
Appendix G: Conceptual Framework for Assessing Effects on Biological Resources

Supplemental Environmental Impact Statement/ Overseas Environmental Impact Statement Mariana Islands Training and Testing

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APPENDIX G Conceptual Framework for Assessing Effects on Biological Resources

The analysis of impacts on biological resources focused on the likelihood of encountering the stressor, the primary stimulus, response, and recovery of individual organisms. Where appropriate, the potential of a biological resource to overlap with a stressor was analyzed with consideration given to the specific geographic area (large marine ecosystems, open ocean areas, range complexes, operating areas, and other training and testing areas) in which the overlap could occur. Additionally, the differential impacts of training versus testing activities that introduce stressors to the resource were considered.

For each of the non-biological resources considered in this Supplemental Environmental Impact Statement/Overseas Environmental Impact Statement, the methods are unique to each specific resource and are therefore described in each resource section. For Sediments and Water Quality, Air Quality, Cultural Resources, Socioeconomics, and for Public Health and Safety, see Section 3.0.1 (Overall Approach to Analysis).

G.1 Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities

This conceptual framework describes the potential effects from exposure to acoustic and explosive activities and the accompanying short-term costs to the animal (e.g., expended energy or missed feeding opportunity). It then outlines the conditions that may lead to long-term consequences for the individual if the animal cannot fully recover from the short-term costs and how these in turn may affect the population. Within each biological resource section (e.g., marine mammals, birds, and fishes) the detailed methods to predict effects on specific taxa are derived from this conceptual framework.

An animal is considered “exposed” to a sound if the received sound level at the animal’s location is above the background ambient noise level within a similar frequency band. A variety of effects may result from exposure to acoustic and explosive activities.

The categories of potential effects are listed below:

- **Injury and other non-auditory injury** – Injury to organs or tissues of an animal
- **Hearing loss** – A noise-induced decrease in hearing sensitivity, which can be either temporary or permanent and may be limited to a narrow frequency range of hearing
- **Masking** – When the perception of a biologically important sound (i.e., signal) is interfered with by a second sound (i.e., noise)
- **Physiological stress** – An adaptive process that helps an animal cope with changing conditions; although, too much stress can result in physiological problems
- **Behavioral response** – A reaction ranging from very minor and brief changes in attentional focus, changes in biologically important behaviors, and avoidance of a sound source or area, to aggression or prolonged flight

Figure G-1 is a flowchart that diagrams the process used to evaluate the potential effects to marine animals exposed to sound-producing activities. The shape and color of each box on the flowchart represents either a decision point in the analysis (green diamonds); specific processes such as responses, costs, or recovery (blue rectangles); external factors to consider (purple parallelograms); and final outcomes for the individual or population (orange ovals and rectangles). Each box is labeled for reference throughout the following sections. For simplicity, sound is used here to include not only sound

waves but also blast waves generated from explosive sources. Box A1, the Sound-Producing Activity, is the source of this stimuli and therefore the starting point in the analysis.

The first step in predicting whether an activity is capable of affecting a marine animal is to define the stimuli experienced by the animal. The stimuli include the overall level of activity, the surrounding acoustical environment, and characteristics of the sound when it reaches the animal.

Sounds emitted from a sound-producing activity (Box A1) travel through the environment to create a spatially variable sound field. The received sound at the animal (Box A2) determines the range of possible effects. The received sound can be evaluated in several ways, including number of times the sound is experienced (repetitive exposures), total received energy, or highest sound pressure level experienced.

Sounds that are higher than the ambient noise level and within an animal's hearing sensitivity range (Box A3) have the potential to cause effects. There can be any number of individual sound sources in a given activity, each with its own unique characteristics. For example, a United States Department of the Navy training exercise may involve several ships and aircraft using several types of sonar. Environmental factors such as temperature and bottom type impact how sound spreads and attenuates through the environment. Additionally, independent of the sounds, the overall level of activity and the number and movement of sound sources are important to help predict the probable reactions.

The magnitude of the responses is predicted based on the characteristics of the acoustic stimuli and the characteristics of the animal (species, susceptibility, life history stage, size, and past experiences). Very high exposure levels close to explosives have the potential to cause injury. High-level, long-duration, or repetitive exposures may potentially cause some hearing loss. All perceived sounds may lead to behavioral responses, physiological stress, and masking. Many sounds, including sounds that are not detectable by the animal, could have no effect (Box A4).

G.1.1 Injury

Injury (Box B1) refers to the direct injury of tissues and organs by shock or pressure waves impinging upon or traveling through an animal's body. Marine animals are well adapted to large, but relatively slow, hydrostatic pressures changes that occur with changing depth. However, injury may result from exposure to rapid pressure changes, such that the tissues do not have time to adequately adjust.

Therefore, injury is normally limited to relatively close ranges from explosions. Injury can be mild and fully recoverable or, in some cases, lead to mortality.

Injury includes both auditory and non-auditory injury. Auditory injury is the direct mechanical injury to hearing-related structures, including tympanic membrane rupture, disarticulation of the middle ear ossicles, and injury to the inner ear structures such as the organ of Corti and the associated hair cells. Auditory injury differs from auditory fatigue in that the latter involves the overstimulation of the auditory system at levels below those capable of causing direct mechanical damage. Auditory injury is always injurious but can be temporary. One of the most common consequences of auditory injury is hearing loss.

