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DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

RIN 0648-XA950

Takes of Marine Mammals Incidental to Specified Activities; Navy Research, Development, Test and Evaluation Activities at the Naval Surface Warfare Center Panama City Division

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice of issuance of an incidental harassment authorization.

SUMMARY: In accordance with provisions of the Marine Mammal Protection Act (MMPA) as amended, notification is hereby given that an Incidental Harassment Authorization (IHA) has been issued to the U.S. Navy (Navy) to take marine mammals, by harassment, incidental to conducting research, development, test and evaluation (RDT&E) activities at the Naval Surface Warfare Center Panama City Division (NSWC PCD).

DATES: This authorization is effective from July 27, 2012, until July 26, 2013.

ADDRESSES: A copy of the application, IHA, and/or a list of references used in this document may be obtained by writing to P. Michael Payne, Chief, Permits and Conservation Division, Office of Protected Resources, National Marine Fisheries Service, 1315 East-West Highway, Silver Spring, MD 20910-3225.

FOR FURTHER INFORMATION CONTACT: Shane Guan, NMFS, (301) 427-8401.

SUPPLEMENTARY INFORMATION:

Background

Sections 101(a)(5)(A) and (D) of the MMPA (16 U.S.C. 1361 et seq.) direct the Secretary of Commerce (Secretary) to allow, upon request, the incidental, but not intentional taking of small numbers of marine mammals by U.S. citizens who engage in a specified activity (other than commercial fishing) if certain findings are made and regulations are issued or, if the taking is limited to harassment, notice of a proposed authorization is provided to the public for review.

Authorization for incidental takings shall be granted if NMFS finds that the taking will have a negligible impact on the species or stock(s), will not have an unmitigable adverse impact on the availability of the species or stock(s) for subsistence uses (where relevant), and if the permissible methods of taking and requirements pertaining to the mitigation, monitoring and reporting of such taking are set forth. NMFS has defined "negligible impact" in 50 CFR 216.103 as: "…an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival."

The National Defense Authorization Act of 2004 (NDAA) (Public Law 108-136) removed the "small numbers" and "specified geographical region" limitations and amended the definition of "harassment" as it applies to a "military readiness activity" to read as follows (Section 3(18)(B) of the MMPA):

(i) any act that injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild [Level A Harassment]; or

(ii) any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering, to a point where such behavioral patterns are abandoned or significantly altered [Level B Harassment].

Section 101(a)(5)(D) of the MMPA established an expedited process by which citizens of the United States can apply for an authorization to incidentally take small numbers of marine mammals by harassment. Section 101(a)(5)(D) establishes a 45-day time limit for NMFS review of an application followed by a 30-day public notice and comment period on any proposed authorizations for the incidental harassment of marine mammals. Within 45 days of the close of the comment period, NMFS must either issue or deny the authorization.

Summary of Request

NMFS received an application on December 28, 2011, from the Navy for the taking, by harassment, of marine mammals incidental to conducting testing of the AN/AQS-20A Mine Reconnaissance Sonar System (hereafter referred to as the Q-20) in the Naval Surface Warfare Center, Panama City Division (NSWC PCD) testing range in the Gulf of Mexico (GOM) from April 2012 through April 2013. The Q-20 sonar test activities are proposed to be conducted in the non-territorial waters of the United States (beyond 12 nautical miles) in the Gulf of Mexico (GOM, see Figure 2-1 of the Navy IHA application).

Description of the Specific Activity

The purpose of the Navy’s activities is to meet the developmental testing requirements of the Q-20 system by verifying its performance in a realistic ocean and threat environment and supporting its integration with the Remote Multi-Mission Vehicle (RMMV) and ultimately the Littoral Combat Ship (LCS). Testing would include component, subsystem-level, and full-scale system testing in an operational environment.

The need for the proposed activities is to support the timely deployment of the Q-20 to the operational Navy for Mine Countermeasure (MCM) activities abroad, allowing the Navy to meet its statutory mission to deploy naval forces equipped and trained to meet existing and emergent threats worldwide and to enhance its ability to operate jointly with other components of the armed forces.

The proposed activities are to test the Q-20 from the RMMV and from surrogate platforms such as a small surface vessel or helicopter. The RMMV or surrogate platforms will be deployed from the Navy's new LCS or its surrogates. The Navy is evaluating potential environmental effects associated with the Q-20 test activities proposed for the Q-20 Study Area (see below for detailed description of the Study Area), which includes non-territorial waters of Military Warning Area 151 (W-151; includes Panama City Operating Area). Q-20 test activities occur at sea in the waters present within the Q-20 Study Area. No hazardous waste is generated at sea during Q-20 test activities.

A detailed description of the NSWC PCD's Q-20 test activities is provided in the Federal Register for the proposed IHA (77 FR 12010; February 28, 2012), and there was no change in the proposed action from the proposed IHA. Therefore, it is not repeated here.

