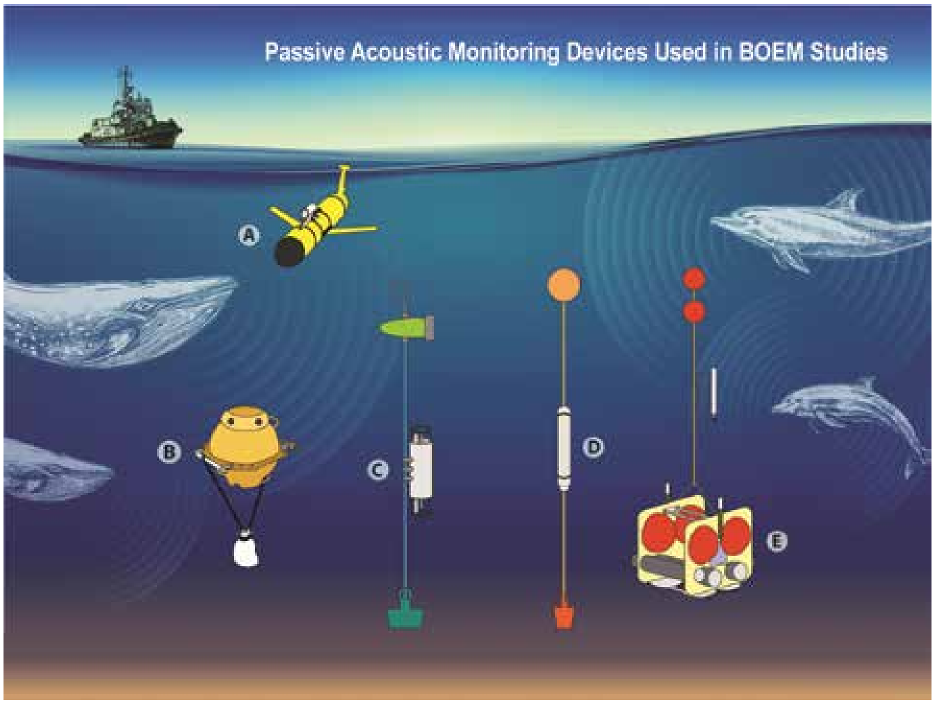
However, understanding the potential impacts of anthropogenic noise on marine life is complex and there is some uncertainty in our current understanding of these effects. As a result, BOEM is driving original research to fill these knowledge gaps. Our scientists are not only measuring naturally occurring sounds, they are also examining the effects of human-produced noise and evaluating these effects in context with current laws and regulations. This will allow BOEM to make decisions that align with our environmental stewardship responsibilities and regulatory requirements.

Balancing human activities with marine life protection is a difficult task. That's why BOEM uses the best science available to approach management decisions. While debates on mitigation practices remain and the opinions on the best path forward are varied, BOEM remains steadfastly committed to funding and supporting the science necessary to better understand anthropogenic sounds and their effects on marine life.

We highlight some of our efforts to understand and minimize the impacts of ocean noise in this edition of *Ocean Science.* On these pages you'll discover articles on technologies for passive acoustic monitoring, reducing impacts from seismic surveys and pile driving, marine life behavioral responses to noise, and BOEM studies conducted through partnerships.

I hope you enjoy learning more about the multiple efforts BOEM is undertaking to improve the overall scientific understanding of anthropogenic noise and its impacts on marine life.

— Walter D. Cruickshank



Passive acoustic monitoring devices used in BOEM studies: A) Slocum glider, B) Marine Acoustic Recording Units (MARU), C) Autonomous Marine Acoustic Recorder (AMAR), D) Cetacean Porpoise Detector (C-POD), and E) High Frequency Acoustic Recording Package (HARP).

Conducting and Applying Acoustics Research at BOEM

Understanding the Ocean Soundscape

Once considered silent, the seas are now known to be alive with sounds. Some are from natural sources, such as storms, earthquakes, and waves. Others come from animals that use acoustic signals for communication and navigation. Shipping, energy development, military operations, construction, and commercial fishing also introduce sounds into the ocean. When anthropogenic, or human generated, sounds are unwanted, they are generally referred to as "noise."

BOEM was one of the first federal pioneers to sponsor research on ocean noise, playing a key role in improving the overall scientific understanding of anthropogenic noise effects on marine life. These efforts have also established requirements to protect marine life during noise-producing Outer Continental Shelf (OCS) energy and mineral development activities.

BOEM Acoustics Research History

BOEM started researching the effects of industrial noise on large whales, seals, and sea lions in the Pacific Ocean in the 1980s, then offshore Alaska. Today, BOEM's research includes additional geographic areas and numerous species. BOEM uses a variety of research methods and technologies (e.g., passive acoustic monitoring, autonomous platforms, animal tags, and acoustic modeling) to collect and interpret the most accurate data. Recognizing the issue's importance, BOEM has expanded its staff to include experts on marine acoustics, and regularly engages with students exploring marine acoustics careers.

During the past three decades, BOEM has invested nearly \$90 million on studies related to protected species and noise-related studies through four general research methods: 1) literature reviews, syntheses, and workshops; 2) field surveys; 3) empirical laboratory and field studies; and 4) sound source verification and modeling.