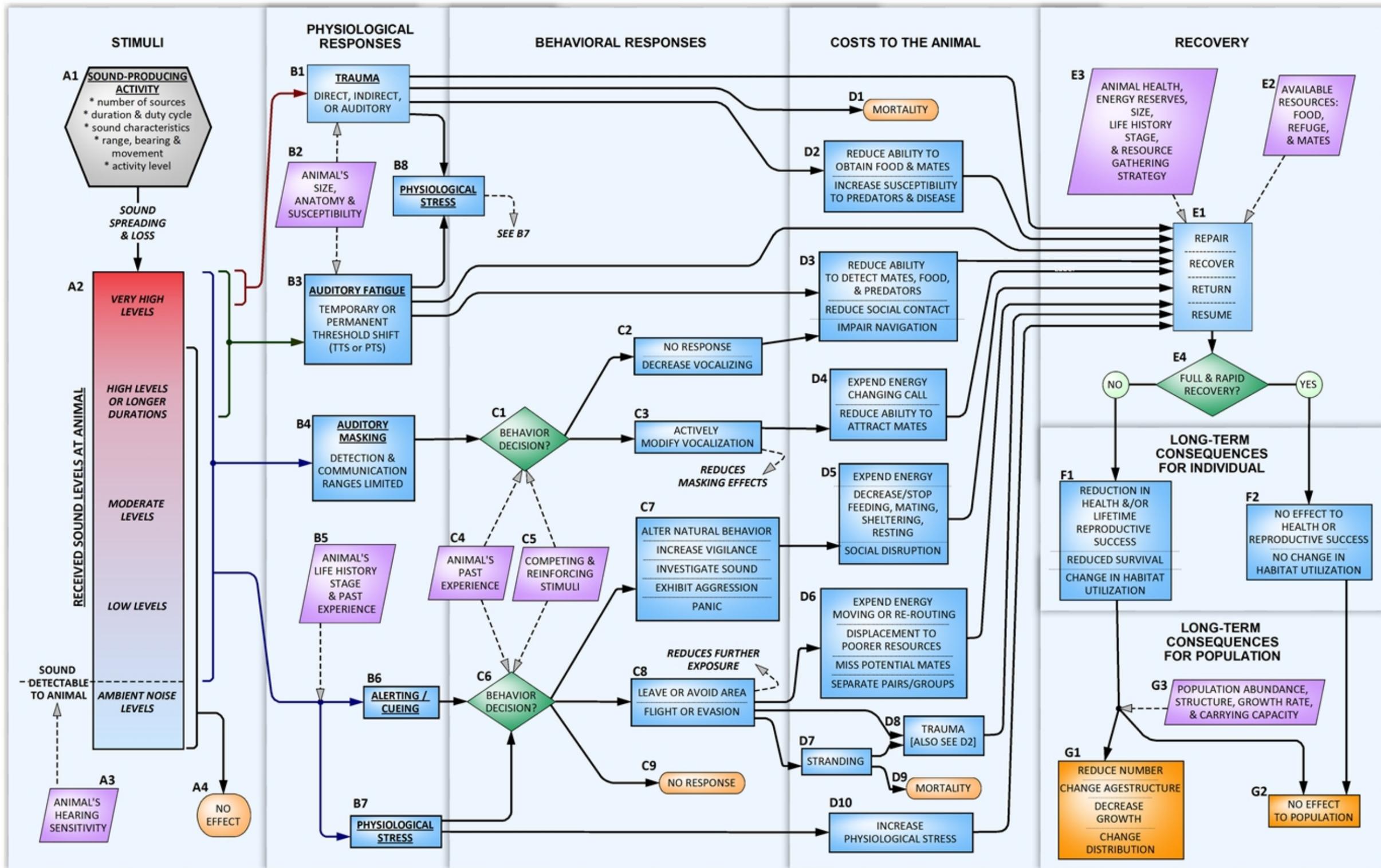


Figure G-1: Flow Chart of the Evaluation Process of Sound-Producing Activities

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Non-auditory injury can include hemorrhaging of small blood vessels and the rupture of gas-containing tissues such as the lung, swim bladder, or gastrointestinal tract. After the ear (or other sound-sensing organs), these are usually the organs and tissues most sensitive to explosive injury. An animal's size and anatomy are important in determining its susceptibility to non-auditory injury (Box B2). Larger size indicates more tissue to protect vital organs. Therefore, larger animals should be less susceptible to injury than smaller animals. In some cases, acoustic resonance of a structure may enhance the vibrations resulting from noise exposure and result in an increased susceptibility to injury. The size, geometry, and material composition of a structure determine the frequency at which the object will resonate. Because most biological tissues are heavily damped, the increase in susceptibility from resonance is limited.

Vascular and tissue bubble formation resulting from sound exposure is a hypothesized mechanism of injury to breath-holding marine animals. Bubble formation and growth due to direct sound exposure have been hypothesized (Crum & Mao, 1996; Crum et al., 2005); however, the experimental laboratory conditions under which these phenomena were observed would not be replicated in the wild. Certain dive behaviors by breath-holding animals are predicted to result in conditions of blood nitrogen super-saturation, potentially putting an animal at risk for decompression sickness (Fahlman et al., 2014), although this phenomena has not been observed (Houser et al., 2009). In addition, animals that spend long periods of time at great depths are predicted to have super-saturated tissues that may slowly release nitrogen if the animal then spends a long time at the surface (i.e., stranding) (Houser et al., 2009).

Injury could increase the animal's physiological stress (Box B8), which feeds into the stress response (Box B7) and also increases the likelihood or severity of a behavioral response. Injury may reduce an animal's ability to secure food by reducing its mobility or the efficiency of its sensory systems, making the injured individual less attractive to potential mates, increasing an individual's chances of contracting diseases or falling prey to a predator (Box D2), or increasing an animal's overall physiological stress level (Box D10). Severe injury can lead to the death of the individual (Box D1).

Damaged tissues from mild to moderate injury may heal over time. The predicted recovery of direct injury is based on the severity of the injury, availability of resources, and characteristics of the animal. The animal may also need to recover from any potential costs due to a decrease in resource gathering efficiency and any secondary effects from predators or disease. Severe injuries can lead to reduced survivorship (longevity), elevated stress levels, and prolonged alterations in behavior that can reduce an animal's lifetime reproductive success. An animal with decreased energy stores or a lingering injury may be less successful at mating for one or more breeding seasons, thereby decreasing the number of offspring produced over its lifetime.