Comments and Responses

A notice of receipt and request for public comment on the application and proposed authorization was published on February 28, 2012 (77 FR 12010). During the 30-day public comment period, the Marine Mammal Commission (Commission) and a private citizen provided comments.

<u>Comment 1:</u> The Commission recommends that NMFS issue the IHA, but condition it to require the Navy to conduct its monitoring for at least 15 minutes prior to the initiation of and for at least 15 minutes after the cessation of Q-20 testing activities.

<u>Response:</u> NMFS agrees with the Commission's recommendations and worked with the Navy to incorporate the said condition to require the Navy to conduct its monitoring for at

least 15 minutes prior to the initiation of and for at least 15 minutes after the cessation of Q-20 testing activities.

Comment 2: One private citizen wrote against NMFS issuing the IHA to the Navy due to concerns about "severe injuries and killings to thousands of marine mammals."

Response: NMFS does not agree with the commenter. As discussed in detail in the Federal Register notice for the proposed IHA (77 FR 12010; February 28, 2012) and in sections below, the Navy's Q-20 testing activity would only affect a small number of marine mammals by Level B behavioral harassment. No injury or mortality to marine mammals is expected to occur, nor will be authorized.

Description of Marine Mammals in the Area of the Specified Activity

There are 29 marine mammal species under NMFS' jurisdiction that may occur in the Q-20 Study Area (Table 1). These include 7 mysticetes (baleen whales) and 22 odontocetes (toothed whales). Table 1 also includes the Federal status of these marine mammal species. Six of these marine mammal species under NMFS' jurisdiction are also listed as federally endangered under the Endangered Species Act (ESA) and could potentially occur in the Study Area: the humpback whale, North Atlantic right whale, sei whale, fin whale, blue whale, and sperm whale. Of these 29 species with occurrence records in the Q-20 Study Area, 22 species regularly occur there. These 22 species are: Bryde's whale, sperm whale, pygmy sperm whale, dwarf sperm whale, Cuvier's beaked whale, Gervais' beaked whale, Sowerby's beaked whale, Blainville's beaked whale, killer whale, false killer whale, pygmy killer whale, short-finned pilot whale, Risso's dolphin, melon-headed whale, rough-toothed dolphin, bottlenose dolphin, Atlantic spotted dolphin, pantropical spotted dolphin, striped dolphin, spinner dolphin, Clymene dolphin, and Fraser's dolphin. The remaining 7 species (i.e., North Atlantic right whale, humpback whale, sei whale, fin whale, blue whale, minke whale, and True's beaked whale) are extralimital and are excluded from further consideration of impacts from the NSWC PCD Q-20 testing analysis.

Table 1. Marine Mammal Species Potentially Found in the Q-20 Study Area

Family and Scientific Name	Common Name	Federal Status
Order Cetacea		
Suborder Mysticeti (baleen whales)		
Eubalaena glacialis	North Atlantic right whale	Endangered
Megaptera novaeangliae	Humpback whale	Endangered
Balaenoptera acutorostrata	Minke whale	
B. brydei	Bryde's whale	
B. borealis	Sei whale	Endangered
B. physalus	Fin whale	Endangered
B. musculus	Blue whale	Endangered
Suborder Odontoceti (toothed whales)		
Physeter macrocephalus	Sperm whale	Endangered
Kogia breviceps	Pygmy sperm whale	
K. sima	Dwarf sperm whale	
Ziphius cavirostris	Cuvier's beaked whale	
Mesoplodon europaeus	Gervais' beaked whale	
M. Mirus	True's beaked whale	
M. bidens	Sowerby's beaked whale	
M. densirostris	Blainville's beaked whale	
Steno bredanensis	Rough-toothed dolphin	
Tursiops truncatus	Bottlenose dolphin	
Stenella attenuata	Pantropical spotted dolphin	
S. frontalis	Atlantic spotted dolphin	
S. longirostris	Spinner dolphin	
S. clymene	Clymene dolphin	

S. coeruleoalba	Striped dolphin	
Lagenodephis hosei	Fraser's dolphin	
Grampus griseus	Risso's dolphin	
Peponocephala electra	Melon-headed whale	
Feresa attenuata	Pygmy killer whale	
Pseudorca crassidens	False killer whale	
Orcinus orca	Killer whale	
Globicephala macrorhynchus	Short-finned pilot whale	

The Navy's IHA application contains information on the status, distribution, seasonal distribution, and abundance of each of the species under NMFS jurisdiction mentioned in this document. Please refer to the application for that information (see ADDRESSES). Additional information can also be found in the NMFS Stock Assessment Reports (SAR). The Atlantic 2011 SAR is available at: http://www.nmfs.noaa.gov/pr/pdfs/sars/ao2011.pdf.