Partnerships

Some of BOEM's most significant research has occurred through partnerships with federal agencies, academia, industry, and international groups. For example, in 1992 the Office of Naval Research provided funding to convert a 1987 BOEM report on oil and gas industry noise effects into a book entitled *Marine Mammals and Noise*. For nearly 25 years, this book has been a key resource for scientists and regulators. BOEM has also co-funded research with the Joint Industry Programme (JIP) on the effects of seismic surveys on migrating humpback whales and has developed new acoustic impact modeling approaches with NOAA Fisheries. BOEM has co-funded scientific reviews by the National Academy of Sciences on noise.

Through the National Oceanographic Partnership Program, BOEM is co-funding the University of New Hampshire to

Retrieving a passive acoustic recorder mooring. Photo by Danielle Cholewiak.

record and analyze patterns across entire acoustic environments (soundscapes). Data from this project, the Atlantic Deepwater Ecosystem Observatory Network (ADEON), will provide critical baseline information on ambient noise, oceanographic conditions, key marine species distribution, and biodiversity patterns across the deepwater regions of the Atlantic OCS. This baseline data could prove useful if OCS energy and minerals activities proceed in these areas.

Keeping up with Acoustics Research

Expanding and sharing knowledge on new findings, research methods, and new technologies is critical to understanding and developing ways to reduce noise impacts. Consequently, BOEM regularly participates in and convenes numerous workshops and conferences.

In 2013, BOEM hosted the Quieting Technologies workshop for U.S. and international experts to examine technologies that reduced the noise from offshore exploratory seismic surveys, pile driving, and associated vessel operations.

In 2018, BOEM participated in several international ocean noise conferences, including one sponsored by the United Nations. BOEM participated in the July 2019 Effects of Noise on Aquatic Life conference, where Dr. Lewandowski delivered a keynote address on the international regulation of ocean noise.

Applying the Knowledge

BOEM applies its research results during offshore development project reviews to evaluate the potential range of noise effects and identify measures that could reduce the impacts if a project moves forward. BOEM's studies also inform appropriate needs during operations to better understand actual noise impacts and mitigations' effectiveness.

The use of airguns during seismic surveys to identify offshore oil and gas resources can pose a noise concern and potentially harm marine mammals that are nearby. After analyzing independent airgun noise range data, BOEM began requiring operators to establish an exclusion zone—monitored by independent marine mammal observers—to ensure there are no marine mammals in the vicinity before and during airgun operations. Operators must also turn off airguns if a marine mammal appears within, or is about to enter, the exclusion zone. More information on BOEM's seismic airgun noise mitigation requirements is found in Programmatic Environmental Impact Statements for both the Atlantic and Gulf of Mexico.

Pile driving for offshore wind turbine foundations is another concern. BOEM applies knowledge gained from its studies to help select Wind Energy Areas that avoid known critical biological areas for endangered or threatened species. BOEM also develops best management practices to minimize impacts from noise-producing activities.

Since BOEM's 2013 Quieting Technologies workshop, industry has been looking to apply new technologies to mitigate airgun effects, and companies submitting construction and operating plans for offshore wind turbines are considering adopting quieting technologies to offset pile driving noise.

Looking Toward the Future

With increasing levels of industrialization, ocean noise is increasing and showing no signs of abating. While BOEM—and many others—have made substantial progress over the last four decades in improving understanding of ocean noise impacts, there is still much to be done. BOEM remains committed to further improving scientific knowledge on ocean noise and developing even stronger connections between science and regulation to ensure that the OCS energy and minerals footprint is the least impactful as possible.

—Dr. Rodney Cluck
Chief, Division of Environmental Sciences
BOEM Office of Environmental Programs
and
Dr. Jill Lewandowski
Chief, Division of Environmental Assessment
BOEM Office of Environmental Programs

For More Information

Atlantic Geological and Geophysical Activities Programmatic Environmental Impact Statement
https://www.boem.gov/Atlantic-G-G-PEIS/

Gulf of Mexico Geological and Geophysical Activities Programmatic Environmental Impact Statement
https://www.boem.gov/GOM-G-G-PEIS/

Fact Sheet: Managing Impacts of Anthropogenic Stressors on Marine Mammals
https://www.boem.gov/Fact-Sheet-on-Sound-Studies/

Assessment of Cumulative Effects of Anthropogenic Stressors on Marine Mammals
https://www.nap.edu/catalog/23479/approaches-to-understanding-the-cumulative-effects-of-stressors-on-marine-mammals

"Effects of Noise on Marine Life" Conferences Proceedings
https://asa.scitation.org/toc/poma/27/1?vol=27&expanded=30$windowStart=50&expanded=27

Quieting Technologies for Reducing Noise During Seismic Surveying and Pile Driving Workshop
https://www.boem.gov/ESPIS/5/5377.pdf

Cetacean and Sound Mapping Project and Symposium
https://www.nefsc.noaa.gov/psb/acoustics/psbAcousticsCetSound.html

Seismic Survey Mitigation Measures and Protected Species Observer Reports
https://www.boem.gov/Ocean-Science-Aug-Nov-2018/

Using Acoustics as a Tool to Study Biological and Physical Phenomena in the Ocean

Because many marine species—especially marine mammals—produce sounds for basic functions, scientists can learn a great deal about their biology by listening to them. Sometimes hydrophones are deployed for months at a time in a technique called Passive Acoustic Monitoring (PAM). In other cases, hydrophone tags attached to large animals track their acoustic behaviors while they are on the move. In either case, scientists can collect critical information about their location, behavior, and sometimes the number of nearby individuals. Additionally, PAM can be used to learn about storms or seasonal trends since acoustic conditions are closely tied to the weather. Because most of the ocean is dark and difficult to access, PAM is an incredibly useful tool that can reveal new insights about biological and physical phenomena.