G.1.2 Hearing Loss

Hearing loss, also called a noise-induced threshold shift, is possibly the most studied type of effect from sound exposures to animals. Hearing loss manifests itself as loss in hearing sensitivity across part of an animal's hearing range, which is dependent upon the specifics of the noise exposure. Hearing loss may be either PTS or TTS. If the threshold shift eventually returns to zero (the animal's hearing returns to pre-exposure value), the threshold shift is a TTS. If the threshold shift does not return to zero but leaves some finite amount of threshold shift, then that remaining threshold shift is a PTS. Figure G-2 shows one hypothetical threshold shift that completely recovers, a TTS, and one that does not completely recover, leaving some PTS.

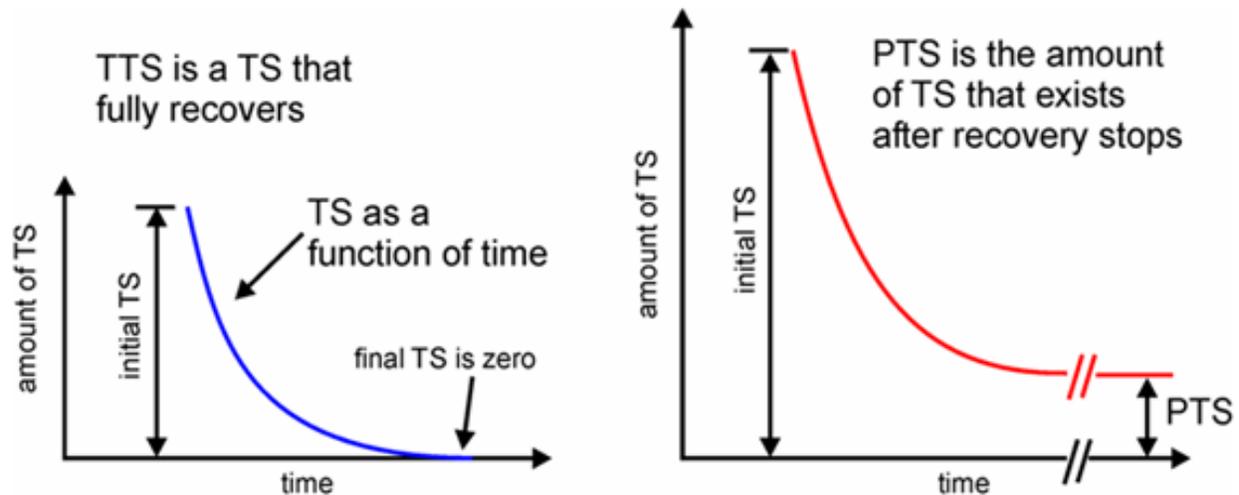


Figure G-2: Two Hypothetical Threshold Shifts

The characteristics of the received sound stimuli are used and compared to the animal’s hearing sensitivity and susceptibility to noise (Box A3) to determine the potential for hearing loss. The amplitude, frequency, duration, and temporal pattern of the sound exposure are important parameters for predicting the potential for hearing loss over a specific portion of an animal’s hearing range. Duration is particularly important because hearing loss increases with prolonged exposure time. Longer exposures with lower sound levels can cause more threshold shift than a shorter exposure using the same amount of energy overall. The frequency of the sound also plays an important role. Experiments show that animals are most susceptible to hearing loss (Box B3) within their most sensitive hearing range. Sounds outside of an animal’s audible frequency range do not cause hearing loss.

The mechanisms responsible for hearing loss may consist of a variety of mechanical and biochemical processes in the inner ear, including physical damage or distortion of the tympanic membrane (not including tympanic membrane rupture which is considered auditory injury), physical damage or distortion of the cochlear hair cells, hair cell death, changes in cochlear blood flow, and swelling of cochlear nerve terminals (Henderson et al., 2006; Kujawa & Liberman, 2009). Although the outer hair cells are the most prominent target for fatigue effects, severe noise exposures may also result in inner hair cell death and loss of auditory nerve fibers (Henderson et al., 2006).

The relationship between TTS and PTS is complicated and poorly understood, even in humans and terrestrial mammals, where numerous studies failed to delineate a clear relationship between the two. Relatively small amounts of TTS (e.g., less than 40–50 decibels measured two minutes after exposure) will recover with no apparent permanent effects; however, terrestrial mammal studies revealed that larger amounts of threshold shift can result in permanent neural degeneration, despite the hearing thresholds returning to normal (Kujawa & Liberman, 2009). The amounts of threshold shift induced by Kujawa and Liberman (2009) were described as being “at the limits of reversibility.” It is unknown whether smaller amounts of threshold shift can result in similar neural degeneration, or if effects would translate to other species such as marine animals.

Hearing loss can increase an animal’s physiological stress (Box B8), which feeds into the stress response (Box B7). Hearing loss increase the likelihood or severity of a behavioral response and increase an animal's overall physiological stress level (Box D10). Hearing loss reduces the distance over which animals can communicate and detect other biologically important sounds (Box D3). Hearing loss could

also be inconsequential for an animal if the frequency range affected is not critical for that animal to hear within, or the hearing loss is of such short duration (e.g., a few minutes) that there are no costs to the individual.

Small to moderate amounts of hearing loss may recover over a period of minutes to days, depending on the amount of initial threshold shift. Severe noise-induced hearing loss may not fully recover, resulting in some amount of PTS. An animal whose hearing does not recover quickly and fully could suffer a reduction in lifetime reproductive success. An animal with PTS may be less successful at mating for one or more breeding seasons, thereby decreasing the number of offspring it can produce over its lifetime.

G.1.3 Masking

Masking occurs if the noise from an activity interferes with an animal's ability to detect, understand, or recognize biologically relevant sounds of interest (Box B4). In this context noise refers to unwanted or unimportant sounds that mask an animal's ability to hear sounds of interest. Sounds of interest include those from conspecifics such as offspring, mates, and competitors; echolocation clicks; sounds from predators; natural, abiotic sounds that may aid in navigation; and reverberation, which can give an animal information about its location and orientation within the ocean. The probability of masking increases as the noise and sound of interest increase in similarity and the masking noise increases in level. The frequency, received level, and duty cycle of the noise determines the potential degree of auditory masking. Masking only occurs during the sound exposure.

