The NOAA Ocean Noise Strategy and Managed Species

INTRODUCTION

There are a number of human activities that can introduce potentially detrimental levels of sound into the aquatic environment (see Chapter 3), affecting a wide range of acoustically sensitive animals. Many of these human-made sounds are incidental to the purpose of the activity, such as the intense impulsive sounds produced during pile driving with impact hammers or the lower level continuous sounds produced by vessel traffic. Other sounds are an integral and necessary part of the activity, such as the sounds produced by active sonar or the impulsive sounds generated by seismic airguns used for oil and gas exploration or research. All of these activities can potentially affect the animals present in the ensonified area (the area in which the sound is detectable above other sounds), some of which are federally managed as protected species. Potential effects range from none to altering important behavioral patterns, masking, hearing impairment, habitat abandonment, or even death, in certain circumstances.

Sound is often of critical importance to aquatic fauna, not only for purposeful communication with conspecifics, but also in the detection of predators and prey, and for navigation and other purposes. Competing sounds that interfere with the detection or interpretation of these important cues can result in detrimental effects to aquatic species utilizing a given "acoustic habitat" (see Chapter 2[5]). Sounds utilized for purposes other than communication span frequency ranges beyond those used in vocalizations. Of growing concern is the need to address the chronic (persistent/longer-term) and aggregated or cumulative effects of rising noise levels resulting from increased human activities across multiple sectors, industries, and federal agencies.

More commonly known and historically addressed through NOAA's existing authorities are the direct or acute (i.e., of rapid onset and shorter duration) physical, physiological, and behavioral impacts that noise exposure can have on marine fauna. These effects are often addressed in the context of a single activity and include hearing impairment (i.e. permanent or temporary threshold shift, see Appendix A), tissue damage, or behavioral disturbance of varying degrees and outcomes (e.g., vocalization changes, migration deflection, avoidance of areas, feeding disruptions). Adverse stress responses, which can have acute and/or chronic effects, have not typically been comprehensively addressed. All of the aforementioned effects, acute and chronic, in certain circumstances and in combination with one another, can translate to adverse health or energetic effects that can ultimately lead to reduced survival, growth or reproductive success of individuals with potentially adverse population impacts.

Through the Marine Mammal Protection Act (MMPA), Endangered Species Act (ESA), Magnuson-Stevens Conservation and Management Act (MSA), and the National Marine Sanctuaries Act (NMSA), NOAA is responsible for the management of all but a small number of marine mammals, all sea turtles, ESA-listed fish and invertebrates, many commercially important fish and significant marine areas. Examples of the effects described in previous paragraphs are known across many marine taxa including marine mammals, fish, invertebrates, and sea turtles. Management and science actions related to noise effects have been more heavily publicized and highlighted for marine mammals and this document seeks to highlight the need to better address the impacts of underwater noise on other taxa, many of the

[5] All of the sound present in a particular location and time, considered as a whole, comprises a "soundscape" (Pijanowski et al. 2011). When examined from the perspective of the animals experiencing it, a soundscape may also be referred to as "acoustic habitat" (Clark et al. 2009, Moore et al. 2012a, Merchant et al. 2015).

examples in this Chapter are specific to marine mammals because of the information available – but the concepts are still often applicable to other taxa.

Through this NOAA Ocean Noise Strategy Roadmap document (Roadmap) and in support of the overall Strategy, NOAA seeks to focus and guide the agency's capabilities and authorities to more effectively address the effects of noise on protected species (meaning the taxa indicated above that are managed under NOAA's authorities) and habitats. NOAA has programs that regulate impacts (including those from noise) on protected species and their habitat, programs that gather data and conduct research related to noise and protected species, and programs that produce underwater noise during the course of their normal operations and duties (e.g., NOAA's use of active scientific sonar sources in the course of fisheries research). In addition to providing new focus on the importance of addressing the chronic and aggregate effects of rising noise levels on acoustic habitat, NOAA also aims to identify and agency actions to better address the acute, direct physical and behavioral effects of noise exposures to individuals and their ultimate effects on the populations. We specifically draw attention to the following additional three needs: (1) better understanding of how noise impacts on individuals can translate to population level effects; (2) better understanding of the aggregated effects, on individuals and populations, of multiple noise sources and cumulative effects of noise combined with other stressors; and (3) broadening NOAA's practices to better address impacts to fish, invertebrates, and sea turtles.

This Chapter (and associated Appendices) is organized in the following manner:

- In the "Building Blocks of Impact Assessment" section and Appendices A and B, we summarize the status of the science as it relates to the categories of information needed to understand, characterize, and manage the effects of noise across four broad taxa for which NOAA has different management responsibilities: marine mammals, fish, invertebrates, and sea turtles.
- In the "Evaluating Population-level and Cumulative Effects of Noise" section, we briefly describe the challenges of evaluating chronic effects and stress, and also include several examples of methodological approaches that can be used to evaluate population level and aggregate noise consequences to NOAA resources.
- In the "Current NOAA Management of Noise Impacts" section, we identify the management authorities through which NOAA can address the effects of human-produced noise on these specific taxa, as well as acoustic habitat. The "Regulatory and Analytical Approaches" section briefly describes some current strategies for implementing these authorities.
- Last, in the "Next Steps for the NOAA Ocean Noise Strategy" section, we identify some high priority science, risk assessment, and management needs intended to guide NOAA actions for addressing noise impacts to all four of these acoustically sensitive taxa and their acoustic habitat.

THE BUILDING BLOCKS OF IMPACT ASSESSMENT

In order to begin to characterize, predict, assess, and manage the potential effects of specific activities that generate underwater sound on an acoustically sensitive animal and its habitat, certain key information is needed: where species are located, how they use sound, and the known effects of noise on that species. Additionally, understanding critical data gaps helps inform science and monitoring priorities. **Appendix A: The Status of Science Needs for Assessing Noise Impacts to NOAA-Managed Species** outlines the status of science regarding sound use by, and noise impacts to, four broad taxonomic groups for which NOAA has different management responsibilities: marine mammals, fish, invertebrates, and sea turtles. **Appendix B: Presence, Abundance, Distribution, Density, Habitat Use, and Population Trends** summarizes the status of information regarding presence, abundance, distribution, density, habitat use, and population trends for these species. We summarize some major points from the Appendices below.

Sound Use and Production

Marine mammals have been more extensively studied than other marine fauna in terms of their hearing sensitivities and absolute hearing thresholds (though less so for mysticetes), as well as their vocalizations. Marine mammals both produce, and use, sounds spanning a wider range of frequencies and decibel levels than other marine taxa, and they use them for a wide variety of purposes. Further, some of the more subtle aspects of hearing in marine mammals such as frequency discrimination, localization ability, and critical ratios have been studied. Fishes are the largest and most diverse vertebrate group, and while we are aware of many adaptations that allow them to both detect and produce sounds for a variety of purposes, there is much that is still unknown. We do know, though, for example, that some fishes are able to detect sound pressure and can hear and determine the direction of sound via particle motion. Also, the presence and location of a swim bladder relative to the ear in fishes may affect the degree of hearing sensitivity as well as the susceptibility of sustaining physical injury to the body when exposed to certain sound pressure levels. Although invertebrates have been studied less than marine mammals and fish, we know that some invertebrates are capable of detecting vibrations and others may detect particle motion and even sound pressure (Budelmann 1992, Popper et al. 2001, Kaifu et al. 2008). Some invertebrates also produce sounds, or use sound for orientation and stunning of prey. Sea turtle hearing and use of sound have not been well studied and sea turtles are not known to intentionally produce sounds underwater. While a few studies document the use of sound to detect important environmental cues, sea turtles are not thought to produce sound for particularly directed purposes, such as communication.