Most of what is known about whales has been learned from watching them at the surface. However, the naturally deep-diving behavior of certain species like sperm and beaked whales renders them virtually invisible to scientists, making it a challenge to know where they are, how many there are, and what they are doing. To improve our understanding, BOEM conducted the first phase of the Marine Mammal Passive Acoustic and Spatial Ecology Project (MAPS). The research took place offshore North and South Carolina, ranging in water depths from approximately 650 ft to 3 mi (200 m to 5,000 m). This was the first time that whale ecology was studied in this region during the winter.

The MAPS team conducted several cruises and acquired multiple types of data. Hydrophone arrays streamed out from the R/V *Song of the Whale*, a quiet research sailboat specially designed for acoustic work. The hydrophones have good directional capability and a broad acoustic bandwidth, which helps provide estimations of how many whales are nearby. Certain sounds are linked with particular behaviors, i.e., sperm whales use echolocating clicks to find prey and patterned clicks (called codas) to communicate with one another and maintain social structure. A 3-D hydrophone array helped researchers identify the whales' depth to understand their distribution throughout the water column. Multi-sensor acoustic recording tags (D-tags) were deployed on some of the whales to record water depth, water temperature, and the sounds made and heard by the whale as it moved through the ocean. Finally, the research team will collected biopsy samples, which provide information on their sex, possible relatedness, and levels of toxins and hormones. These techniques allowed the team to get a rich picture of a day in the life of a whale. Because the North and South Carolina coastline is a key migratory and feeding corridor for several species, accurate information about their distribution and occurrence patterns is necessary to predict potential impacts of BOEM activities in these areas.

In the Arctic, BOEM has been using acoustic tools to study the distribution of marine mammals and biophysical trends. From 2010 to 2018, BOEM, in partnership with National

Scientists from Marine Conservation Research, the University of North Carolina Wilmington, and Duke University aboard the R/V *Song of the Whale*. Photo by Marine Conservation Research.

Scientists from Duke University and BOEM approach a sperm whale off North Carolina to attach a suction cup sound and motion tag. Photo by Marine Conservation Research.

Oceanographic and Atmospheric Administration (NOAA), sponsored the Chukchi Acoustics, Oceanography, and Zooplankton (CHAOZ) study and its extension at Hanna Shoal.

CHAOZ used PAM moorings and physical, chemical, and biological sensors to capture the mean properties (e.g., species presence, transport, salinity, ice thickness, nutrient concentration) over time, as well as the variability in the system. The moorings permitted observations when ice makes the region inaccessible to ships, while minimizing the need for research activities that might interfere with the whale hunt during the annual bowhead whale migrations through the Chukchi and Beaufort Seas. Results showed that bowheads and belugas have consistent seasonal migrations related to season and ice cover, while grey whale movements were more closely tied to prey availability.

The researchers created a Chukchi Sea noise budget, which describes and quantifies sounds from living and non-living sources, to assess the influence of discrete sound types, as well as the aggregate contribution of multiple sources, on the overall acoustic environment. The acoustic environment was highly variable across space, time, and frequencies.

For example, when ice forms in the fall, there is a negative correlation between noise and ice cover (the ice blocks noise from surface winds); in the spring, when ice is breaking apart, there is a high positive correlation with noise levels. The data-driven model developed in this study predicted that ambient noise levels would increase in the future, due to the anticipated increase in open water over larger areas and longer time periods, combined with an increase in storms. This research allows BOEM to better predict how sound levels may change over time due to climatological shifts, industrial activity, and animal behavior, and provides critical baseline data about the seasonal patterns of protected species in this region.

Finally, BOEM is studying the waters of the Mid-and South Atlantic Planning Areas as part of the Atlantic Deepwater Ecosystem Observatory Network (ADEON). Instead of only listening to the sounds of particular marine mammal species, the team is recording and analyzing patterns in the entire acoustic environment. In addition, other sensors will measure water quality, currents, and meteorological conditions. They will also use active acoustic methods to look for plankton and fish in the water column. Together, the data from these seven moorings will provide critical baseline information about ambient noise, oceanographic conditions, distribution of key marine species, and patterns in biodiversity across the deepwater regions of the Atlantic OCS.