A behavior decision (either conscious or instinctive) is made by the animal when the animal detects increased background noise, or possibly, when the animal recognizes that biologically relevant sounds are being masked (Box C1). An animal's past experiences can be important in determining the behavioral response when dealing with masking (Box C4). For example, an animal may modify its vocalizations to reduce the effects of masking noise. Other stimuli present in the environment can influence an animal's behavior decision (Box C5) such as the presence of predators, prey, or potential mates.

An animal may exhibit a passive behavioral response when coping with masking (Box C2). It may simply not respond and keep conducting its current natural behavior. An animal may also stop calling until the background noise decreases. These passive responses do not present a direct energetic cost to the animal; however, masking will continue, depending on the acoustic stimuli.

An animal may actively compensate for masking (Box C3). An animal can vocalize more loudly to make its signal heard over the masking noise. An animal may also shift the frequency of its vocalizations away from the frequency of the masking noise. This shift can actually reduce the masking effect for the animal and other animals that are listening in the area.

If masking impairs an animal's ability to hear biologically important sounds (Box D3) it could reduce an animal's ability to communicate with conspecifics or reduce opportunities to detect or attract more distant mates, gain information about their physical environment, or navigate. An animal that modifies its vocalization in response to masking could also incur a cost (Box D4). Modifying vocalizations may cost the animal energy, interfere with the behavioral function of a call, or reduce a signaler's apparent quality as a mating partner. For example, songbirds that shift their calls up an octave to compensate for increased background noise attract fewer or less-desirable mates, and many terrestrial species advertise body size and quality with low-frequency vocalizations (Slabbekoorn & Ripmeester, 2007). Masking may also lead to no measurable costs for an animal. Masking could be of short duration or intermittent such that biologically important sounds that are continuous or repeated are received by the animal between masking noise.

Masking only occurs when the sound source is operating; therefore, direct masking effects stop immediately upon cessation of the sound-producing activity. Masking could have long-term consequences for individuals if the activity was continuous or occurred frequently enough.

G.1.4 Physiological Stress

Marine animals naturally experience physiological stress as part of their normal life histories. The physiological response to a stressor, often termed the stress response, is an adaptive process that helps an animal cope with changing external and internal environmental conditions. Sound-producing activities have the potential to cause additional stress. However, too much of a stress response can be harmful to an animal, resulting in physiological dysfunction.

If a sound is detected (i.e., heard or sensed) by an animal, a stress response can occur (Box B7). The severity of the stress response depends on the received sound level at the animal (Box A2), the details of the sound-producing activity (Box A1), and the animal's life history stage (e.g., juvenile or adult, breeding or feeding season), and past experience with the stimuli (Box B5). An animal's life history stage is an important factor to consider when predicting whether a stress response is likely (Box B5). An animal's life history stage includes its level of physical maturity (i.e., larva, infant, juvenile, sexually mature adult) and the primary activity in which it is engaged such as mating, feeding, or rearing/caring for young. Prior experience with a stressor may be of particular importance because repeated experience with a stressor may dull the stress response via acclimation (St. Aubin & Dierauf, 2001) or increase the response via sensitization. Additionally, if an animal suffers injury or hearing loss, a physiological stress response will occur (Box B8).

The generalized stress response is characterized by a release of hormones (Reeder & Kramer, 2005) and other chemicals (e.g., stress markers) such as reactive oxidative compounds associated with noise-induced hearing loss (Henderson et al., 2006). Stress hormones include norepinephrine and epinephrine (i.e., the catecholamines), which produce elevations in the heart and respiration rate, increase awareness, and increase the availability of glucose and lipid for energy. Other stress hormones are the glucocorticoid steroid hormones cortisol and aldosterone, which are classically used as an indicator of a stress response and to characterize the magnitude of the stress response (Hennessy et al., 1979).

An acute stress response is traditionally considered part of the startle response and is hormonally characterized by the release of the catecholamines. Annoyance type reactions may be characterized by the release of either or both catecholamines and glucocorticoid hormones. Regardless of the physiological changes that make up the stress response, the stress response may contribute to an animal's decision to alter its behavior.

Elevated stress levels may occur whether or not an animal exhibits a behavioral response (Box D10). Even while undergoing a stress response, competing stimuli (e.g., food or mating opportunities) may overcome any behavioral response. Regardless of whether the animal displays a behavioral response, this tolerated stress could incur a cost to the animal. Reactive oxygen compounds produced during normal physiological processes are generally counterbalanced by enzymes and antioxidants; however, excess stress can lead to damage of lipids, proteins, and nucleic acids at the cellular level (Berlett & Stadtman, 1997; Sies, 1997; Touyz, 2004).

Frequent physiological stress responses may accumulate over time increasing an animal's chronic stress level. Each component of the stress response is variable in time, and stress hormones return to baseline levels at different rates. Elevated chronic stress levels are usually a result of a prolonged or repeated

disturbance. Chronic elevations in the stress levels (e.g., cortisol levels) may produce long-term health consequences that can reduce lifetime reproductive success.

G.1.5 Behavioral Reactions

Behavioral responses fall into two major categories: alterations in natural behavior patterns and avoidance. These types of reactions are not mutually exclusive, and many overall reactions may be combinations of behaviors or a sequence of behaviors. Severity of behavioral reactions can vary drastically between minor and brief reorientations of the animal to investigate the sound, to severe reactions such as aggression or prolonged flight. The type and severity of the behavioral response will determine the cost to the animal. The total number of vehicles and platforms involved, the size of the activity area, the distance between the animal and activity, and the duration of the activity are important considerations when predicting the initial behavioral responses.