Impacts of Noise

Studies of the impacts of noise on marine mammals are numerous and cover a wide range of species, sound sources and characteristics, environments (laboratory and field), and observed effects. Documented impacts range from none, to behavioral disturbance (avoidance, vocalization changes, changes in swim speed and direction, alarm responses), adverse stress responses, masking, hearing impairment (temporary or permanent), tissue damage, and death. Studies on fish have focused more on characterizing the physical effects such as hearing impairment, barotrauma, and death, but behavioral effects such as changes in direction, speed, or schooling patterns as well as changes in stress hormones have been documented. Unlike in marine mammals, hearing impairment is considered recoverable in fishes because many of the species that have been researched indicate they can grow back their hair cells. However, there remains much that is unknown about hearing in fishes and the ability to recover from hearing damage because of the great number of fish species that have not been studied. Less research has been conducted on invertebrates, but some research on cephalopods has indicated high intensity low frequency sounds, as well as long exposures to continuous sounds, may damage the hair cells in their statocysts, which could inhibit their ability to perform important life functions, although behavioral studies that would support such conclusions have not been conducted. Fewer targeted studies document the impacts of noise on sea turtles. Some studies have documented multiple types of changes in behavior in response to a few sound sources, but other studies have documented no changes. For all taxa, the focus is expanding to better understand the effects of changes in the soundscape.

Species Presence, Abundance, and Distribution

A key building block of risk assessment is reliable information on the potentially impacted species or stock presence, abundance and distribution, both spatially and seasonally. Select species have been well studied in certain areas and seasons. Appendix B outlines where available abundance and distribution data may be accessed, as well as other important information on habitat use and life history. However, there is a lack of adequate abundance and distribution information for most protected species. For example, NOAA is mandated to collect stock assessment data for protected species and the agency has developed a systematic method for ranking the adequacy of stock assessments. For marine mammals, only about 17% of the marine mammal stocks NOAA Science Centers track and collect data for are considered to have adequate assessments and about 47% of the stocks have either never had an assessment conducted, or the last one was over 10 years ago. About 34% of ESA-listed fish are considered to have adequate stock assessments. None of NOAA's ESA-listed invertebrate species (coral and abalone) or sea turtle species are considered to have adequate assessments. NOAA is constantly working to maximize the effectiveness of stock assessment data collection within given resource availability.

Characterization of Human Introduced Sounds

Understanding the characteristics of sound sources and noise-producing activities is an important part of impact assessment and is discussed in Chapter 3. Some examples of activities or types of human-made sound that may have the potential to adversely impact marine fauna acutely and/or chronically include: vessel noise (offshore and nearshore - commercial and recreational vessels); active sonar (military and research activities); seismic airguns (for oil and gas exploration and research); underwater explosives (military operations, harbor deepening, fishing deterrents, and rig removal); pile driving (impact and vibratory); renewable energy sources (e.g., wind, wave, and tidal farms); acoustic deterrents; dredging; icebreaking; drilling, and; rocket launches.

EVALUATING POPULATION-LEVEL AND CUMULATIVE IMPACTS OF NOISE

Beyond some of the basic pieces of impact assessment addressed above, we highlight here some of the more challenging components of understanding the impacts of noise on marine fauna, as well as some emergent methodologies that are currently being applied. Specifically we discuss the difficulty of assessing stress and chronic effects and the shortage of needed data to do so. Further, we discuss an emerging quantitative framework for addressing the need to better characterize and predict how acute and chronic disturbance effects can translate to effects on individual fitness and populations. Last, we look at some analytical examples of where data and modeling have been used to assess the effects of both the aggregated sounds of multiple activities, as well as noise in combination with other stressors. Several of the examples relate specifically to marine mammals (because that is what is available), but have broader applicability as well.

Stress

Adverse stress responses are one in a suite of potential effects that should be addressed when evaluating the impacts of noise on an individual or population. We highlight adverse stress responses here because while data indicate that they can have serious consequences to individuals, they have been largely under-represented in impact assessments, likely because of the complexity of detecting these responses in wild populations and the lack of adequate baseline stress-marker datasets to which field measurements can be compared to appropriately assess context and significance.

The Office of Naval Research's (ONR) Marine Mammals and Biology Program has several major research interest areas or thrusts, including better understanding the Effects of Sound on Marine Life topic, which aims to better understand and characterize the behavioral, physiological (hearing and stress response), and potentially population-level consequences of sound exposure on marine life. Physiological Stress

Responses is one of the specific thrusts of the Effects of Sound on Marine Life program (http://www.onr.navy.mil/en/Science-Technology/Departments/Code-32/All-Programs/Atmosphere-Research-322/Marine-Mammals-Biology/Marine-Mammal-Biology-Thrusts.aspx). ONR's 2014 annual report (Cockrem 2014) compiles information from 239 papers or book chapters relating to stress in marine mammals. While these articles were marine-mammal specific, some of the information is also more broadly applicable to other marine vertebrate taxa, for which there is even less data available.

Cochrem (2014) explains that animals are continuously aware of and respond to changes in their environment and when physical or social stimuli are threatening or harmful, then neural and neuroendocrine pathways are activated and a stress response is initiated. These threatening or potentially harmful changes in the environment (or perceived to be threatening or harmful), which can either require cognitive appraisal or be completely physical (i.e., temperature), are termed stressors (Cochrem 2014). A stress response occurs when a stressor activates the neuroendocrine stress system (NSS), resulting in glucocorticoid (cortisol or corticosterone) release from the adrenal cortex (Cochrem 2014). A stress response can last from minutes to hours, and includes increased sympathetic nervous system activity and a rapid and transient release of catecholamines from the adrenal medulla (Cochrem 2014). While we typically focus on adverse stress responses, stress responses are part of a natural process to help animals adjust to changes in their external or internal environment (maintain homeostasis), and can also be either beneficial or neutral.

Although extensive terrestrial vertebrate datasets illustrate that the impacts of chronic stress effects can adversely impact individuals through immune suppression, inhibition of other hormonal systems, and the disruption of reproductive function, such studies within marine systems remain rare. In a unique circumstance, (Rolland et al., 2012) suggested evidence of a reduction in stress hormone levels associated with reduced exposure of North Atlantic right whales to noise from large commercial vessels. Laboratory studies showing explicit stress responses to noise and field noise measurements have increased our ability to compare hormone levels with other potentially causative variables. However, there are no large cross-sectional datasets of stress markers in free-ranging marine populations, which means that we lack an understanding of natural variation within individuals based on sex, age, and reproductive status. Further, we don't fully understand the relationship among various hormones and the quantitative differences to be expected among sample types (e.g., blood, blubber, feces) in free-ranging individuals. Because of this, there is a current inability to interpret context and the biological significance of variation in stress markers in individuals.

Acoustic Habitat Effects

Earlier in this Chapter we referenced NOAA's augmented focus to ensure that the chronic effects of rising noise levels on the acoustic habitat of protected species (i.e., the masking of important species-specific acoustic cues) are better addressed through the agency's efforts. While these types of effects are touched on in Appendix A, Chapter 2 describes these effects in detail and recommends management and science actions to better address them.