— Jacob Levenson, Erica Staterman, and Heather Crowley
BOEM

For More Information

MAPS video

https://www.boem.gov/Studying-Sperm-Whales-and-Beaked-Whales-in-the-Atlantic

MAPS project digital field diary

https://openexplorer.nationalgeographic.com/expedition/beakedwhales

CHAOZ, Chukchi Acoustic, Oceanography and Zooplankton Study

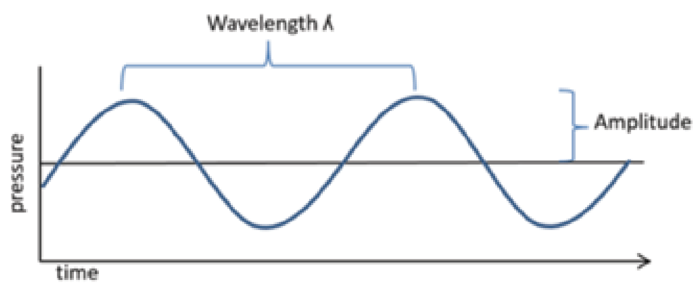
https://www.fisheries.noaa.gov/region/alaska#science

Atlantic Deepwater Ecosystem Observatory Network

https://adeon.unh.edu/

Verifying the Physical Qualities of Industrial Sound Sources

BOEM considers the characteristics of man-made sounds in its environmental documents since that, in part, determines the nature of impact on wildlife. This is done through a multi-step process. First, information about the sound source itself (e.g., amplitude, duration, frequencies, water depth, etc.) is described. That information is often incorporated into an ocean propagation model, which predicts the sound field at various distances from the source. based on the acoustic properties of the source, sound speed, The model is based on the acoustics properties of the source, sound speed, and interactions between the ocean surface and ocean bottom. This model allows BOEM to predict the amplitude of the sound that would be received by an animal at a given distance from the source, thereby better anticipating how they may be affected.



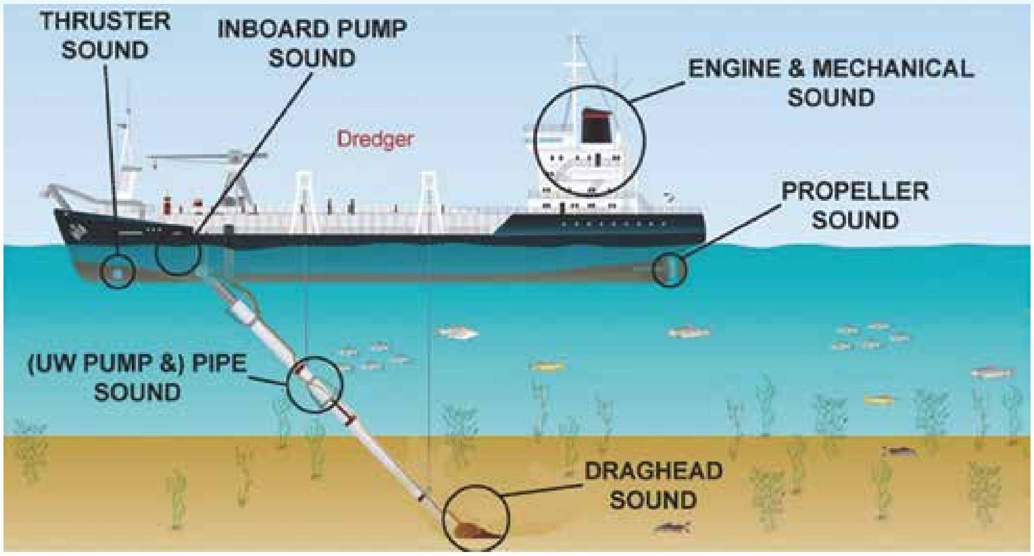
- Wavelength = Distance between identical points on consecutive waves.
- Frequency = The number of waves that pass a point per unit time. The perceptual meaning of frequency is "pitch."
- Amplitude = Distance between the top of a crest and point of equilibrium. The perceptual meaning of amplitude is "loudness."

For some of the sounds produced or used in BOEM-authorized activities, exact information about the source itself is unknown, which means that estimates of impacts tend to be overestimated. In these cases, it is necessary to measure these sounds *in situ* to better inform acoustic models.

For example, in 2012, the U.S. Army Corps of Engineers and BOEM measured underwater sounds from three different trailing suction hopper dredges (TSHD) during a beach nourishment project at National Aeronautics and Space Administration (NASA's) Wallops Flight Facility in Virginia. Scientists recorded dredge sounds using hydrophones at two depths and various distances from the TSHDs. The full range of potential operational modes and conditions (e.g., size, speed, full vs. empty hopper, etc.) were examined. The noise generated spanned a range of frequencies, with the peak energy below 500 hertz (a range that overlaps with the hearing range of many marine species). Noise was loudest during transit when the dredge was not loaded, but traveling at the greatest speeds. Higher propulsion power, higher pump speeds, and higher transit speeds generally resulted in higher noise levels. An important finding was that noise from the TSHDs faded into the background noise as the distance from the dredge increased.