A physiological stress response (Box B7) such as an annoyance or startle reaction, or cueing or alerting (Box B6) may cause an animal to make a behavior decision (Box C6). Any exposure that produces an injury or hearing loss is also assumed to produce a stress response (Box B7) and increase the severity or likelihood of a behavioral reaction. Both an animal's experience (Box C4) and competing and reinforcing stimuli (Box C5) can affect an animal's behavior decision. The decision can result in three general types of behavioral reactions: no response (Box C9), area avoidance (Box C8), or alteration of a natural behavior (Box C7).

An animal's past experiences can be important in determining what behavior decision it may make when dealing with a stress response (Box C4). Habituation is the process by which an animal learns to ignore or tolerate stimuli over some period and return to a normal behavior pattern, perhaps after being exposed to the stimuli with no negative consequences. Sensitization is when an animal becomes more sensitive to a set of stimuli over time, perhaps as a result of a past, negative experience that could result in a stronger behavioral response.

Other stimuli (Box C5) present in the environment can influence an animal's behavioral response. These stimuli may be conspecifics or predators in the area or the drive to engage in a natural behavior. Other stimuli can also reinforce the behavioral response caused by acoustic stimuli. For example, the awareness of a predator in the area coupled with the sound-producing activity may elicit a stronger reaction than the activity alone would have.

An animal may reorient, become more vigilant, or investigate if it detects a sound-producing activity (Box C7). These behaviors all require the animal to divert attention and resources, therefore slowing or stopping their presumably beneficial natural behavior. This can be a very brief diversion, or an animal may not resume its natural behaviors until after the activity has concluded. An animal may choose to leave or avoid an area where a sound-producing activity is taking place (Box C8). A more severe form of this comes in the form of flight or evasion. Avoidance of an area can help the animal avoid further effects by avoiding or reducing further exposure. An animal may also choose not to respond to a sound-producing activity (Box C9).

An animal that alters its natural behavior in response to stress or an auditory cue may slow or cease its natural behavior and instead expend energy reacting to the sound-producing activity (Box D5). Natural behaviors include feeding, breeding, sheltering, and migrating. The cost of feeding disruptions depends on the energetic requirements of individuals and the potential amount of food missed during the disruption. Alteration in breeding behavior can result in delaying reproduction. The costs of a brief interruption to migrating or sheltering are less clear.

An animal that avoids a sound-producing activity may expend additional energy moving around the area, be displaced to poorer resources, miss potential mates, or have social interactions affected (Box D6). The amount of energy expended depends on the severity of the behavioral response. Missing potential mates can result in delaying reproduction. Groups could be separated during a severe behavioral response such as flight and offspring that depend on their parents may die if they are permanently separated. Splitting up an animal group can result in a reduced group size, which can have secondary effects on individual foraging success and susceptibility to predators.

Some severe behavioral reactions can lead to stranding (Box D7) or secondary injury (Box D8). Animals that take prolonged flight, a severe avoidance reaction, may injure themselves or strand in an environment for which they are not adapted. Some injury is likely to occur to an animal that strands (Box D8). Injury can reduce the animal's ability to secure food and mates, and increase the animal's susceptibility to predation and disease (Box D2). An animal that strands and does not return to a hospitable environment may die (Box D9).

G.1.6 Long-Term Consequences

The potential long-term consequences from behavioral responses are difficult to discern. Animals displaced from their normal habitat due to an avoidance reaction may return over time and resume their natural behaviors. This is likely to depend upon the severity of the reaction and how often the activity is repeated in the area. In areas of repeated and frequent acoustic disturbance, some animals may habituate to the new baseline; conversely, species that are more sensitive may not return, or return but not resume use of the habitat in the same manner. For example, an animal may return to an area to feed but no longer rest in that area. Long-term abandonment or a change in the utilization of an area by enough individuals can change the distribution of the population. Frequent disruptions to natural behavior patterns may not allow an animal to recover between exposures, which increase the probability of causing long-term consequences to individuals.

The magnitude and type of effect and the speed and completeness of recovery (i.e., return to baseline conditions) must be considered in predicting long-term consequences to the individual animal (Box E4). The predicted recovery of the animal (Box E1) is based on the cost to the animal from any reactions, behavioral or physiological. Available resources fluctuate by season, location, and year and can play a major role in an animal's rate of recovery (Box E2). Recovery can occur more quickly if plentiful food resources, many potential mates, or refuge or shelter is available. An animal's health, energy reserves, size, life history stage, and resource gathering strategy affect its speed and completeness of recovery (Box E3). Animals that are in good health and have abundant energy reserves before an effect takes place will likely recover more quickly.

Animals that recover quickly and completely are unlikely to suffer reductions in their health or reproductive success, or experience changes in habitat utilization (Box F2). No population-level effects would be expected if individual animals do not suffer reductions in their lifetime reproductive success or change their habitat utilization (Box G2). Animals that do not recover quickly and fully could suffer reductions in their health and lifetime reproductive success; they could be permanently displaced or change how they use the environment; or they could die (Box F1). These long-term consequences to the individual can lead to consequences for the population (Box G1); although, population dynamics and abundance play a role in determining how many individuals would need to suffer long-term consequences before there was an effect on the population.

Long-term consequences to individuals can translate into consequences for populations dependent upon population abundance, structure, growth rate, and carry capacity. Carrying capacity describes the theoretical maximum number of animals of a particular species that the environment can support. When a population nears its carrying capacity, its growth is naturally limited by available resources and predator pressure. If one, or a few animals, in a population are removed or gather fewer resources, then other animals in the population can take advantage of the freed resources and potentially increase their health and lifetime reproductive success. Abundant populations that are near their carrying capacity (theoretical maximum abundance) that suffer consequences on a few individuals may not be affected overall. Populations that exist well below their carrying capacity may suffer greater consequences from any lasting consequences to even a few individuals. Population-level consequences can include a change in the population dynamics, a decrease in the growth rate, or a change in geographic distribution.