Population Effects

Because of the methodological challenges (including difficulty identifying all of the contributing variables), as well as the time and resource commitment necessary, few studies have quantified the ultimate impacts to marine mammal populations associated with disturbance from noise or other causes. Lusseau and Bejder (2007) present data from three long-term studies illustrating the connections between disturbance from whale-watching boats and population-level effects in cetaceans. Across these three multi-year studies, the effects of increased boat traffic from tourism ranged from a

15% decrease in abundance (Shark Bay Australia, bottlenose dolphins, Bejder et al., 2006), a transition from a short-term avoidance strategy to long-term displacement resulting in reduced reproductive success and increased stillbirths (Fiordland New Zealand, bottlenose dolphins, Lusseau 2004), to decreased foraging opportunities and increased traveling time that a simple bioenergetics model equated to decreased energy intake of 18% and increased energy output of 3-4% (Vancouver Island Canada, northern resident killer whale, Williams et al., 2006). These studies are presented because of the lack of similar studies for other activity types, not because of an enhanced concern for whale watching above other activity types. In fact, Weinrich and Corbell (2009) report that the reproductive success of female humpback whales was not affected by whale watching exposures in southern New England.

In order to understand how the effects of activities to individual marine animals may or may not impact stocks and populations, it is necessary to understand not only what the likely disturbances are going to be, but how those disturbances or other impacts may affect the reproductive success and survivorship of individuals, and then how those impacts to individuals translate to population changes. As noted above, one of the major interest areas for the Office of Naval Research's (ONR) Marine Mammals and Biology Program is better understanding the population-level consequences of sound exposure on marine life. Following on the earlier work of a committee of the U.S. National Research Council (NRC 2005), ONR has funded the Potential Consequences of Acoustic Disturbance (PCAD) effort from 2009-2015, which included four working group case studies and was modified to the Potential Consequences of Disturbance (PCoD) to allow for the consideration of more data using other disturbance types as surrogates for noise in the case studies. Supported by the PCoD effort, New et al. (2014) outline an updated conceptual model of the relationships linking disturbance to changes in behavior and physiology, health, vital rates, and population dynamics (see Figure 1-1). While this effort targets marine mammals, this conceptual model is likely broadly applicable in illustrating the potential pathways from individual disturbances to population-level impacts for other taxa.

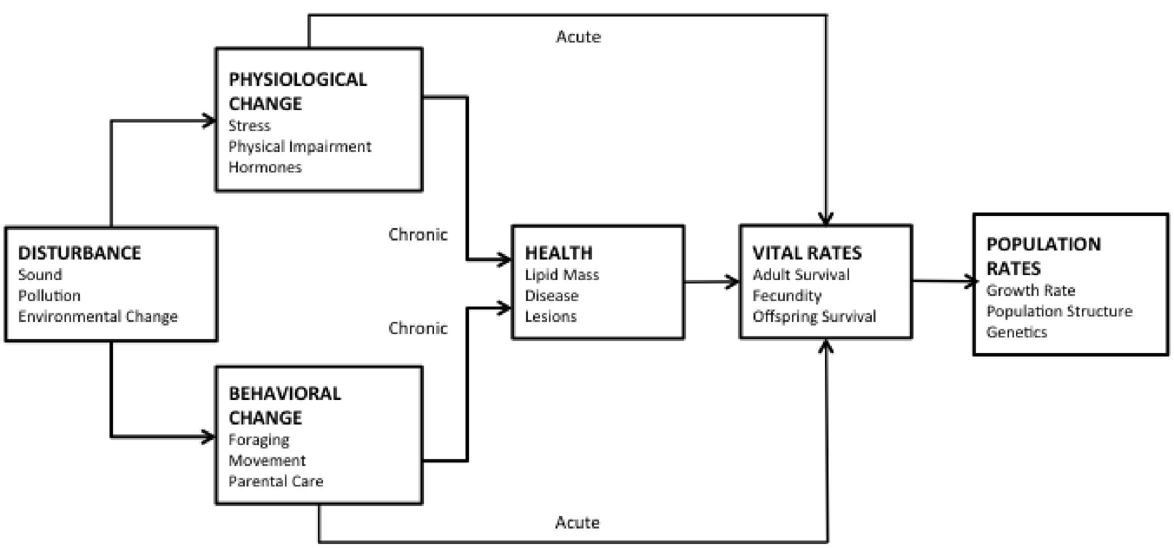

Figure 1-1. Potential Consequences of Disturbance conceptual model of the relationships linking disturbance to changes in behavior and physiology, health, vital rates, and population dynamics (New et al., 2014).

As described in the PCoD model, adverse behavioral and physiological changes resulting from disturbance (stimulus or stressor) can either have acute or chronic pathways of affecting vital rates (Figure 1-1). For example, acute pathways can include changes in behavior or habitat use, or increased stress levels that directly raise the probability of mother-calf separation or predation. Chronic effects on vital rates occur when behavioral or physiological change has an indirect effect on a vital rate that is mediated through changes in health over a period of time, such as when adverse changes in time/energy budgets affects lipid mass, which then affects vital rates (New et al., 2014). New et al. outline this general framework, compile the relevant literature that supports it, and include specific examples of types of behavioral, physiological and biological changes, health effects, vital rates and population rates (within each box, above) for which there are data illustrating the connections between these stages of effects for certain species and situations. Further, these authors, and others involved in the PCoD effort, have developed state-space energetic models for four example species (southern elephant seal, North Atlantic right whale, beaked whale, and bottlenose dolphin), that illustrate how specific information about anticipated behavioral changes or reduced resource availability can potentially be used to effectively forecast longer-term, population-level impacts (New et al., 2014; New et al., 2013a; Schick et al., 2013; New et al., 2013b) when enough data are available. However, more work and data are needed before these sorts of models can be broadly applied for management use. In fact, work is still needed even for the more narrow application to specific taxa, as indicated in Pirotta et al. (2014), which illustrates that traditional visual group follow data did not provide enough information to allow biologically robust inference in the case of the model applied to the population-level effects from tourism on bottlenose dolphins in New Zealand (mentioned above).

Unfortunately, empirical data adequate to fully and accurately quantify the relationship between behavioral or physiological changes and fitness impacts do not exist for any marine mammal species, and the existing models for the species with the most data (e.g., elephant seals) are very species- and scenario-specific. However, some inferences regarding the relative importance of certain factors may be appropriate for different species in certain circumstances. Meanwhile, to help address this gap in adequate empirical data, an “interim” version of the PCoD framework has been developed that uses a formal expert elicitation process to estimate parameters (and associated uncertainty) that define how changes in behavior or physiology affect vital rates and incorporate them into a stochastic model. The framework was designed to help predict the anthropogenic disturbances on animal populations in specific circumstances. King et al. (2015) report on the outcome of the first interim PCoD effort to assess the effects of UK offshore wind farm construction on harbor porpoises. Similar efforts are currently underway to evaluate the effects of Navy activities on beaked whales and sperm whales in certain areas and the effects of seismic surveys on Cook Inlet beluga whales. Though care must be taken in the application of predictions based on expert elicitation, the interim PCoD method may appropriately inform impact assessments in certain circumstances. ONR continues to support PCoD work towards species-specific case study energetic models, improved interim expert elicitation processes for data-poor scenarios, and data-based tools that can be more broadly applied to address population-level effects.

Aggregate or Cumulative Effects of Sound

Marine animals, especially in more coastal areas, are often exposed to multiple stressors (including sound) in a given time or space, and there is a general recognition that the cumulative effects of multiple stressors may have a greater impact on individuals or species than a single stressor. In the United States, a variety of federal and state laws require evaluations of cumulative effects in the course of deciding whether and how to authorize or implement a federal or state action. Unfortunately, while guidelines exist for assessing the relative level of cumulative effects on a species, from a practical standpoint this process is quite challenging because of the paucity of data on how various stressors affect species. The effect of a particular stressor on an individual may be dependent on the species, life stage, geographic location, and season, among other variables. Ideally, assessments of cumulative effects would evaluate impacts of the stressor on the population in addition to the individual.