Similarly, BOEM has studied the sounds produced by underwater explosives, which are used to decommission offshore structures. Decommissioning is an activity that is permitted by the Bureau of Safety and Environmental Enforcement (BSEE), and BSEE is responsible for both Marine Mammal Protection Act and Endangered Species Act compliance associated with this activity. Explosive severance and, in particular, detonations below the mud-line (BML) are likely to produce lower sound pressure levels than open-water configurations at the same propagation distances, due to attenuation of energy by sediments and the confinement of the explosion within well casings and platform pilings. To better predict the attenuating effects of BML detonations, an underwater calculator (UWC) model was modified to further allow the structural

Decommissioning a platform. Photo by Tre Glenn, BOEM.



and depth components to be considered within the propagation models. A joint BOEM-BSEE study examined 8 well casings (conductors) and explosions to cut 11 pilings to calibrate and validate the UWC. This study shows that having more varied data conditions is essential to improving the universal application of the UWC throughout the Gulf of Mexico and beyond. The identification and measurement of additional conditions and scenarios is ongoing as is data interpretation. Study results will be published in the near future.

BOEM, along with the U.S. Geological Survey, has also undertaken a three-part study to verify acoustic properties of High Resolution Geophysical (HRG) Survey systems, which are used in all three BOEM program areas (Conventional Energy, Renewable Energy, and Marine Minerals Programs). HRG systems include most of the commonly used oceanographic and geophysical survey tools including side scan, chirp, swath bathmetry, multibeam, Boomer, Bubble Gun, echosounders, and Interferometer sonars, as well as sparkers and small airguns. The first study conducted a detailed characterization and calibrated measurement of these systems in a highly controlled environment. The U.S. Navy's Naval Undersea Warfare Center conducted this testing, which resulted in the definitive measurement of these systems in a key publication by Crocker and Fratantonio (2016). The second study then examined the sound fields produced by these same systems in three different shallow-water depths (10, 30, and 50–100 m [32.8, 98.4, and 164–328 ft]) and two different bottom reflection conditions (mud and sand). Preliminary results of these *in situ* measurements are available in Halvorsen and Heaney (2018), but the final data will only be available after the third project, which will utilize acoustic models to complete the data's calibration. This third project will also examine and identify which acoustic propagation models and modelling approaches are best for each of these systems in the shallow-water environments found on the continental shelf.

Another study, Real-time Opportunity for Development Environmental Observations (RODEO), also focused on verifying physical qualities of industrial sound sources. The real-time observations during wind farm construction help BOEM gain insights into actual disturbances to the environment. These include pre-construction ambient noise levels compared to the sounds generated during construction (pile driving and cable laying), sound duration and propagation distances, sounds generated by vessel traffic, devices or technology for reducing sound levels during construction, and sounds from wind turbine operation.

— Geoffrey Wikel, Tre Glenn, Stan Labak
BOEM

For More Information

Characterization of Underwater Sounds Produced by Trailing Suction Hopper Dredges during Sand Mining and Pumpout Operations
https://www.boem.gov/ESPIS/5/5380.pdf

Pressure Wave and Acoustic Properties Generated by the Explosive Removal of Offshore Structures in the Gulf of Mexico
https://www.boem.gov/ESPIS/5/5505.pdf

Crocker, S.E. and F.F. Fratantonio (2016). "Characteristics of Sounds Emitted During High-resolution Marine Geophysical Surveys."
https://www.boem.gov/ESPIS/5/5551.pdf

Halvorsen, M.B. and K.D. Heaney (2018). "Propagation Characteristics of High-resolution Geophysical Surveys: Open Water Testing."
https://espis.boem.gov/final%20reports/BOEM_2018-052.pdf

Fact Sheet on Geophysical and Geological Surveys
https://www.boem.gov/Geological-and-Geophysical-Surveys/

RODEO: Real-time Opportunity for Development Environmental Observations
https://opendata.boem.gov/BOEM-ESP-Ongoing-Study-Profiles-2018-FYQ2/BOEM-ESP-AT-14-01.pdf

Understanding the Impacts of Noise on Marine Species

Because many BOEM-authorized activities introduce anthropogenic noise into the ocean, and because this noise may affect marine life, it is critical that BOEM anticipate these potential impacts before authorizing activities. However, not all species have a scientifically documented response to noise. In these instances, BOEM's Environmental Studies Program must fill these knowledge gaps.

One such knowledge gap is the extent to which pile-driving noise may affect longfin squid and black sea bass during wind farm construction in the northwestern Atlantic Ocean. These two commercially and recreationally important species occur in areas where offshore wind construction is planned. BOEM is conducting a study with NOAA Fisheries, in partnership with the Woods Hole Oceanographic Institution (WHOI), to simulate the effects of noise on these species.

For the study, researchers played recordings of actual pile-driving noise to squid and black sea bass in small tanks and monitored their behavior. The recordings were made at depths and distances similar to those that the animals would encounter in their natural environment at Rhode Island's Block Island Wind Farm at an approximate distance of 1,640 ft (500 m) away at depths of around 85 ft (26 m). Since black sea bass hearing thresholds are unknown, scientists are also conducting electrophysical measurements of hearing to complement the behavioral study.

In August 2018, the research team presented the tank trial preliminary results to fishermen, scientists, and resource managers at the American Fisheries Society annual meeting in Atlantic City, New Jersey. Scientists were especially interested in the species-specific behavioral responses to repeated noise exposure. Squid displayed an alarm response at noise onset but quickly grew accustomed to noise after 5–15 minutes. Researchers also measured the squids' feeding success during pile-driving playbacks, and observed that it was not significantly affected. Black sea bass, however, exhibited different behavior.