G.2 Conceptual Framework for Assessing Effects from Energy-Producing Activities

G.2.1 Stimuli

G.2.1.1 Magnitude of the Energy Stressor

Regulations do not provide threshold criteria to determine the significance of the potential effects from activities that involve the use of varying electromagnetic frequencies or lasers. Many organisms, primarily marine vertebrates, have been studied to determine their thresholds for detecting electromagnetic fields, as reviewed by Normandeau et al. (2011); however, there are no data on predictable responses to exposure above or below detection thresholds. The types of electromagnetic fields discussed are those from mine neutralization activities (magnetic influence minesweeping). High-energy and low-energy lasers were considered for analysis. Low-energy lasers (e.g., targeting systems, detection systems, laser light detection and ranging) do not pose a risk to organisms (Swope, 2010) and, therefore, will not be discussed further. Radar was also considered for analysis and was determined not to pose a risk to biological resources.

G.2.1.2 Location of the Energy Stressor

Evaluation of potential energy exposure risks considered the spatial overlap of the resource occurrence and electromagnetic field and high-energy laser use. Wherever appropriate, specific geographic areas of potential impact were identified and the relative location of the resource with respect to the source was considered. For example, the greatest potential electromagnetic energy exposure is at the source, where intensity is greatest and the greatest potential for high energy laser exposure is at the ocean's surface, where high-energy laser intensity is greatest. All light energy, including laser light, entering the ocean becomes absorbed and scattered at a rate that is dependent on the frequency of the light. For most laser applications, the energy is rapidly reduced as the light penetrates the ocean.

G.2.1.3 Behavior of the Organism

Evaluation of potential energy exposure risk considered the behavior of the organism, especially where the organism lives and feeds (e.g., surface, water column, seafloor). The analysis for electromagnetic devices considered those species with the ability to perceive or detect electromagnetic signals. The analysis for high-energy lasers and radar particularly considered those species known to occur at or above the surface of the ocean.

G.2.2 Immediate Response and Costs to the Individual

Many different types of organisms (e.g., some invertebrates, fishes, turtles, birds, mammals) are sensitive to electromagnetic fields (Normandeau et al., 2011). An organism that encounters a

disturbance in an electromagnetic field could respond by moving toward the source, moving away from it, or not responding at all. The types of electromagnetic devices used in the Proposed Action simulate the electromagnetic signature of a vessel passing through the water column, so the expected response would be similar to that of vessel movement. However, since there would be no actual strike potential, a physiological response would be unlikely in most cases. Recovery of an individual from encountering electromagnetic fields would be variable, but since the physiological response would likely be minimal, as reviewed by Normandeau et al. (2011), any recovery time would also be minimal.

Very little data are available to analyze potential impacts on organisms from exposure to high energy lasers. For all but the highest-energy lasers, the greatest laser-related concern for marine species is damage to an organism's ability to see.

G.2.3 Long-Term Consequences to the Individual and Population

Long-term consequences are considered in terms of a resource's existing population level, growth and mortality rates, other stressors on the resource from the Proposed Action, cumulative impacts on the resource, and the ability of the population to recover from or adapt to impacts. Impacts of multiple or repeated stressors on individuals are cumulative.

G.3 Conceptual Framework for Assessing Effects from Physical Disturbance or Strike

G.3.1 Stimuli

G.3.1.1 Size and Weight of the Objects

To determine the likelihood of a strike and the potential impacts on an organism or habitat that would result from a physical strike, the size and weight of the striking object relative to the organism or habitat must be considered. For example, most small organisms and early life stages would simply be displaced by the movement generated by a large object moving through, or falling into, the water, whereas a larger organism could potentially be struck by an object since it may not be displaced by the movement of the water. The weight of the object is also a factor that would determine the severity of a strike. A strike by a heavy object would be more severe than a strike by a low-weight object (e.g., a decelerator/parachute, flare end cap, or chaff canister).

G.3.1.2 Location and Speed of the Objects

Evaluation of potential physical disturbance or strike risk considered the spatial overlap of the resource occurrence and potential striking objects. Analysis of impacts from physical disturbance or strike stressors focuses on proposed activities that may cause an organism or habitat to be struck by an object moving through the air (e.g., aircraft), water (e.g., vessels, in-water devices, towed devices), or dropped into the water (e.g., non-explosive practice munitions and seafloor devices). The area of operation, vertical distribution, and density of these items also play central roles in the likelihood of impact. Wherever appropriate, specific geographic areas of potential impact are identified. Analysis of potential physical disturbance or strike risk also considered the speed of vessels as a measure of intensity. Some vessels move slowly, while others are capable of high speeds.

G.3.1.3 Buoyancy of the Objects

Evaluation of potential physical disturbance or strike risk in the ocean considered the buoyancy of targets or expended materials during operation, which will determine whether the object will be encountered at the surface, within the water column, or on the seafloor.

G.3.1.4 Behavior of the Organism

Evaluation of potential physical disturbance or strike risk considered where organisms occur and if they occur in the same geographic area and vertical distribution as those objects that pose strike risks.

G.3.2 Immediate Response and Costs to the Individual

Before being struck, some organisms would sense a pressure wave through the water and respond by remaining in place, moving away from the object, or moving toward it. An organism displaced a small distance by movements from an object falling into the water nearby would likely continue on with no response. However, others could be disturbed and may exhibit a generalized stress response. If the object actually hit the organism, direct injury in addition to stress may result. The function of the stress response in vertebrates is to rapidly raise the blood sugar level to prepare the organism to flee or fight. This generally adaptive physiological response can become a liability if the stressor persists and the organism cannot return to its baseline physiological state.

Most organisms would respond to sudden physical approach or contact by darting quickly away from the stimulus. Other species may respond by freezing in place or seeking refuge. In any case, the individual must stop whatever it was doing and divert its physiological and cognitive attention to responding to the stressor. The energy costs of reacting to a stressor depend on the specific situation, but in all cases the caloric requirements of stress reactions reduce the amount of energy available to the individual for other functions such as predator avoidance, reproduction, growth, and metabolism.

