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Ocean Noise: Sources, Trends, and Solutions for Understanding and Mitigating Impacts on Marine Life

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DISCUSSION PAPER

Dr. Howard Rosenbaum is a Senior Conservation Scientist and Director of the Wildlife Conservation Society's Ocean Giants Program, which aims to secure the future of whales, dolphins, and other marine species. He is a Senior Scientist at the American Museum of Natural History, core faculty member at Columbia University, a member of the United States Delegation to the International Whaling Commission, and the IUCN Cetacean Specialist Group and Important Marine Mammal Area Task Force. Rosenbaum has led marine mammal conservation projects around the world, including the Indian, Pacific, and Atlantic Oceans and the Arctic. For more than 27 years, Dr. Rosenbaum's innovative science has helped protect marine species from current and emerging threats in their most important habitats. In the 1990s, he initiated WCS's work on whale and dolphin populations off the coasts of Madagascar and Gabon, which continues to address current threats to these iconic marine species. Recently, Rosenbaum and Southall organized 'At the Crossroads: Global Shipping Lanes and Whale Conservation' side-event at the February 2017 UN Preparatory Meeting, with a key focus of Ocean Noise as marine pollution (see https://sdg14.wcs.org/Events/Global-Shipping-and-Whale-Conservation).

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Introduction

Animals in the ocean rely on sound to live. The vastness of the sea and the reduced utility of visual, chemical, and tactile senses put a premium on the use of the acoustic channels to convey information. Most vertebrate species produce signals to communicate with one another in social and reproductive contexts. Fish have evolved complex forms of acoustic signaling over hundreds of millions of years. Many species listen to sounds in the environment to locate predators or prey and to generally orient in complex, dynamic, and opaque worlds. Some specialized marine mammal species (dolphins and porpoises) use high-resolution, high-frequency, underwater biosonar to target prey. The production and reception of sound in some species is of such significance that it dominates aspects of their physical and neural anatomy. While sound is not the only mode of communication in marine life and there remains much that we don't know, it is clear that sound is vitally important for marine animals to make a living across a wide range of taxa.

Given this global reality, questions and concerns about how the human introduction of noise into the marine environment on increasingly large scales may affect marine animals is well-founded. This issue is not new. Such questions were first raised over a half century ago and fairly extensive research on many species has been conducted with increasing intensity over the past few decades. Many questions remain and we lack basic information on hearing for many species, most notably the large whales who make and rely on low-frequency sounds. But major progress has been made in understanding how animals hear and may be impacted by noise. There are clear differences between taxa in terms of the kinds of sounds that are important and that may be detrimental, such as the contrast between the low-frequency-oriented whales and the high-frequency-oriented dolphins mentioned. While overall amplitude is clearly relevant in terms of how sounds in the ocean may affect animals, other aspects of sound like frequency, directionality, duration, novelty, and other factors can be as or even more important (*e.g.*, Ellison et al., 2012). The more similar in frequency a sound is to the kinds of sounds an animal is tuned to, the more likely it is to have potential physical effects or to interfere with communication. Factors such as proximity, relative movement, and whether a sound may resemble a predatory sound strongly affect whether a sound may elicit a behavioral response.

State of the Science and Information/Physical and Biological Implications

Much of the early focus on the potential negative effects of human noise on marine animals was driven by lethal strandings of marine mammals, notably beaked whales, in conjunction with the use of military sonar (Filadelfo et al., 2009). This remains an important issue with relevant conservation concerns and considerable current interest and research (see: Southall et al., 2016; Southall, 2017). However, as the field of marine bioacoustics has matured and direct measurements of hearing and the effects of noise on hearing in a number of species has evolved, it has become clear that there are broader, global issues related to sub-lethal effects of noise than the relatively rare but headline-grabbing whale stranding events (*e.g.*, Clark et al., 2009; Southall et al., 2013; Estabrook et al., 2016; Hatch et al., 2016). Specifically, issues related to disturbance of animals from important feeding or breeding areas and interference (masking) of communication (e.g., Estabrook et al., 2016; Hatch et al., 2016) and navigational signals have received increasing consideration (see Southall et al 2013 and associated documents, https://iwc.int/2008-mass-

stranding-in-madagascar). Increases in low-frequency ambient noise in most of the world's oceans have been occurring since the beginning of mechanized vessel transportation, but we are now beginning to quantify and understand the extent to which both deliberate use of sound (e.g., sonar, seismic airgun surveys) and incidental noise (e.g., shipping, construction) contribute to ocean soundscapes over broader time and space scales (e.g., Hildebrand et al., 2009; Hatch et al., 2016). While the ocean is very much a naturally noisy place with waves, rain, earthquakes, lightning strikes, and animals all contributing to the typical ambient noise, human activity adds considerable energy, especially for low-frequency sound that travels disproportionately better under water. From the perspective of broad-scale masking potential, aggregate sounds from more continuous, low-frequency sources (e.g., shipping) have the potential to affect many more animals over larger areas than point sources which may individually be more intense and more likely to elicit behavioral responses.