Studies that provide quantitative evidence of population-level effects of one stressor are relatively rare; collecting quantitative information on the population-level effects of all stressors in a system seems virtually unattainable given resource limitations and the complexity of population responses to environmental and human-related features. Given the complexity and the lack of quantitative data on effects of single stressors on marine mammals, regulators often do the best they can to evaluate cumulative effects, at least in a relative fashion, by listing all known activities in a geographic area and making a qualitative assessment of whether the activity is likely to affect the population independently, or in conjunction with other stressors . In one current effort, the National Academies of Science have convened an expert group to conduct a workshop and review the present scientific understanding of cumulative effects of anthropogenic stressors on marine mammals with a focus on anthropogenic sound. The group will further assess current methodologies used for evaluating cumulative effects and identify new approaches that could improve these assessments.

In addition to the challenges with assessing the effects of multiple stressors, it is often challenging to even effectively characterize or predict the likely impacts from multiple sound sources. Several recent efforts have sought to improve our understanding of the aggregate exposure of multiple sound sources on marine mammals. The NOAA-led Cetacean and Sound Mapping Project (http://cetsound.noaa.gov) sought to develop tools to predict and map cumulative, human-induced, annual average low frequency underwater sound fields throughout U.S. managed waters. In 2012, a symposium was held to discuss various methodologies for applying these new maps to managing chronic noise implications for cetacean species, and these maps have been used in first-order chronic noise assessments to inform Environmental Impact Statements. Further integration of noise fields with marine mammal distribution, density and behavioral information to quantify impacts has been addressed in a few place-based case studies. Hatch et al. (2012) sought to quantify levels of masking of biologically important foraging calls made by right whales in and around the Stellwagen Bank National Marine Sanctuary. Streever et al. (2012) modeled the sound fields from various sound sources in the Beaufort Sea, allowed modeled animals to migrate through the area, and calculated an “aggregate exposure” to multiple sources of sound. A follow up effort in the Beaufort Sea is under way that uses expert opinion to assess the likelihood that a response variable will be affected by sound, the severity of the impact if it occurs, and the experts’ certainty that we understand the system sufficiently to make a statement about impacts. Both the quantitative and qualitative approaches could be expanded to include consideration of cumulative effects of stressors other than sound on marine mammals.

CURRENT NOAA MANAGEMENT OF NOISE IMPACTS

NOAA’s responsibilities include the implementation of multiple federal statutes that provide for the protection and conservation of marine species and stocks, as well as their habitat. While the U.S. does not have any federal statutes or regulations in place that are specifically designed to address underwater noise, we currently regulate the impacts of underwater noise (among other impacts, including in air noise) on animal groups for which the agency has responsibility/authority through multiple federal statutes, as well as other initiatives discussed below. It is important to note that, to date, much of the management of noise effects on marine mammals, fish, invertebrates, and sea turtles has occurred through primarily project-specific consultations and permitting pursuant to the MMPA, the ESA, the NMSA, and the MSA. In some instances, other less targeted mechanisms have been used to provide broader recommendations (e.g., Fish and Wildlife Coordination Act to address fish and invertebrate impacts). While some of these consultations are programmatic in nature, their analyses are not typically comprehensive on a scale that would adequately address either the long life spans or very large geographic ranges of all of the marine species potentially impacted, and they don't address aggregate or cumulative effects very well. Additionally, even when the importance of a given area is understood, either for its broader acoustic habitat value or because of known value to a specific species or group, ***places are typically more difficult to manage through the more project-specific lenses of ESA and MMPA*** (though, see Chapter 2)***.***

As a federal agency, pursuant to the National Environmental Policy Act (NEPA), NOAA also has the responsibility to analyze the impacts of its own activities (e.g., conducting scientific research, operating a fleet of vessels, issuing MMPA authorizations) on the human environment. This analysis must consider a range of reasonable alternatives (including mitigation measures), all potentially impacted resources (e.g., biological resources and social resources), and cumulative impacts, and must be made available to both the public and agency decision-makers. The product of this process is a NEPA document that, where appropriate, will include a full discussion of the acoustic impacts of an activity on marine taxa.

NOAA's work with the International Maritime Organization's (IMO) to develop voluntary guidelines for reducing underwater noise from commercial shipping, which were adopted in April 2014 is another important example of NOAA's efforts to more broadly minimize noise impacts on marine species and their acoustic habitats. This international mechanism serves as a long-term tool for NOAA, other U.S. agencies, and other governments to address noise impacts on a broader spatial scale than U.S. statutes allow.

Below we briefly describe the four main statutory authorities through which NOAA currently addresses the impacts of ocean noise on marine species. Appendix C further describes the specific applicable sections of the statutes summarized below and also lists other authorities through which NOAA could address noise impacts on species and acoustic habitat (described further in the "Next Steps for NOAA Ocean Noise Strategy" section.

Marine Mammal Protection Act (MMPA)

The MMPA states that marine mammals are resources of great international significance and should not be permitted to diminish beyond the point at which they cease to be a significant functioning element of the ecosystem. Section 2 (2) of the MMPA further states that the primary objective of their management should be to maintain the health and stability of marine mammals and their ecosystems, and that efforts should be made to protect essential habitats, including rookeries, mating grounds, and areas of similar significance from the adverse effect of man's actions. The MMPA lays out very explicit protections and programs for *all* marine mammal species and stocks and their habitat, and NOAA is responsible for implementing these mandates for most marine mammal species (except for the 5 taxa under USFWS jurisdiction: manatees, dugongs, walrus, polar bears, and sea otters).

As part of the plan to serve this broader goal, the MMPA prohibits the take of marine mammals, with certain exceptions, one of which is the issuance of incidental take authorizations (ITAs). Section 101(a)(5) of the MMPA allows for NOAA/USFWS to issue ITAs provided that: (1) the total taking will have a negligible impact on the affected species (or stock), and (2) the total taking will not have an unmitigable adverse impact on the availability of the affected species or stocks for subsistence uses. Further, NOAA/USFWS must clearly set forth the permissible methods of taking and the requirements pertaining to the mitigation, monitoring and reporting of the take (for more information about Section 101 of the MMPA see http://www.nmfs.noaa.gov/pr/permits/incidental/).

Title IV of the MMPA lays out the responsibilities of NOAA and the USFWS for implementing the Marine Mammal Health and Stranding Response Program (MMHSRP). Pursuant to the MMHSRP, NOAA responds to, investigates, and reports out on marine mammal strandings, including those potentially associated with exposure to loud sounds (for more information about the MMHSRP see http://www.nmfs.noaa.gov/pr/health/stranding.htm).

Endangered Species Act (ESA)

The purposes of the ESA include providing a means to conserve the ecosystems of endangered species and threatened species (those threatened with extinction) and to provide a program for the conservation of the species themselves. The ESA seeks to avoid extinction and recover threatened and endangered species to a point at which they no longer need ESA protections. The Endangered Species Act (ESA) lists the following number of species as threatened or endangered: 27 marine mammals; 57 fish; 16 sea turtles, and; 24 invertebrates.

As one part of a plan to serve these broader goals, Section 9 of the ESA prohibits the take of ESA-listed species, with limited exceptions. Section 7 of the ESA requires that each federal agency, in consultation with NOAA/USFWS, insure that any agency action is not likely to jeopardize the continued existence of any endangered or threatened species, or result in the adverse modification of their critical habitat. Provided these findings are made, incidental take of ESA-listed species may be exempted by NOAA or USFWS. Section 10 of the ESA allows for the issuance of incidental take permits to non-federal entities. NOAA or USFWS typically identify terms and conditions (e.g., mitigation or monitoring) that the action agency or permit holder must abide by in order to be exempted of/permitted for the incidental take.

