Published on *MPA News* (https://mpanews.openchannels.org)

Seismic Surveys and MPAs: How Should Managers Address the Issue of Underwater Noise?

There has always been natural "noise" in the sea. Undersea volcanoes, for example, can produce extremely loud sounds - intense enough, hypothetically, to kill a man at close range (if the boiling water and lava did not get him first). The low-frequency vocalizations of some whale species are intense enough to travel 10,000 miles.

But over the past 150 years, the noise levels in our oceans have increased significantly. This is due to human activity. The propeller noise from shipping has raised the baseline for low-frequency ambient ocean sound worldwide. There is noise produced by undersea construction, such as pile-driving (e.g., hammering posts into the seafloor, such as for docks or drilling platforms). Sonar is used to map the ocean bottom or (for naval defense purposes) to scan for submarines. And airguns are used in seismic surveying: exploring the geologic substructure of the seafloor by sending sound energy into the ground and analyzing the returned energy.

What is the impact of this added noise on sea life? Because sound dissipates with distance, a loud sudden noise experienced by a fish or marine mammal will have a greater effect at close range than far away. The noise from pile-driving, for example, can be loud enough to stun fish nearby, but may have little (or less) effect on marine life several kilometers away. That said, marine mammals, because they are so dependent on sound to communicate, may be particularly sensitive. The effect of "masking", for example - when rising background noise interferes with the ability of individuals to hear or be heard - can block a range of signals among members of a species, such as signals to help identify mates, communicate the presence of food sources, or warn of the presence of predators.

This article focuses primarily on seismic surveying. Because the offshore petroleum industry is actively seeking new sources of oil and gas, and conducts seismic surveying to explore for sub-sea hydrocarbon reserves, MPAs are increasingly encountering the possibility of such surveying inside their boundaries or in nearby waters. *MPA News* has received letters from MPA managers in recent years seeking advice on what intensity of seismic surveying can be considered safe for marine life. Here we describe a recent case that involved seismic surveying inside an MPA, and examine what managers in general can do to reduce the potential for negative impacts.

Impacts of sound

In very broad terms, seismic surveying works under the same general principle as sonar or even echolocation (used by dolphins and whales to detect prey). An energy source sends pulses of sound outward, which then travel through the water column or the seafloor. Some of the sound waves refract (bend) or reflect off surfaces, and a receiver detects the returning sound. By noting patterns in the returned sound, it is possible to estimate properties of the surface(s) that reflected or refracted it - whether the surface is the seafloor, a subsurface oil deposit, a magma chamber beneath an undersea volcano, or a school of fish swimming around (in the case of dolphin echolocation).

Aside from those similarities, however, there are some big differences. Seismic surveying, which uses a ship-towed array of multiple airguns as its sound source, relies mainly on low-frequency sound waves of 100 hertz or less. In contrast, the high-pitched "pings" produced during a multibeam sonar survey usually have peak levels in the tens to hundreds of kilohertz.

The difference in frequency plays a role in how each system affects the environment, says Leila Hatch, marine ecologist at Stellwagen Bank National Marine Sanctuary in the US. Although all sound diminishes with distance, she says, low-frequency sounds diminish more slowly, meaning their impact can last over longer distances than those of high-frequency sounds. "Energy at low frequencies can travel great distances," says Hatch. "Thus, there can be a larger potential range of impact to organisms whose hearing is tuned to lower frequencies, or who use low frequencies to communicate, including many of the large baleen whales." Potential impacts of noise on sea life range according to the intensity of the sound. At lower intensities, or at greater distance from the sound source, organisms may simply exhibit avoidance behavior (although, with enough noise, they may also be impacted by masking of signals, as described earlier). At higher intensities, there can be temporary or permanent hearing loss. At ultra-high intensity, there can be organ hemorrhaging and death. In some cases, intense naval low-frequency active sonar (<1000 Hz) has been accused of playing a role in the stranding of marine mammals, particularly beaked whales. (See, for example, the 2006 *Journal of Cetacean Research and Management* article "Understanding the impacts of anthropogenic sound on beaked whales" at www.saplonline.org/oceans/Noise/IONC/Docs/Coxetal_2006.pdf).

To manage such impacts, some countries have established standards to govern the deployment of acoustic tools. The standards are based on received sound levels rather than the sound levels at source. The US National Marine Fisheries Service, for instance, has set a standard that the received sound level for impulsive signals - such as those produced by airguns in seismic surveying - should be no more than 180 decibels (dB) for cetaceans and 190 dB for pinnipeds. Above these levels, there is risk of permanent hearing damage and other physical injury, depending on the sensitivity of the species. To comply with these standards, seismic survey programs and multibeam sonar operations are required to take steps to reduce levels of exposure for marine mammals when possible. When that is not possible, operators must ensure that the number of marine mammals exposed is small and impacts to overall populations is negligible (among other requirements). There are multiple mitigation and monitoring measures that can be taken to help ensure the standards are met - see the box "Strategies to reduce impact..." at the end of this article.