This evolution in thinking to expand earlier considerations related to more intense injurious kinds of noise impacts to include broader, sub-lethal, habitat and social communication issues has significant implications for marine conservation and sustainable industry practices. Many kinds of intense sound producing activities in the ocean already require some federal, state, or local authorizations and evaluations of potential environmental impacts. These often include monitoring and mitigation measures to avoid knowingly exposing animals to very high levels of sound, and monitoring movement and activity of animals in the proximity of operations. For some activities such as seismic surveys, such requirements, along with rapidly improving science and evolving ways of visualizing distribution patterns of protected species and how they interact with noise-producing activities have led to the derivation of responsible practices to reduce potential noise effects for more discrete activities (see: Broker et al., 2012; Nowacek and Southall, 2016).

Likely future trends, science, research, and technology gaps

Efforts are now well underway to measure and mitigate some of the more chronic sources of noise, such as shipping. Recognizing the need to evaluate broader-scale and longer-period issues related to aggregate noise from many sources, the U.S. National Oceanic and Atmospheric Administration (NOAA) developed a multi-pronged initiative to monitor and evaluate ocean soundscapes, and the extent to which animals and humans contribute to it (see: Hatch et al., 2016). On a related note, a lengthy process spearheaded by NOAA and the U.S. Coast Guard within the International Maritime Organization (IMO) recently lead to the formation of vessel-quieting guidelines for large commercial ships (IMO MEPC, 2013; 2014; see: Southall et al., 2017). While still voluntary, this was a very notable development in that it represents the first formal effort within the global shipping community to begin to address the vexing issue of low-frequency noise from ships and its considerable contribution to ocean ambient noise in many areas. Recent efforts within the United Nations to begin to address this issue through broader voluntary commitments for member states have begun to build on the earlier IMO efforts (see below). Local efforts such as those underway in conjunction with the expansion of the Port of Vancouver in British Columbia are also building on earlier efforts by targeting specific levels of traffic and noise and offering incentive programs that reward operation of vessels in ways that reduce their noise footprint.

More recent global initiatives for the oceans are starting to focus on ocean noise. During the preparatory meeting for June's UN Oceans Conference to discuss implementation of Sustainable Development Goal 14 (SDG 14: "Conserve and sustainably use the oceans, seas, and marine

resources for sustainable development"), The Wildlife Conservation Society, IUCN and the Government of France hosted a side event to raise awareness among UN member states and other stakeholders about global shipping and impacts on whales from ocean noise and ship strikes. The event's specific focus was reviewing the current state of knowledge regarding the issues of ship strikes and ocean noise, as well as the best practices in aligning shipping and whale conservation objectives. Beyond raising awareness in the lead-up to the June 2017 UN Oceans Conference, the specific goal of this event was to bring together key stakeholders to explore actions that could align conservation, industry, regulatory, and UN member states' perspectives toward the Call for Action being developed for adoption during the Conference in June 2017. A voluntary commitment was developed and endorsed by a range of institutions and parties that target potential ocean noise reduction targets by 2025 (https://oceanconference.un.org/commitments/?id=18553). At the Our Ocean Conference convened by the European Union last week (October 5 and 6, 2017; https://ourocean2017.org), the same groups reaffirmed their commitment to develop noise reduction targets for individual noise sources. A Working Group will kick-off in 2018 to conduct a Situation Analysis on ocean noise, generating an inventory of primary sources, key industry actors, and best practices. Commitments will be finalised and submitted to the IUCN World Conservation Congress for endorsement as an IUCN Resolution in September 2020. Another important international effort on ocean noise trends and impacts on large time and space scales is the International Quiet Ocean Experiment (http://www.iqoe.org/). What began as a concept to intentionally reduce noise in an area of the ocean to evaluate contributions and impacts has evolved into a broader set of questions about global patterns of noise and sources of noise that affect soundscapes. IQOE has engaged in a number of specific projects, including partnering in a working group with POGO to develop an essential ocean variable on ocean acoustics and an ongoing effort to develop a web-based source of data from ocean acoustic observatories.

In the mid-Atlantic region, there are significant ocean planning efforts underway that do involve key sectors contributing to ocean noise levels (http://midatlanticocean.org). Some of the analyses involving Ecologically Rich Areas in the mid-Atlantic have also focussed on acoustically sensitive cetacean hotspots, but not specifically with a focus on ocean noise (Roberts et al. 2016). Many of these aspects involve a range of potential impacts from renewable energy development. In March 2017, the Bureau of Ocean Energy Management (BOEM) convened a workshop to discuss best practices around renewable energy development, and ocean noise impacts to protected species was a key focus. More recently, BOEM initiated the preparation of a five-year National Outer Continental Shelf Oil and Gas Leasing Program (National OCS Program) for 2019-2024. A number of comments submitted for this 5 year plan (and the previous 2017-2022 five year plan) highlight the impacts of increasing noise on marine wildlife in all OCS planning areas. Although specific ocean uses and ecological characteristics vary between regions, increasing anthropogenic noise in the ocean is a significant concern in all OCS regions. A robust assessment of the cumulative impacts and aggregate sources of Ocean Noise (e.g., shipping, renewable energy, and oil and gas exploration and production) has been overall lacking. Finally, in informal discussions with shipping industry representatives and IMO personnel, it has been suggested that the next class of bulk carrier ships being built will be more efficient and produce less noise; these are projected for operation by 2023 and beyond.