Section 4 of the ESA allows for the protection of designated critical habitat, which is defined as:

- within the geographical area occupied by the species at the time of listing, if they contain physical or biological features essential to conservation, and those features may require special management considerations or protection; and
- outside the geographical area occupied by the species if the agency determines that the area itself is essential for conservation.

Critical habitat is based on "primary constituent elements," which are the physical or biological features essential to the conservation of a species, such as space for growth, food, cover, etc. One species of marine mammal, Cook Inlet beluga whale, has a primary constituent element identified in its critical habitat designation that addresses noise impacts: "waters with in-water noise below levels resulting in the abandonment of critical habitat areas by Cook Inlet belugas." For more information about the Endangered Species Act, visit: http://www.nmfs.noaa.gov/pr/laws/esa/.

National Marine Sanctuaries Act (NMSA)

The NMSA allows for the designation and protection (by NOAA) of national marine sanctuaries -- areas of the marine environment with special national significance due to their conservation, recreational, ecological, historical, scientific, cultural, archaeological, educational, or aesthetic qualities. The primary objective is to protect special areas of the marine environment.

Regulations may be issued for specific sanctuaries or the system as a whole, and can (among other things) specify the activities that can and cannot occur within the sanctuary and/or those that require permitting (Section 308). Currently, none of the 14 sites managed or co-managed by the Office of National Marine Sanctuaries (ONMS) prohibit outright the production of underwater noise within their boundaries. However, Section 304(d) of the NMSA additionally requires federal agencies whose actions are likely to destroy, cause the loss of, or injure a sanctuary resource to consult with the ONMS before taking the action. ONMS then recommends reasonable and prudent alternatives (which may include mitigation or monitoring) to protect sanctuary resources. Where noise impacts are addressed, 304(d) recommendations may address any noise-sensitive species within the sanctuary (e.g., marine mammals or fish) as well as targeting acoustic habitat concerns more broadly (for more about management of National Marine Sanctuaries resources see: http://sanctuaries.noaa.gov/management/welcome.html).

Magnuson-Stevens Fishery Conservation and Management Act (MSA)

Fish require healthy surroundings to survive and reproduce. NOAA Fisheries works with regional fishery management councils to identify the essential habitat for every life stage of each federally managed fish and invertebrate species using the best available scientific information. Essential fish habitat (EFH) includes all types of aquatic habitat—wetlands, coral reefs, seagrasses, rivers—where fish (and some invertebrates) spawn, breed, feed, or grow to maturity. Essential fish habitat has been described for approximately 1,000 managed species to date.

NOAA and the councils also identified more than 100 “habitat areas of particular concern” or HAPCs. These are considered high priority areas for conservation, management, or research because they are rare, sensitive, stressed by development, or important to ecosystem function.

Through EFH consultations pursuant to the Magnuson Stevens Act, NOAA works with federal agencies to conserve and enhance essential fish habitat (EFH). Consultation is required when a federal agency authorizes, funds, or undertakes an action that may adversely affect EFH. Adverse effects include: direct or indirect physical, chemical, or biological alterations of the waters or substrate; loss of, or injury to species and their habitat, and other ecosystem components; or reduction of the quality and/or quantity of EFH. The federal agency must provide NOAA Fisheries with an assessment of the action’s impacts to EFH, and NOAA Fisheries provides the federal agency with EFH Conservation Recommendations to avoid, minimize, mitigate, or otherwise offset those adverse effects. Federal agencies must provide a detailed written explanation to NOAA Fisheries describing which recommendations, if any, it has not adopted.

REGULATORY AND ANALYTICAL APPROACHES

The standards, thresholds, and terminology vary, but all of the statutes identified above generally aim to assess and minimize the impacts to individuals, populations, and habitats of marine taxa. Impact analyses conducted pursuant to these different statutes will sometimes use different analytical methods because of the differences in the requirements of the statutes or the nature of the activities or impacts assessed, but they are all required to be based upon the best available science.

Acoustic Thresholds

One tool that NOAA currently uses to characterize and assess acute impacts of noise exposure is acoustic exposure thresholds. For marine mammals, these generic thresholds have historically (for the most part) been presented in the form of single received levels for particular source categories (e.g., impulse or continuous,) above which an exposed animal would be predicted to incur auditory injury or be behaviorally harassed. For example, root mean square (RMS) sound pressure level (SPL) 180 and 190 dB thresholds have been used for the onset of ***acoustic injury*** of cetaceans and pinnipeds, respectively, and RMS SPL 160 and 120 dB thresholds have been used for the onset of ***behavioral harassment*** of all marine mammals from impulse and continuous sources, respectively. These two specific effect types (acoustic injury and behavioral harassment) align well with statutory definitions of some components of “take” in MMPA and ESA, and “injury” under the NMSA. NOAA has also used dose-response-type curves to quantify behavioral harassment of marine mammals from active sonar involved in military readiness activities.

Because of the paucity of information for fishes, sea turtles, and invertebrates, acoustic thresholds have been applied in a more regionally-specific manner, and often only specifically in the context of particular activity types for which adverse effects have been documented (e.g., sea turtles to explosives). Generally, more supporting data exist for frequently conducted activities that produce acute, intense, high energy, impulsive sounds, such as pile driving, underwater explosions, and seismic surveys. For example, a coalition of federal (including NOAA Fisheries West Coast Region) and state resources and transportation agencies along the West Coast, the Fisheries Hydroacoustic Working Group (FHWG), used data from a variety of sound sources (primarily underwater explosions and seismic airguns) and species to establish interim acoustic criteria for the onset of injury of fish from impact pile driving (FHWG 2008). These criteria, in turn, are sometimes used to estimate the risk to fishes from other types of impulsive sounds. They are not appropriate, however, for non-impulsive, continuous sounds. However, several impact pile driving and other sound source studies have been conducted since the 2008 thresholds were established, and may be used in the future to revisit these criteria and develop different ones for fishes specifically for pile driving and other impulsive and non-impulsive sound sources (e.g., Casper et al. 2012, Casper et al. 2013, Bolle et al. 2012, Halvorsen et al. 2011, Halvorsen et al. 2012a,b,c, Halvorsen et al. 2013, Hawkins et al. 2014a, Bolle et al. 2016). Most historical research has used peak pressure to evaluate the effects on fishes from underwater sound. Current research, however, suggests that sound exposure level (SEL_{cum}), a measure of the total sound energy expressed as the time-integrated, sound pressure squared, is also a relevant metric for evaluating the effects of sound on fish.

It is important to note that the identification of these likely direct physical or behavioral effects via the use of acoustic thresholds is only one part of any broader impact finding under MMPA, ESA, MSA or NMSA, and does not consider adverse stress effects. These statutes must also assess impacts on habitat (including acoustic habitat), as well as the ultimate results of all of the effects on the fitness of individuals (health, reproductive success, and survival) and subsequent population growth rates and/or likely impacts to resources within sanctuaries. However, acoustic thresholds are important both because they help regulated entities understand when a federal consultation may be appropriate and because of requirements under both the MMPA and ESA to quantify the impacts of acoustic exposure on a project-by-project basis.

One of the limitations of relying on the action-specific regulatory approaches of the MMPA, ESA, MSA and NMSA to address the impacts of noise is that it makes it more challenging to address chronic (longer-term) and multi-source impacts that co-occur across longer time frames, larger areas, and multiple activities. Additionally, some activities that contribute significantly to background noise levels are challenging, if not impossible, to regulate case-specifically (e.g., large commercial shipping) or do not typically go through the MMPA, ESA, MSA, or NMSA processes. To date, acoustic habitat has not been regularly addressed in MMPA, ESA, MSA, or NMSA consultations.