The ability of an organism to return to what it was doing following a physical strike (or near miss resulting in a stress response) is a function of fitness, genetic, and environmental factors. Some organisms are more tolerant of environmental or human-caused stressors than others and become acclimated more easily. Within a species, the rate at which an individual recovers from a physical disturbance or strike may be influenced by its age, sex, reproductive state, and general condition. An organism that has reacted to a sudden disturbance by swimming at burst speed would tire after some time; its blood hormone and sugar levels may not return to normal for 24 hours. During the recovery period, the organism may not be able to attain burst speeds and could be more vulnerable to predators. If the individual were not able to regain a steady state following exposure to a physical stressor, it may suffer depressed immune function and even death.

G.3.3 Long-Term Consequences to the Population

Long-term consequences are considered in terms of a resource's existing population level, growth and mortality rates, other stressors on the resource from the Proposed Action, cumulative impacts on the resource, and the ability of the population to recover from or adapt to impacts. Impacts of multiple or repeated stressors on individuals are cumulative.

G.4 Conceptual Framework for Assessing Effects from Entanglement

G.4.1 Stimuli

G.4.1.1 Physical Properties of the Objects

For an organism to become entangled in military expended materials, the materials must have certain properties, such as the ability to form loops and a high breaking strength. Some items could have a relatively low breaking strength on their own, but that breaking strength could be increased if multiple loops were wrapped around an entangled organism.

G.4.1.2 Physical Features of the Resource

The physical makeup of the organism itself is also considered when evaluating the risk of entanglement. Some species, by their size or physical features, are more susceptible to entanglement than others. For example, more rigid bodies with protruding snouts (e.g., hammerhead shark) or large, rigid fins (e.g., humpback whale) would have an increased risk of entanglement when compared to species with smoother, streamlined bodies such as lamprey or eels.

G.4.1.3 Location of the Objects

Evaluation of potential entanglement risk considered the spatial overlap of the resource occurrence and military expended materials. Distribution and density of expended items play a central role in the likelihood of impact. Wherever appropriate, specific geographic areas of potential impact are identified.

G.4.1.4 Buoyancy of Objects

Evaluation of potential entanglement risk considered the buoyancy of military expended materials to determine whether the object will be encountered within the water column (including the surface) or on the seafloor. Less buoyant materials, such as torpedo guidance wires, sink rapidly to the seafloor. More buoyant materials include less dense items (e.g., decelerators/parachutes) that are weighted and would sink slowly to the seafloor and could be entrained in currents.

G.4.1.5 Behavior of the Organism

Evaluation of potential entanglement risk considered the general behavior of the organism, including where the organism typically occurs (e.g., surface, water column, seafloor). A defense response by some large whales (when encountering rope) is to spin, thereby entangling themselves further in the "object." This makes selecting for non-looping and lower breaking strength in objects such as ropes very important. The analysis particularly considered those species known to become entangled in nonmilitary expended materials (e.g., "marine debris") such as fishing lines, nets, rope, and other derelict fishing gear that often entangle marine organisms.

G.4.2 Immediate Response and Costs to the Individual

The potential impacts of entanglement on a given organism depend on the species and size of the organism. Species that have protruding snouts, fins, or appendages are more likely to become entangled than smooth-bodied organisms. Also, items could get entangled by an organism's mouth, if caught on teeth or baleen, with the rest of the item trailing alongside the organism. Materials similar to fishing gear, which is designed to entangle an organism, would be expected to have a greater entanglement potential than other materials. An entangled organism would likely try to free itself of the entangling object and in the process may become even more entangled, possibly leading to a stress response. The net result of being entangled by an object could be disruption of the normal behavior, injury due to lacerations, and other sublethal or lethal impacts.

G.4.3 Long-Term Consequences to the Individual and Population

Consequences of entanglement could range from an organism successfully freeing itself from the object or remaining entangled indefinitely, possibly resulting in lacerations and other sublethal or lethal impacts. Stress responses or infection from lacerations could lead to latent mortality. The analysis will focus on reasonably foreseeable long-term consequences of the direct impact, particularly those that could impact the fitness of an individual. Changes in an individual's growth, survival, annual

reproductive success, or lifetime reproductive success could have population-level impacts if enough individuals are impacted. This population-level impact would vary among species and taxonomic groups.

G.5 Conceptual Framework for Assessing Effects from Ingestion

G.5.1 Stimuli

G.5.1.1 Size of the Objects

To assess the ingestion risk from military expended materials, this analysis considered the size of the object relative to the animal's ability to swallow it. Some items are too large to be ingested (e.g., non-explosive practice bombs and most targets) and impacts from these items are not discussed further. However, these items may potentially break down into smaller ingestible pieces over time. Items that are of ingestible size when they are introduced into the environment are carried forward for analysis within each resource section where applicable.

G.5.1.2 Location of the Objects

Evaluation of potential ingestion risk considered the spatial overlap of the resource occurrence and military expended materials. The distribution and density of expended items play a central role in the likelihood of impact. Wherever appropriate, specific geographic areas of potential impact were identified.

G.5.1.3 Buoyancy of the Objects

Evaluation of potential ingestion risk considered the buoyancy of military expended materials to determine whether the object will be encountered within the water column (including the surface) or on the seafloor. Less buoyant materials, such as solid metal materials (e.g., projectiles or munitions fragments), sink rapidly to the seafloor. More buoyant materials include less dense items (e.g., target fragments and decelerators/parachutes) that may be caught in currents and gyres or entangled in floating kelp. These materials can remain in the water column for an indefinite period of time before sinking. However, decelerators/parachutes are weighted and would generally sink, unless that sinking is suspended, in the scenario described here.

G.5.1.4 Feeding Behavior

Evaluation of potential ingestion risk considered the feeding behavior of the organism, including where (e.g., surface, water column, seafloor) and how (e.g., filter feeding) the organism feeds and what it feeds on. The analysis particularly considered those species known to ingest nonfood items (e.g., plastic or metal items).