During the pile-driving playbacks, individual fish would cease surface bobbing behavior and move towards the bottom of the tank into a resting phase. The black sea bass resting response persisted longer than the squids'—up to 5 minutes post exposure. Moving towards the seafloor is a response that has been observed in other fishes, and may be

Australian humpback whales photographed during the BRAHHS study. Photo courtesy of the BRAHHS project.

Scientists prepare to collect a biopsy from a whale offshore the Atlantic coast - MAPS study. Photo by Marine Conservation Research.

the reason that catch rates of some fisheries have changed in response to certain noise types. BOEM plans to expand the black sea bass trials in a larger, 32,000-gallon tank at the NOAA Fisheries Sandy Hook Laboratory in New Jersey. This next phase will allow the team to observe the behavior of schools of fish, not just individuals.

In partnership with the Joint Industry Programme (a consortium of oil and gas companies), BOEM helped to fund the multi-year "Project BRAHSS: Behavioral Response of Australian Humpback Whales to Seismic Surveys." Researchers conducted several controlled behavioral response experiments that exposed dozens of whales to airgun noise at levels similar to actual industrial seismic surveys during their spring migration. Whales were observed from boats and by observers on shore; some whales were outfitted with tags to measure their location, depth, and dive duration. A series of hydrophones and a propagation model were also used to map the sound field during the experiments. As a control, the team observed the whales' reactions in the presence of ships but without airgun noise. An important element of this study was the testing of "ramp-up," a commonly-used mitigation procedure in which the volume of airgun sounds gradually increases over time in an effort to "warn" the whales.

While there was high variability in individual whale behavior, some general conclusions can be made. The whales altered their usual migration path to maintain a consistent distance from the noise source or to reduce the rate at which they approached it. Some changes occurred in dive duration, blow rates, and other surface behaviors, but these changes depended on group composition. The change in observed behaviors can be explained by both the received sound level and by the whales' proximity to the seismic vessel. The whales also responded to ships in the absence of noise, which should be an important consideration in future studies. Finally, although ramp-up had an overall deterrent effect, the results do not suggest that a ramp-up effort would be more effective than starting with a constant, lower-intensity airgun. Since whale behavior is complex and highly variable across individuals, the study's conclusions are also complex—despite a large research team, elaborate experimental design, and relatively high sample size.

BOEM hopes to fill another knowledge gap. In the summer of 2017, a team of Australian scientists published a study demonstrating that seismic airguns may affect zooplankton at much greater distances than previously assumed. Early studies on fish eggs, larvae, and other planktonic organisms showed effects on the order of tens of meters away from the airguns, but the 2017 study showed impacts up to nearly 1 mi (1.2 km) away. BOEM is pursuing international collaborations to conduct another field study under conditions more typical of the U.S. OCS.

— Jim Price, Brian Hooker, and Erica Staaterman
BOEM

For More Information

Behavioral Effects of Sound Sources from Offshore Renewable Energy Construction on the Black Sea Bass and Longfin Inshore Squid

https://www.boem.gov/AT-17-02

BRAHSS: Behavioral Response of Australian Humpback Whales to Seismic Surveys

https://www.brahss.org.au/

Zooplankton Study

https://www.nature.com/articles/s41559-017-0195?proof=true&platform=oscar&draft=collection

Keeping Up with the Latest Developments in Marine Acoustics

The field of marine bioacoustics is expanding rapidly as more and more studies reveal that a wide range of marine species produce sounds or are sensitive to sounds. It is important for BOEM to keep abreast of the latest science in order to produce accurate impact assessments and identify remaining knowledge gaps. In addition, international attention on anthropogenic noise has grown in recent decades and countries around the world are taking different approaches to regulate and manage noise in their oceans. BOEM has participated in a number of international events and meetings, which has allowed us to better frame the context of our regulations here in the U.S. and potentially consider alternate ways to manage noise.

Although there have been many areas of expansion, one more recent example has been to understand the effects of human-made sound on fish and invertebrates. In 2012, BOEM played a pivotal role in synthesizing existing knowledge on the effects of noise on fish, fisheries, and invertebrates by hosting a workshop with the world's top experts on this topic. The intention was to obtain information to better inform National Environmental Policy Act (NEPA) analyses, develop appropriate mitigation measures, and identify needs for future research through the BOEM Environmental Studies Program. The literature synthesis, authored by some of the top fish acousticians in the world, serves as a comprehensive reference and helped formed the basis for the first "sound exposure guidelines" for fish and sea turtles, which the American National Standard Institute published in 2014. These sound exposure guidelines delineate the sound levels at which effects—ranging from behavioral changes to hearing loss to mortal injury—may occur for adult fish, larval fish, and sea turtles. This document is used by regulators around the world to predict potential acoustic impacts to a range of species.

Retrieving a surface-float oceanographic mooring. Photo by Angela Keeling-Garcia.