Mitigation

The activity-specific structure of the current regulatory framework also means that there is not a standard required set of mitigation or monitoring to always apply to noise-producing activities. That said, the following types of mitigation measures are commonly required or recommended to address acoustic impacts to marine mammals, and a subset of them are sometimes applied to other taxa, though protective measures for fish, invertebrates, and sea turtles are typically more limited to mitigating the potential for acute injurious impacts:

- Real-time detection and action (to limit acute/direct impacts)
  - Power down/shutdown zones to minimize the likelihood of injury to marine mammals, fish, turtles or invertebrates, or the behavioral harassment of large groups of marine mammals or mother/calf or pup pairs
  - Visual observers for protected species (shore, ship and aerial, unmanned crafts) and/or passive acoustic technicians (increasingly common) to support real-time measures
  - Daytime operations only or use of nighttime specific technology to enhance detection
- Seasonal/Area Limitations (to limit chronic/long-term effects, but also acute effects including behavioral)
  - Avoidance/minimization of operations in seasons and/or areas of biological importance or with particularly sensitive species(e.g., sanctuaries, HAPCs, salmon migration routes, critical habitat)
- Noise abatement/reduction (to reduce both chronic and acute impacts)
  - Sound attenuation methods for pile driving (bubble curtains, pile caps, etc.)
  - Ramp-up procedures with airguns (and sometimes pile driving)
- Sound source verification to ensure adequate mitigation zones and accurate prediction of effects

Of note, protected species observers (PSOs) are used for many activities with the potential to adversely impact marine fauna, both to implement mitigation measures, such as shutdowns or to ensure that safety zones are clear before activities take place, and to collect data for monitoring. NOAA published the NOAA Technical Memorandum "National Standards for a Protected Species Observer and Data Management Program" (Baker et al, 2014), which provides recommendations to more broadly enhance coordination, establish national PSO standards for qualifications and training, institute standardized data collection and reporting requirements, and develop data quality assurance process, among other things that could be used to support a more consistent approach.

Monitoring

As noted above, the MMPA has an explicit requirement for monitoring to better understand the impact of authorized activities on marine mammals, and the ESA, NMSA, and EFH also contain mechanisms for including monitoring requirements (note the requirements discussed in this section are separate from NOAA's separate internal mandate to conduct science). Because the activities requiring permits and consultations range so widely in temporal and spatial scope, monitoring plans that satisfy the requirements also range in robustness and scope. For example, monitoring requirements may range from pinniped counts conducted before, during, and after a small pier maintenance action to full-fledged (and sometimes peer-reviewed) research projects for oil and gas development or Navy training (see http://www.navymarinespeciesmonitoring.us/regions/ for full details of all required monitoring study objectives, methods, timelines, funding, and completed results). Reports containing monitoring results must be submitted and NOAA subsequently makes those reports available to the public. Transparency and sharing of *raw* data has increased through time and may now largely be obtained, if requested, with the exception of acoustic data that may implicate national security concerns (acoustic signal or locational data) or proprietary energy lease information (locational data).

NEXT STEPS FOR THE NOAA OCEAN NOISE STRATEGY

The purpose of NOAA's Ocean Noise Strategy, as highlighted here in this Roadmap, is to focus the agency's authority and capacity to characterize and manage ocean noise impacts for the benefit of NOAA trust resources. Through expertise and authority, the goal is for individual NOAA programs (regulatory, science, and noise-producing) to identify recommendations and concepts in this Roadmap that are most applicable and constructive towards their broader program goals, and work them into a program-specific implementation plan. Management strategies, risk assessment tool needs, and monitoring and science needs will necessarily vary among species, populations, and habitat. However, some science and advancements in management approaches may also be relevant across species groups and areas, providing opportunity for collaboration and consolidation of agency resources. Eight broadly applicable, high priority areas of agency improvement are identified here (in no particular order):

1. Consistent Messaging, Internal Education, and Coordination: All NOAA offices should, ideally, be using the same terminology and concepts to describe the issues surrounding aquatic noise impacts on species and acoustic habitat. The development and compilation of a glossary of noise terms and concepts, especially as they relate to effects on marine species and their acoustic habitats, would be very helpful and could be developed by expanding the glossary developed for NOAA's new acoustic guidelines. Beyond a common lexicon, NOAA should be consistently describing the full suite and relative importance of the potential effects of noise in both internal and external settings. This Roadmap aims in particular to support the agency's consistent articulation of the importance of protecting acoustic habitat, in addition to minimizing acute (physical and behavioral), chronic, and cumulative impacts associated with noise. Additional work would be needed to develop the glossary and ensure that NOAA's workforce is well-versed in the basics of acoustics (introductory materials to more advanced materials), as well as the latest science on the impacts of noise on marine species and habitats.

NOAA programs with a noise impact nexus are implemented across the agency through multiple line offices and levels (national, regional, specific sanctuaries, etc.). Clearly, it is critical that coordination is planned across these programs where appropriate. For example, it makes sense, both biologically and logistically, to regularly coordinate mitigation and monitoring priorities, as well as any new risk assessment methodologies or science, across the primary regulatory programs. One ongoing example of successful internal coordination and information sharing is the NOAA Acoustic Coordination Group, which meets 3-4 times a year, and sponsors a listserv to discuss both management and science issues related to acoustics.

2. National Guidance for Acoustic Thresholds and Other Management Tools: The development of consistent national guidance for acoustic thresholds for all of NOAA's trust resources would provide strong support for NOAA's accomplishment of the Strategy goals. In a process separate from this Roadmap, NOAA has developed the "Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing" that includes revised acoustic thresholds for assessing acoustic impacts on marine mammal hearing (permanent and temporary threshold shifts) (NMFS 2016). The Guidance's review process included multiple peer and public reviews of the scientific rationale and methods. NOAA is now working on developing updated Technical Guidance to assess behavioral harassment of marine mammals. To support the Strategy goals, NOAA could pursue developing similar national acoustic injury thresholds for fish, sea turtles, and, potentially invertebrates. While official national guidance on acoustic thresholds is being developed for any of these purposes, coordinated interim principles and practices would ensure consistent application of existing acoustic data.

For NOAA management practitioners, it is valuable to have guidelines that describe how to implement various typical management recommendations that can be shared with the regulated community. Examples of these types of guidance include how to do sound source verification, how to estimate isopleths associated with different effect thresholds, or how to design effective passive acoustic monitoring (PAM) for a particular project. These types of guidelines could be developed and implemented nationally (with regional and program input) to promote consistency and alleviate either duplicative effort or contradicting recommendations across regions and programs.

3. Exploring and Coordinating the Use of Applicable NOAA Authorities: In the previous section, the federal statutes through which NOAA has traditionally addressed ocean noise impacts were outlined. Appendix C contains a spreadsheet indicating a longer list of the applicable statutes, executive orders, and other formal programs (and specific mechanisms and Sections) through which NOAA *could* address ocean noise issues, both in relation to specific species *and also* acoustic habitat, either through raising awareness, making official recommendations, or including regulatory requirements. We recommend that the NOAA Programs implementing these statutes work together to add reference to ocean noise issues (using the consistent messaging mentioned above) where not currently addressed. Additionally, improved coordination between, for example, regulatory MMPA and ESA programs and the Marine Mammal Health and Stranding Response Program, such as overlaying maps of authorized sound use activities with unusual mortality events, spill or stranding investigations, or other health indicators (along with the subsequent analyses triggered by the mapping connections), could facilitate better assessment and prediction of the impacts of noise on individuals and/or populations .