Technology and gaps

As noted above, monitoring and measuring levels of ocean noise typically involves the use of remote passive acoustic monitoring units. These are widely used, and range from commerically available to custom-made. Depending on goals and costs, they can be programmed to detect biological sounds and levels of ocean noise in a given area. They have been and are being used in the mid-Atlantic area, typically focussing on renewable energy development and North Atlantic right whale migration (*e.g.*, Rice et al. 2014). WCS and The Woods Hole Oceanographic Institution (WHOI) recently deployed a near-real time acoustic-monitoring buoy just outside of New York City Harbor off the coast of Long Island. This buoy detects the sounds of humpback, fin, sei, and highly endangered North Atlantic right whales as well as ocean noise and sends information about those sounds to the team via satellite link (see www.blueyork.org).

While there are some important developments in technology for monitoring Ocean Noise, a comprehensive coordinated and systematic approach at the regional level in the mid-Atlantic is the most important and glaring gap. While the scientific community is learning quite a bit about Ocean Noise levels in the Atlantic, these efforts are the results a posteriori approaches that pull together results from various individual studies. For example, this synthesis approach is yielding important information about the distribution and movements of North Atlantic right whales and other marine life (Bort et al., 2015). A comprehensive approach to establish baseline Ocean Noise conditions for the mid-Atlantic would be extremely valuable in conjunction with baselines for marine life. Once established, any changes and associated potential impacts resulting from Ocean Noise could be documented and assessed.

Likely effects on ocean economy

Government and industry investments in monitoring Ocean Noise levels and establishing baselines are essential. Forward-thinking measures to monitor potential impacts can occur with moderate costs, especially if done in partnerships – can be more effective and efficient with data sharing. This can be a more proactive way to deal with this problem than having strict regulations put in place by federal or state authorities because of a lack of information.

Investment in these environmental approaches are often not fully considered until there is a problem, and are typically costlier when the efforts are reactive. Considerate pro-active investment in efforts to establish baseline conditions for marine life and Ocean Noise levels in the short-term may be viewed by some as more costly, unneeded expenditures, or even unnecessary. However, it is our view that if the investment is made strategically, it will only promote best practices for marine life and important habitats in the context of an ocean economy toward 2030.

Conclusions and Recommendations

While some of the more dramatic physical and lethal effects of noise on marine life appear to be more isolated than may have been previously expected, there are some real and serious concerns about ocean noise, particularly regarding sub-lethal impacts to wildlife and important habitats from increasing levels of ocean noise. Substantial research and monitoring efforts in the past few

decades have enabled a more focused and prioritized vision of issues of concern and focus. For certain noise sources, potential effects have been clearly identified and recommendations for responsible planning have been developed. An article published in *Frontiers in Ecology and the Environment* by Nowacek *et al.* in September 2015, entitled "Marine seismic surveys in ocean noise: Time for coordinated and prudent planning," includes an assessment of the available scientific literature on impact thresholds and provides recommendations for assessing the cumulative impacts of multiple and prolonged exposures to seismic surveys. Recent science suggesting various trophic levels of impacts raise new questions and concerns. McCauley *et al.* (2017) documented significant mortality for zooplankton from seismic surveys within a specific context. Zooplankton form the base of the ocean food chain and are an important source of food for right whales and other baleen whales. Zooplankton also include the larval life stage of many commercially fished species. These types of impacts from ocean noise could have cascading ecosystem effects for marine life and their most important habitats; these kinds of integrated ecosystem studies are one of the most important areas of future research.

As a general summary to this issue for consideration and discussion, we conclude with a series of top-level recommendations that have been formulated within several of the international efforts described above:

- Ocean noise is a global concern and requires international collaboration and partnerships, particularly as human populations and use of resources increase and exert a cumulative suite of pressures on our marine ecosystems.
- Noise from ships and other sources is a pervasive, global issue. Discussion of best practice scenarios involves the shipping industry and governments working together and ranges from potential future quieter zones that could be part of MPAs or IMMAs to further efforts that implement quieting technology in the next generation of ships to reduce the impacts to whales and other marine life.
- Targeted research on understanding ocean noise impacts to marine mammals from shipping traffic (along with other noise sources) combined with technological advances have led to a number of successful conservation/industry partnerships to reduce impacts. These efforts can guide development of new and emerging measures.
- Discussions contrasting the effectiveness of voluntary versus mandatory guidelines are essential, and include key points such as:
    - There is a need to engage various stakeholders to work together to find solutions that are tractable with real, achievable benchmarks within the framework of SDG 14 and toward 2030
    - Voluntary guidelines being adopted and implemented by the International Maritime Organization (IMO) need greater uptake with other industry sectors, which may be improved by effective education, communication and incentive-based systems, along with clear understanding of whale distribution and occurrence and areas of biological importance for whales, while also weighing economic impacts to shipping and other industries.

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