G.5.2 Immediate Response and Costs to the Individual

Potential impacts of ingesting foreign objects on a given organism depend on the species and size of the organism. Species that normally eat spiny hard-bodied invertebrates would be expected to have tougher mouths and guts than those that normally feed on softer prey. Materials similar in size and shape to the normal diet of an organism may be more likely to be ingested without causing harm to the animal; however, some general assumptions were made. Relatively small objects with smooth edges, such as shells or small-caliber projectiles, might pass through the digestive tract without causing harm. A small sharp-edged item may cause the individual immediate physical distress by tearing or cutting the mouth, throat, or stomach. If the object is rigid and large (relative to the individual's mouth and throat), it may block the throat or obstruct digestive processes. An object may even be enclosed by a cyst in the gut

lining. The net result of ingesting large foreign objects is disruption of the normal feeding behavior, which could be sublethal or lethal.

G.5.3 Long-Term Consequences to the Individual and Population

The consequences of ingesting nonfood items could be nutrient deficiency, bioaccumulation, uptake of toxic chemicals, compaction, and mortality. The analysis focused on reasonably foreseeable long-term consequences of the direct impact, particularly those that could impact the fitness of an individual. Changes in an individual's growth, survival, annual reproductive success, or lifetime reproductive success could have population-level impacts if enough individuals were impacted. This population-level impact would vary among species and taxonomic groups.

G.6 Conceptual Framework for Assessing Effects from Secondary Stressors

This conceptual framework describes the potential effects to marine species exposed to stressors indirectly through impacts on habitat and prey availability (e.g., sediment or water quality, and physical disturbance). Stressors from United States Department of the Navy training and testing activities could pose indirect impacts on marine biological resources via indirect effects to habitat or to prey. These include indirect impacts from (1) explosives, explosives byproducts and unexploded munitions, (2) metals, (3) chemicals, and (4) transmission of disease and parasites. The methods used to determine secondary stressors on marine resources are presented below. Once a category of primary stressor has been analyzed to determine how a marine biological resource is impacted, an analysis follows of how a secondary stressor is potentially impacting a marine resource. After the secondary stressors are identified, a determination on the significance of the secondary impact is made. The same criteria to determine the level of significance for primary impacts are used for secondary stressors. In addition, it is possible for a significant primary impact to produce a beneficial indirect impact. For example, sinking exercises could generate a significant impact on the seafloor and surrounding habitats, while causing a potential beneficial secondary impact by creating hard-bottom habitat for invertebrates, producing a food source for fishes, and creating structural refuges for other biological resources.

G.6.1 Secondary Stressors

G.6.1.1 Impacts on Habitat

Primary impacts defined in each marine resource section were used to develop a conceptual model to predict the potential secondary stressors on each habitat or resource. This conceptual model incorporated factors such as the co-occurrence of stressors in space and time, the impacts or assessment endpoints of individual stressors (e.g., habitat alteration, changes in animal behavior or physiology, injury, mortality, or changes in human use), and the duration and intensity of the impacts of individual stressors. For example, a secondary stressor from a munitions strike could be habitat degradation. The primary impact or stressor is the actual strike on the habitat such as the seafloor, with the introduction of military expended materials, munitions, and fragments inducing further habitat degradation.

Secondary stressors can also induce additive impacts on habitats. These types of impacts are also determined by summing the individual stressors with identical and quantifiable assessment endpoints. For example, if one stressor disturbed 0.25 square nautical miles (NM²) of benthic habitat, a second stressor disturbed 0.5 NM², and all other stressors did not disturb benthic habitat, then the total benthic habitat disturbed would be 0.75 NM². For stressors with identical but not quantifiable assessment endpoints, potential additive impacts were qualitatively evaluated using available scientific knowledge

and best professional judgment. Other habitat impacts such as underwater detonations were assessed by size of charge (net explosive weight), charge radius, height above the seafloor, substrate types in the area, and equations linking all these factors. The analysis also considered that impacts of underwater explosions vary with the bottom substrate type and that the secondary impacts would also be variable among substrate types.

G.6.1.2 Impacts on Prey Availability

Assessing the impacts of secondary stressors on prey availability falls into two main areas over different temporal scales: the cost to an individual over a relatively short amount of time (short-term) and the cost to an individual or population over a longer period of time (long-term).

G.6.2 Immediate Response and Costs to the Individual

After a primary impact was identified, an analysis of secondary stressors on that resource was initiated. This analysis examined whether indirect impacts would occur after the initial (primary) impact and at what temporal scale that secondary stressor would affect the resource (short-term or long-term). An assessment was then made as to whether the secondary stressor would impact an individual or a population. For example, an underwater explosion could impact a single resource such as a fish or multiple other species in the food web (e.g., prey species such as plankton). The analysis also took into consideration whether the primary impact affected more than an individual or single species. For example, a prey species that would be directly injured or killed by an explosive blast could draw in predators or scavengers from the surrounding waters that would feed on those organisms, and in turn could be more directly susceptible to being injured or killed by subsequent explosions. For purposes of this analysis, indirect impacts on a resource did not require trophic transfer (e.g., bioaccumulation) in order to be observed. It is important to note that the terms “indirect” and “secondary” describe how the impact may occur in an organism or its ecosystem and does not imply reduced severity of environmental consequences.

G.6.3 Long-Term Consequences to the Individual and Population

Long-term consequences of secondary stressors on an individual or population are often difficult to determine. Once a primary impact is identified, the severity of that impact helps to determine the temporal scale at which the secondary stressor can be measured. For most marine resources, the abundance of prey species near a detonation point would be diminished for a short period (weeks to months) before being repopulated by animals from adjacent waters. In some extreme cases, recovery of the habitat or prey resources could occur over a relatively long time frame (months to years). It is important to note that indirect impacts often differ among resources, spatial, and temporal scales.

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