Traditional approaches to regulating ocean noise issues have necessarily been somewhat constrained by the project-specific and shorter-term focus of the statues under which NOAA worked. However, there is some temporal and spatial flexibility in the traditionally-used statues to explore broader (e.g., programmatic) approaches to analysis and management of chronic large-scale impacts. Additionally, consideration of some of the additional tools presented in Appendix C gives NOAA more room to coordinate broader-scale strategies across multiple programs, as resources and opportunities allow – provided we have a well-articulated justification and approach. Additionally, Chapter 2 outlines a broad place-based approach for prioritizing the management of acoustic habitat.

Last, when considering approaches for addressing ocean noise impacts, international examples are available. The European Union has recognized ocean noise as an indicator of environmental quality under its Marine Strategy Framework Directive (EU 2008) and, further, is in the process of developing targets for achieving “good environmental status” for ocean noise and acute noise-generating activities. Nowacek et al., 2015, identify existing international mechanisms that they suggest could potentially be modified to address ocean noise impacts, such as the International Convention for the Prevention of Pollution from Ships.

4. Development of Risk Assessment Tools: To support the Strategy, risk assessment tools would be targeted towards the analyses required to support decisions under NOAA’s statutory authorities, which essentially involve characterizing, analyzing, and mitigating the impacts of sound on individuals, stocks, populations (see Chapter 4), and their habitat (including acoustic habitat).

Spatially explicit risk assessments are an important tool for developing and prioritizing management actions. Specific targets could include maintaining lower background noise levels in acoustic habitat or reducing noise in areas of high densities of acoustically sensitive species. We can quantify risk by combining species distributions, species-specific acoustic sensitivities, and sound maps. Risk assessments may be conducted comparing the highest intensity of sound received from specific activities (e.g., navy sonar, seismic airguns, or pile driving) or comparing highest energy accumulated over time from chronic and aggregated sound sources (e.g., shipping lanes), depending on whether risk from acute or chronic noise is being assessed. These assessments can be used to identify the most effective management actions at reducing impacts by evaluating changes in predicted impacts when changes in sound-producing activities and sound levels are applied. This type of assessment focuses on impacts in defined geographic areas. Alternatively, it may be important to consider cumulative noise impacts faced by individuals throughout their lifetime. This type of assessment requires integrating risk across all areas used by the individuals (e.g., breeding and feeding areas *and* migratory corridors). Having the tools available to conduct both types of assessment, along with others, will strengthen and support NOAA's conservation actions and related decisions, and further aid the public and regulated community in planning and analyses to support environmental compliance and impact minimization.

Following are some of the basic components that would allow the sorts of risk assessments outlined above and to create a more effective NOAA risk assessment framework:

- Tools to model: (1) sound propagation in the context of realistic environmental parameters, and; (2) marine animal sound exposure. Output would be available in a variety of metrics and be capable of addressing accumulation over time and auditory weighting functions.
- Data to inform, or tools to model, ambient or average background sound levels (soundscape, see Chapter 3) over which risk assessments may be layered (including a database of measured sound source verifications).
- Maps of NOAA-authorized activities (produced by NOAA) and noise-producing activities not regulated by NOAA, where available (e.g., Marine Cadastre website).
- Platforms, servers, and data layers that allow for the geospatial analysis of the temporally, spatially, and spectrally-specific overlays of sound-producing activities and protected marine species at a wide range of temporal and spatial scales.
- Permanently maintained, standardized, and web-accessible database or portal for acoustic and marine animal data.

These tools are a high priority for NOAA practitioners, but would also ideally be made available to the public as soon as possible.

Further development of risk assessment frameworks will require improved quantitative capacity to evaluate the population-level and cumulative consequences resulting from co-occurrence of noise and marine animals. These frameworks and models would include consideration of health and disease risks where known and be applicable to certain species. In addition to the PCoD effort mentioned previously and other marine mammal-centric efforts underway, there are numerous well-developed risk assessment frameworks in the toxicology field that could potentially applied to noise and aquatic animal issues.

Specifically in regard to the better understanding of chronic noise effects, new quantitative tools are currently being developed that may be able to better characterize the acoustic space available to an animal to detect critical acoustic cues. The information is gained from our understanding of the animal's hearing, vocal behavior, and the surrounding soundscape, which is informed by both natural and anthropogenic sounds (Clark et al. 2009). However, these highly specific and quantitative tools can be resource-prohibitive for project-specific analyses. In addition, managers still struggle to connect the quantification of reduced acoustic space with a particular degree of impacts on protected species, either at the individual or population level. There is a need for the development of semi-quantitative tools, either standing alone or built into broader analyses, in which masking or acoustic habitat degradation effects can be incorporated for consideration.

In the past, noise impact assessments have relied heavily on the received sound level of which an animal was likely to be exposed in order to estimate the likely severity of the resulting impacts. However, in addition to targeted studies in marine mammals and fish indicating that frequency and duration (beyond just differing sensitivities at different frequencies) can affect the likelihood of auditory impairment, there is increasing evidence that contextual factors other than the received sound level are important in assessing impacts. Contextual factors including the activity states of exposed animals, the novelty of a sound, and the relative spatial positions between sound source and receiver, can strongly affect the probability of a behavioral response and the significance of that response to the fitness of the exposed individual (Ellison et al. 2011). For an accurate characterization and evaluation of likely noise impacts, it is critical to consider not only frequency and other sound characteristics, but other contextual factors when the information is available (Francis and Barber 2013).

5. Prioritize Baseline Science Needs: The highest priority science needs for assessing and minimizing acoustic impacts can be arranged along a continuum from understanding individual components of the problem (mapping sound and species distributions and quantifying the effects of sound on individuals and populations) to synthesizing information in risk assessments. A list of *general* priority information needs (non-comprehensive and in no particular order) for noise assessment appears below. These can be more specifically focused by taxa or species based on the status of existing data summarized in Appendices A and B, though generally speaking, more basic information is needed for sea turtles, invertebrates, and fish. Chapter 3 also addresses key information gaps in NOAA's current understanding of soundscapes and a need for enhanced passive acoustic monitoring. NOAA has already begun collecting, compiling and making available some of this information.

- Presence, abundance, density, and distribution mapping of protected species and prey, including:
    - prioritization based on overall vulnerability and noise sensitivity, as well as ecosystem assessments
    - for existing datasets - increased spatial and temporal resolution
    - systematic updates
- Increased understanding of species sound use, auditory thresholds and hearing mechanisms, especially for non-marine mammal species, including:
    - differentiation of life stages for fishes
    - special emphasis on turtles
- Increased understanding of noise levels that cause hearing loss, other physical injuries and masking especially for fishes, but also for invertebrates, turtles, and mysticetes including:
    - prioritization of science based on sound sources known to pose more risk to species
    - increased understanding of other environmental factors that contribute to hearing loss and other impacts.
    - Increased understanding of particle motion effects
- Increased understanding of behavioral sensitivity and responses to noise, including:
    - for marine mammals, responses to actual sound sources under realistic exposure conditions and duration (e.g., caution with laboratory studies)