In recent years, BOEM has participated in several international meetings with regulators and scientists to better understand global perspectives on ocean noise. In June 2018, BOEM's Dr. Jill Lewandowski gave remarks at the United Nations Open-Ended Informal Consultative Process on Oceans and Law of the Sea 19th meeting focused on "Anthropogenic Underwater Noise." She was among 30 speakers who aimed to shed light on the issue. The meeting was informal, without any negotiations or international agreements, but helped raise awareness on this topic leading up to the UN Ocean Conference in 2020. In September 2018, several BOEM staff participated in the Effects of Sound on Marine Mammals and Joint Industry Programme on Sound and Marine Life combined meeting in the Netherlands. In addition to presenting some of BOEM's work, the team worked with the International Offshore Petroleum Environmental Regulators group to organize a forum for regulators from 12 different countries to share information about their strategies for managing and mitigating impacts of noise in different countries. In July 2019, our acoustics team participated in another international conference on the Effects of Noise on Marine Life. Given the global nature of this issue, it is important that BOEM maintains a presence in such international forums to share knowledge but also learn from others as to different ways to study and manage this issue.

Finally, BOEM is routinely working with leading experts in marine acoustics to better understand and contextualize potential impacts from BOEM-regulated sound sources. A recent project, which will wrap up later in 2019, convened a group of experts to create a new analytical framework. This framework utilizes expert opinions to produce an estimation of the relative levels of risk to different marine mammal populations, after exposure to noise. Prior to the development of this framework, the best identified approach to estimating "population-level effects" of an action relied on the U.S. National Academies of Sciences National Research Council's (NRC's) model known as Population Consequences of Disturbance (PCoD). Unfortunately, the data required to implement these models often does not exist or is very difficult and time-consuming to acquire.This new framework is designed to bypass these difficulties by replacing it with the best available expert scientific opinions, until the detailed data are available for PCoD. Additionally, the experts' framework and critical assessments are transparent and easily reviewed by regulators and the public, allowing a deeper understanding of the results and easy revision as new information becomes available. The final reports will provide a sample evaluation of the risk associated with geological and geophysical (G&G) surveys in a typical year in the Gulf of Mexico. It will also address the aggregate risk of multiple, simultaneous G&G activities that often take place there.

BOEM's scientists and contractors have increasingly played a role in not only ensuring that the unique requirements and needs for our Conventional Energy, Renewable Energy, and Marine Minerals Programs are being met, but also that our efforts are efficiently incorporated and used by the larger underwater acoustic community. BOEM will continue to engage both domestically and internationally as a means to widen our knowledge and find creative solutions to tackle this complicated issue.

— Erica Staaterman, Jill Lewandowski, and Stan Labak
BOEM

Real-time auto-detection buoy being deployed through the A-frame. Photo by Angela Keeling-Garcia.

For More Information

Effects of Noise on Fish, Fisheries, and Invertebrates in the U.S. Atlantic and Arctic from Energy Industry Sound-Generating Activities. Workshop Report

https://espis.boem.gov/final%20reports/5361.pdf

Sound Exposure Guidelines for Fishes and Sea Turtles. Springer Briefs in Oceanography

https://link.springer.com/book/10.1007%2F978-3-319-06659-2

National Research Council's Population Consequences of Disturbance (PCoD) model

https://onlinelibrary.wiley.com/doi/full/10.1002/ece3.4458

Spotlight on the BOEM Acoustics Team

A team of scientists at BOEM's headquarters office helps the bureau tackle acoustic issues. Tamara Arzt and Erica Staaterman work in the Division of Environmental Assessment, with Jill Lewandowski as the Division Chief, and Stan Labak works in the Division of Environmental Sciences.

Why did you decide to work for BOEM?

Erica: I was intrigued by the opportunity to work at the intersection of science and policy, recognizing that a government position offered a greater possibility for impactful work than in academia.

Stan: I had worked as a government contractor for various organizations in the Department of Defense for many years, developing and testing sonar systems and producing the environmental documents that allowed that testing. When an opportunity arose to have a larger voice on the environmental topics, I decided to pursue it.

Tamara: I wanted to return to federal service after taking some time to work for local government. I had previously worked for Interior's Bureau of Land Management (BLM) where I focused on a variety of environmental and federal natural resource management issues. Working for BOEM allowed me to return to a focus on what I truly enjoyed: the ability to work with multiple stakeholders on sensitive natural resource management issues using science and policy to balance environmental protection with energy development.

BOEM's Acoustics Team, (left to right) Jill Lewandowski, Stan Labak, Erica Staaterman, and Tamara Arzt. Photo by Marjorie Weisskohl, BOEM

Jill: I worked previously in the private sector, for both industry and not-for-profits, but transitioned to the federal government 19 years ago (14 of which have been with BOEM on acoustic issues). The federal government offers an unmatched opportunity to tackle environmental issues at a national and even global scale and carefully craft sustainable decisions that allow economic progress while still protecting the environment.

How has your education and experience prepared you for the job?

Erica: My undergraduate degree in biology and my Ph.D. in applied marine physics complement each other nicely. I am able to understand the technical language of acoustics while also bringing in my knowledge of marine biology. Also, my previous experience with PAM has allowed me to engage in BOEM-funded studies that use this common technique to study marine species.