John Ford, a marine mammal biologist with Canada's Department of Fisheries and Oceans (DFO), says more research is needed to fine-tune the standards by the type of sound (e.g., low- or high-frequency) and the species to be protected. "These are recognized as crude standards," he says.

[Editor's note: For historical reasons, sound in water is referenced to a different intensity than sound in air. As a rough technique for converting sound levels from water to air, subtract 62 dB from the sound level in water: i.e., a 190-dB sound underwater would be approximately equivalent to 128 dB in air. See www.fas.org/man/dod-101/sys/ship/acoustics.htm.]

The Endeavour case

In 2008, a team of researchers from US universities informed the Canadian government of its interest in conducting a seismic survey inside the Endeavour Hydrothermal Vents Marine Protected Area, off the Pacific coast of Canada. The 93-km^2 MPA was designated in 2003 to protect fields of deep-sea hydrothermal vents and their associated biological communities on the seafloor. Although most marine seismic surveying is conducted to search for oil and gas, this survey would be different. The purpose was to study the structure and longevity of the volcanic heat source that drives hydrothermal activity at the site, as well as the plate tectonics of the region. Knowledge generated by the survey could benefit understanding and management of the MPA, and also provide insights on volcanic and earthquake-related hazards to the Pacific Northwest region of the US and Canada.

In consultation with the Canadian government ahead of time, the research team agreed to mitigation measures that were more conservative than common Canadian practice to that point. The scientists expanded the marine mammal safety zone around the ship to a radius of 1220 meters, at which distance the received sound level would be 180 dB. (If a whale were spotted within the safety zone, the array would be powered down until the whale left the zone.) Also, a pre-startup watch period was expanded from 30 minutes to 60 minutes as a safeguard against any deep-diving whales' being in the safety zone.

In August 2009, a week before the expedition was to start, two Canadian conservation NGOs filed a lawsuit against the government to disallow the study. The lawsuit argued that noise from the surveying would harm marine mammals at the site (blue whales and fin whales sometimes live in the area) and thus did not comply with Canadian law to protect endangered species. They also argued that MPAs, in particular, deserved to be governed under the precautionary principle: that any possibility of harm to the ecosystem should be avoided when possible. This was not the first MPA to encounter this argument. In 2003, the government of the Australian state of Victoria refused an application for seismic surveying inside the Twelve Apostles Marine National Park. The Victorian environment minister said at the time, "A higher environmental test applies to national parks and we have adopted a precautionary approach in this case."

In response to the Endeavour lawsuit, DFO's Ford proposed that the radius of the safety zone around the vessel be expanded to 7 km: the goal would be to reduce received sound to a maximum of 160 dB outside the zone. (A threshold of 160 dB is believed by some marine mammal researchers to be the point above which behavioral disturbance can occur.) The research team consented to Ford's recommended change, and increased its number of marine mammal observers in order to monitor the larger radius. Ultimately, a Canadian court ruled that the environmental NGOs had failed to prove that the survey would cause "irreparable harm"; therefore, the court could not halt the survey. The expedition proceeded in September. (Notably, a marine seismic survey that was proposed in 2007 for the fjords of northwest British Columbia, Canada, was disallowed by the government in part because an adequately large safety zone was not possible in such confined waters, says Ford.)

William Wilcock, a marine geophysicist at the University of Washington in the US, served as co-investigator on the Endeavour survey expedition. He says the threat to marine mammals was negligible, as blue and fin whales would not typically be in the Endeavour region during the time of year of the survey. In an essay written with his Endeavour co-investigators (Doug Toomey and Emilie Hooft), Wilcock said, "During the 16 days of seismic data collection, no whales were observed by the marine mammal observers. But had they been, the mitigation measures that were in place before the legal action would have been more than sufficient to ensure that they were not harmed." (The essay is available at http://gore.ocean.washington.edu/research/etomo_evironmentalists_091809.pdf.)

Wilcock believes the legal challenge by environmentalists was part of a strategy by them to prohibit any seismic surveying off the Pacific coast of Canada, for fear that it might open the door to oil and gas surveys in the region. There is currently no hydrocarbon exploration off Canada's Pacific coast, in contrast to the country's Arctic and Atlantic waters where exploration has been permitted. Wilcock says the fact the government required stricter mitigation for the Endeavour survey could lead to later legal problems for the government. "In future court actions, how will the government explain the discrepancy between the mitigation measures required for the Endeavour study and the less onerous ones used elsewhere in regions where marine mammal encounters are much more likely?" he asks.