  - baseline behavioral data to compare noise-induced changes to
  - targeted attention to effects of contextual variables beyond sound level
  - targeted attention to effects at multiple scales (e.g., tags that track horizontal movement *and* tags that record finer scale data such as clicks, acceleration, dive tracks)
- Identification of times, areas or species of particular concern for risk assessment, e.g.:
  - important areas for reproduction, feeding, migration, etc.
  - particular contextual situations of concern (e.g., populations undergoing severe epidemic or heavy exposure to oil spill)
  - identification of fish and invertebrate species that may be particularly susceptible to human noise (based on functional hearing or broad responses to sound) prioritized according to species that are ecologically, commercially and recreationally important.
- Collection of baseline stress-marker datasets to which field measurements can be compared to appropriately to assess context and significance of noise-caused adverse stress responses.
- Increased understanding of masking (see Chapters 2 and 3) and, importantly, the consequences of reduced listening space for all taxa.
- Soundscape characterization and mapping (see Chapter 3), including:
  - long-term monitoring of background noise in frequency bands relative to marine species hearing
  - location, timing, intensity and frequency of particular sound sources
- Collection and understanding of basic energetic information to link individual responses to effects on survivorship and reproductive success and, ultimately, population-level consequences.
- Understanding of effects of aggregate noise sources, as well as cumulative effects of noise with non-acoustic sources

Of note, NOAA has developed an internal process for compiling key science needs (more broadly) at the regional level. Maintenance of key science needs for assessing acoustic impacts should be cross-referenced with the regional Protected Resources Science Investment and Planning Process (PRSIPP) to ensure inclusion of newest science from the Science Centers, as well as to inform the broader NOAA science prioritization process.

6. Continue to Support Mitigation Development: Where noise is concerned, mitigation should be broadly designed to do one of two things: (1) reduce the temporal or spatial overlap of ensonified areas with marine taxa (or acoustic habitat) in particular times, places or circumstances, and/or (2) reduce the sound level at the source (which may include replacing the source with a different type of source capable of the same function). In reducing the spatio-temporal overlay of noise with marine animals and acoustic habitat, there are two general types of solutions: real-time avoidance of overlap of sound and managed species, and pre-planned larger-scale avoidance of sound use in important areas or times. Real-time measures are typically used to minimize acute effects, such as injury or severe behavioral responses, whereas broader activity planning may reduce acute, and potentially significant, behavioral effects, and is also the most effective spatiotemporal method to address more chronic acoustic habitat effects, such as masking.

In addition to improving and expanding some of the traditional mitigation measures identified in the previous section (e.g., real-time shutdowns and project-specific sound attenuation), and referring to the bulleted lists immediately above, it is important to continue engaging stakeholders and focusing on broader-scale technological development that will result in noise reduction over multiple projects and long time-scales. These include continued vessel quieting improvements and the exploration of technologies that can replace louder or more impactful sound sources (e.g., seismic airguns) with quieter sources that provide the same functionality while introducing less sound into the water. Additionally, we need to continue to identify the areas/times/contexts that are most critical to marine species so that we can reduce their overlay with potentially harmful sound exposure. Also, we need to continue to develop technologies and methodologies to enhance the detection of marine species (e.g., infrared, glider platforms). Finally, we need to incorporate communication protocols that facilitate rapid response when serious injury or stranding occurs concurrently with authorized or permitted sound-producing activities.

7. Enhance Efficacy and Transparency of Monitoring Approaches: As noted above, the MMPA has an explicit requirement for monitoring to better understand what impact the authorized activities have on marine mammals. The ESA, NMSA, and EFH also contain mechanisms for including monitoring requirements for assessing or quantifying the effects of managed activities on marine mammals, sea turtles, fishes, invertebrates, and their habitat. In other words, through its regulatory mandates, NOAA has the authority to require monitoring from entities seeking authorization to impact NOAA trust resources pursuant to the statutes described earlier in this Chapter, and for assessing the impacts of physical environmental parameters on marine mammal health (MMPA Title IV). This required monitoring should typically be commensurate with the anticipated impacts, and NOAA has gathered significant amounts of valuable information through these requirements in the past.

When NOAA program analysts consider recommended monitoring for activities with acoustic impacts, focusing on the concepts below would allow NOAA to ensure the best use of resources both within the Agency and by the entities/agencies from which NOAA requires monitoring:

- Keep in mind the priority data gaps identified above in the Science Needs section, and further maintain a list of specific priority study questions that relate to the applicable region and regulatory authority through which the analysts are recommending/requiring monitoring.
- Both in recommending monitoring and in maintaining a list of priority questions that monitoring should be designed to address, keep the following in mind:
    - The variety of timescales, asset/resource availability, and complexity across which monitoring may be applied (e.g., a daily pinniped beach census versus a controlled behavioral response study utilizing tags and multiple platforms)
    - The potential for meta-analyses of multiple monitoring efforts contributing to bigger questions
    - The need for methods standardization (e.g., addressing potential biases, requiring methods and reporting formats that allow for the most effective interpretation of results, as well as comparison to, and integration with, other results)
- Ensure that monitoring requirements and list of priority questions are informed by:
    - Evolving science and previous monitoring results
    - An understanding of regional ecosystem function
    - Existing and ongoing studies and programs to leverage monitoring
- Develop mechanism(s) to detect how multiple activities might contribute to a combined effect on individuals or a population.
- Incorporate adaptive components that will allow for modification of measures or solicitation of additional information as needs emerge through the regulatory timeframe.
- Ensure adequate data storage, sharing, and accessibility to NOAA users and the public
- Develop and implement a transparent process to:

- Educate and focus the regulated community on priority questions
- Integrate incoming monitoring data between applicants, as well as among scientists
- Regularly review and adapt priority questions

NOAA has worked extensively with the Navy over about 10 years on the development of their Comprehensive Monitoring Plan, through which they address the monitoring requirements of the MMPA and ESA for Navy training and testing activities across multiple regions within the US EEZ. Their monitoring provides a good example of an integrated, goal-oriented, and transparent monitoring process (see http://www.navymarinespeciesmonitoring.us/regions/). Similarly, BP engaged a scientific advisory group and worked extensively over years with resource agencies and subsistence communities to implement a long-term monitoring plan that addressed the impacts of the operation of the Northstar production island and led to multiple peer-reviewed articles that inform impact analyses today. Other companies in the Arctic, such as Shell and Conoco Phillips, have also supported good collaboration and robust monitoring plans that have improved our understanding of the effects of seismic operations (see NMFS project website for monitoring reports from : http://www.nmfs.noaa.gov/pr/permits/incidental/oilgas.htm).

8. Develop Mechanisms for Outreach, Collaboration, and Stakeholder Engagement: To fully support the Strategy, NOAA would promote public understanding of noise impacts in U.S. waters and abroad through targeted outreach efforts. There are multiple reasons why engagement with stakeholders is critical. Much of the research related to noise effects is conducted by entities outside of NOAA, including other Federal agencies (e.g., Navy or BOEM) and academic institutions or consortiums. Also, engagement with the regulated, or noise-producing, community allows NOAA to ensure that noise management implementation plans are effective and practicable. Systematic and regular engagement with stakeholders allows for coordination of related research, management, and risk assessment efforts to maximize synergy and resource savings. Over the course of NOAA's CetSound and NOAA Ocean Noise Strategy efforts, NOAA, Navy, BOEM, the Marine Mammal Commission, Duke University, Heat, Light, and Sound Inc., and others have collaborated and jointly funded (multiple separate examples and partners) marine mammal surveys, marine mammal density modeling, soundscape modeling, the development of risk assessment tools, expert elicitation to identify biologically important areas, and multiple workshops to address specific noise-related issues – all of which advance our collective ability to more effectively address the effects of noise on protected species and their habitat. NOAA will continue to explore and invite input regarding mechanisms to improve collaboration, including joint development and funding of workshops and decision-making tools, inter-disciplinary and inter-agency working groups, targeted solicitation of input through regulatory processes, and other methods.

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