Stan: My formal education provided the basic platform for my understanding of the technical aspects of my work, but it is really the at-sea testing time and on-the-job training that exposed me to the constantly changing and expanding issues and topics surrounding acoustics and their potential impacts to the marine environment.

Tamara: My undergraduate degree was in Government and my Masters in Public Administration focused on endangered species and public participation within the NEPA process. After grad school I worked for an Alternative Dispute Resolution organization, where I focused on facilitating many federal natural resource issues. The next step was law school where I focused on environmental law. This combination of hands-on training with my formal education has given me a number of tools to navigate and work with multiple stakeholders to create mutually beneficial and sustainable solutions to the challenges that arise in this field.

Jill: Well, nothing quite works exactly like the textbooks tell you! My educational background taught me how systems should work (e.g., ecosystems, political systems). My experience showed me that education alone cannot give you the full picture on complicated issues, like ocean acoustics, where the content is highly technical, occurs at a global scale, and is fringed with public controversy and conflict. Instead, a blend of education and experience is essential to looking for solutions at a macro scale.

What do you enjoy most about your job?

Erica: I enjoy the intellectual complexity of the challenges that we face, and the fact that we are constantly shifting our goals and expected outcomes of our work. Every week is different, and it keeps us on our toes.

Stan: I enjoy solving puzzles, and my position at BOEM provides me with an endless supply of technical puzzles and challenges, ranging from understanding and verifying the underwater acoustic data produced to support one of our projects to determining a new method to measure or predict the potential acoustic impacts from our activities.

Tamara: What I enjoy most about my job is the level of responsibility you are given, especially in a smaller agency. Being able to work independently with so many different stakeholders, ranging from other federal agencies, industry, and NGOs, to academia and the general public is energizing. Working as a team to search for enduring solutions and building lasting relationships to address future challenges is fulfilling.

Jill: The people—both those I work with in the federal government or the many, many individuals involved in this issue globally. I have met so many people who work tirelessly to find a better solution to this tough issue. No one person has the full technical knowledge, policy awareness, and/or collaborative skills to tackle this issue alone. I have learned a great deal from all of them. By sharing their knowledge and unique perspectives with me, I can better put all the pieces together for a more complete picture on workable solutions.

Which project was the most memorable?

Stan: For the last three years I have been involved with three related projects that have been working toward the goal of being able to characterize most commonly used oceanographic or survey sonar systems in the complex shallow-water environments where we use them. These projects have been fun and challenging because they touch on all of the critical aspects of predicting sonar system's sound fields: the engineering calibration of these sources in controlled situations; the measurement of the system in the field; and the optimal predictive modeling of these systems during future operations and conditions.

Jill: This is a tough one as there have been so many. If I had to pick, I would actually say my dissertation research where I interviewed 58 stakeholders and reviewed 230 documents addressing ocean acoustic issues. It was enlightening to spend 1–3 hours talking openly with each person about their challenges, solutions, and conflict with others on this issue. I have been able to synthesize this knowledge and apply it in projects every day at BOEM.

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Explore ocean information from your Computer with new OceanReports tool

A new, web-based interactive tool for ocean mapping and planning created by BOEM and NOAA will give everyone—from ocean industries to coastal managers, students, as well as the general public—the opportunity to explore ocean information from his or her own computer.

The new OceanReports web tool provides users specialized "ocean neighborhood analyses," including maps and graphics, by analyzing more than 100 ocean datasets instantaneously. Just draw an area and, in less than 2 seconds, get results for 67 themed info-graphics. It is one of many special tools available on marinecadastre.gov.

This map, created with the OceanReports tool, shows four data layers: cargo ship tracks, North Atlantic Right Whale seasonal management areas, vessel routing lanes, and mid-Atlantic ports.

U.S. ocean waters comprise nearly 4 million square miles and are one of the largest Exclusive Economic Zones (EEZs) in the world. Now when you draw or choose any area in the U.S. EEZ using the OceanReports app, you can get detailed information about habitats and species, industries at work, potential hazards such as undersea cables, shipwrecks, economic value of ocean commerce, and oceanography.

This large collection of "ocean intelligence" can now be accessed to help sustain and grow one of the world's largest blue economies. OceanReports builds on more than a decade of data collection to transform how seemingly disparate ocean information can be delivered to the Nation's ocean and coastal industries, which in 2018 added $320 billion in gross domestic product to the Nation's economy.

Also, while OceanReports provides a fountain of data for use by industry and science, it is still easy enough to use in the classroom to help students studying biology, chemistry, geography, and even other disciplines like economics. BOEM worked diligently with NOAA to create this tool, which benefits the ocean community while helping BOEM carry out its mission—the responsible development of ocean energy and marine mineral resources for the nation.

OceanReports is an example of strong federal interagency coordination and cooperation on ocean policy, as put forward by the President's Ocean Policy to Advance the Economic, Security and Environmental Interests of the United States (Executive Order 13840), signed June 19, 2018.

For More Information

OceanReports Tool
https://marinecadastre.gov/oceanreports

Executive Order
https://www.whitehouse.gov/presidential-actions/executive-order-regarding-ocean-policy-advance-economic-security-environmental-interests-united-states