Sabine Jessen of the Canadian Parks and Wilderness Society (CPAWS) - which, along with the Living Oceans Society, had filed suit to stop the Endeavour survey - is disappointed the study was allowed to proceed, but is pleased that safety was improved. "We hope our challenge resulted in improved monitoring of marine mammals," says Jessen. "CPAWS' motivation was to protect the Endeavour Vents MPA, and other Marine Protected Areas in Canada, from harmful disturbances that we believe to be illegal."

She says scientists need to take responsibility for ensuring they use the best available technology to minimize risks to the natural environment. Moreover, she says, it is government's responsibility to apply the precautionary approach. "Government must ensure that potentially harmful scientific experiments are not permitted on the basis of a lack of full scientific certainty of the likelihood or magnitude of harmful impacts," she says. She adds this is particularly the case for MPAs. "Acoustic disturbance of MPAs should be limited to the greatest degree possible." She suggests MPAs should be managed to provide "acoustic comfort" to their resident species.

Advice for managers

Wilcock and his co-investigators say there have been no clear cases yet where seismic experiments have injured or killed marine mammals. "Provided that seismic experiments are performed with sensible mitigation measures (e.g., marine mammal observers; ramping up the sound source over time), the only impact on marine mammals is that some avoid the sound source," they wrote in their Endeavour essay. However, if the time and place of a seismic experiment coincide with an important marine mammal feeding or birthing ground, they add, it would be advisable to change the season or location of the experiment. If such changes are not possible, they say, "then the [resource] managers must make a difficult determination of whether the societal benefits of the research at a particular site outweigh the impacts on the environment." (Wilcock, Toomey, and Hooft emphasize the benefits of their Endeavour research and point out that commercial ships regularly pass through the MPA there producing significant propeller noise and the threat of whale strikes.)

DFO's Ford considers a maximum of 160 dB for received sound to be "the best standard we have" for guarding against negative impacts to cetaceans, notwithstanding the uncertainties involved in gauging marine mammal sensitivity. He adds, however, that the range at which that level is reached - and hence the size of the safety zone - can vary with the type of survey, depth, and other factors. Therefore a preset safety zone at an arbitrary distance may be overly large for some surveys, and not large enough for others.

Hatch of the Stellwagen Bank National Marine Sanctuary says MPA managers should educate themselves on current governmental guidelines for safe practices. "The best tools for reducing risk of injury are to produce less sound within frequencies that affect marine mammal hearing and communication, and to operate outside time periods and areas where marine mammals are present," says Hatch. "The MPA manager should engage the surveyor in dialogue on how best to reduce or eliminate impacts. That includes providing information to the survey team on the distribution, densities, and behavior of species in the MPA that could be impacted. In areas where such information is lacking, best practice would dictate gathering baseline data prior to conducting seismic surveys there."

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BOX: Additional publications on underwater noise

Overview of the impacts of anthropogenic underwater sound in the marine environment (2009, OSPAR).
www.ospar.org/documents/dbase/publications/p00441_Noise%20Background%20document.pdf

Maritime traffic effects on biodiversity in the Mediterranean Sea, volume 1: Review of impacts, priority areas and mitigation measures (2009, IUCN).
http://data.iucn.org/dbtw-wpd/edocs/2008-042-1.pdf

"The impacts of anthropogenic ocean noise on cetaceans and implications for management" (2007,*Canadian Journal of Zoology*).
http://article.pubs.nrc-cnrc.gc.ca/ppv/RPViewDoc?_handler_=HandleInitialGet&journal=cjz&volume=85&calyLang=eng&articleFile=z07-101.pdf

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BOX: Strategies to reduce impact of seismic surveying on marine mammals

- **Avoid surveying in areas with sensitive species:** gather data on how animals use an area prior to conducting seismic surveys there
- **Safety zone around the survey:** make this zone large enough to ensure that received sound levels outside of it are below a maximum limit
- **Pre-shoot watch:** look for marine mammals inside the safety zone prior to start-up of the airgun source
- **Visual observers:** look for marine mammals inside the safety zone during the survey, and power-down the seismic activity if marine mammals are sighted
- **Passive acoustic monitoring:** listen for vocalizing marine mammals
- **Soft-start or ramp-up:** gradually build up the airgun sound level to allow marine mammals to depart the area before sound levels peak
- **Minimize airgun sound propagation:** use the lowest practicable volume throughout the survey
- **Restrict airgun use during nighttime hours:** conduct surveys only when there is sufficient light for marine mammal observations

Source: Adapted by *MPA News* from Weir *et al.*, "Marine mammal mitigation during seismic surveys and recommendations for worldwide standard mitigation guidance". Published by the Whale and Dolphin Conservation Society, UK. www.ketosecology.co.uk/MitigationSC58E12Final.pdf

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