A Brief Background on Sound

An understanding of the basic properties of underwater sound is necessary to comprehend many of the concepts and analyses presented in this document. A summary is included below.

Sound is a wave of pressure variations propagating through a medium (for the sonar considered in this IHA, the medium is marine water). Pressure variations are created by compressing and relaxing the medium. Sound measurements can be expressed in two forms: intensity and pressure. Acoustic intensity is the average rate of energy transmitted through a unit area in a specified direction and is expressed in watts per square meter (W/m^2). Acoustic intensity is rarely measured directly, it is derived from ratios of pressures; the standard reference pressure for underwater sound is 1 μPa; for airborne sound, the standard reference pressure is 20 μPa (Urick, 1983).

Acousticians have adopted a logarithmic scale for sound intensities, which is denoted in decibels (dB). Decibel measurements represent the ratio between a measured pressure value and a reference pressure value (in this case 1 μPa or, for airborne sound, 20 μPa). The logarithmic nature of the scale means that each 10 dB increase is a tenfold increase in power (e.g., 20 dB is a 100-fold increase, 30 dB is a 1,000-fold increase). Humans perceive a 10-dB increase in noise as a doubling of sound level, or a 10 dB decrease in noise as a halving of sound level. The term "sound pressure level" implies a decibel measure and a reference pressure that is used as the denominator of the ratio. Throughout this document, NMFS uses 1 μPa as a standard reference pressure unless noted otherwise.

It is important to note that decibels underwater and decibels in air are not the same and cannot be directly compared. To estimate a comparison between sound in air and underwater, because of the different densities of air and water and the different decibel standards (i.e., reference pressures) in water and air, a sound with the same intensity (i.e., power) in air and in water would be approximately 63 dB lower in air. Thus, a sound that is 160 dB loud underwater would have the same approximate effective intensity as a sound that is 97 dB loud in air.

Sound frequency is measured in cycles per second, or Hertz (abbreviated Hz), and is analogous to musical pitch; high-pitched sounds contain high frequencies and low-pitched sounds contain low frequencies. Natural sounds in the ocean span a huge range of frequencies: from earthquake noise at 5 Hz to harbor porpoise clicks at 150,000 Hz (150 kHz). These sounds are so low or so high in pitch that humans cannot even hear them; acousticians call these infrasonic and ultrasonic sounds, respectively. A single sound may be made up of many different frequencies together. Sounds made up of only a small range of frequencies are called "narrowband," and sounds with a broad range of frequencies are called "broadband;" airguns are an example of a broadband sound source and tactical sonars are an example of a narrowband sound source.

When considering the influence of various kinds of sound on the marine environment, it is necessary to understand that different kinds of marine life are sensitive to different frequencies of sound. Based on available behavioral data, audiograms derived using auditory evoked potential, anatomical modeling, and other data, Southall et al. (2007) designate "functional hearing groups" and estimate the lower and upper frequencies of functional hearing of the groups. Further, the frequency range in which each group's hearing is estimated as being most sensitive is represented in the flat part of the M-weighting functions developed for each group. The functional groups and the associated frequencies are indicated below:

- Low-frequency cetaceans (13 species of mysticetes): Functional hearing is estimated to occur between approximately 7 Hz and 22 kHz.
- Mid-frequency cetaceans (32 species of dolphins, six species of larger toothed whales, and 19 species of beaked and bottlenose whales): Functional hearing is estimated to occur between approximately 150 Hz and 160 kHz.
- High-frequency cetaceans (eight species of true porpoises, six species of river dolphins, Kogia, the franciscana, and four species of cephalorhynchids): Functional hearing is estimated to occur between approximately 200 Hz and 180 kHz.
- Pinnipeds in Water: Functional hearing is estimated to occur between approximately 75 Hz and 75 kHz, with the greatest sensitivity between approximately 700 Hz and 20 kHz.
- Pinnipeds in Air: Functional hearing is estimated to occur between approximately 75 Hz and 30 kHz.

Because ears adapted to function underwater are physiologically different from human ears, comparisons using decibel measurements in air would still not be adequate to describe the effects of a sound on a whale. When sound travels away from its source, its loudness decreases as the distance traveled (propagates) by the sound increases. Thus, the loudness of a sound at its source is higher than the loudness of that same sound a kilometer distant. Acousticians often refer to the loudness of a sound at its source (typically measured one meter from the source) as the source level and the loudness of sound elsewhere as the received level. For example, a humpback whale three kilometers from an airgun that has a source level of 230 dB may only be exposed to sound that is 160 dB loud, depending on how the sound propagates. As a result, it is important not to confuse source levels and received levels when discussing the loudness of sound in the ocean.

As sound travels from a source, its propagation in water is influenced by various physical characteristics, including water temperature, depth, salinity, and surface and bottom properties that cause refraction, reflection, absorption, and scattering of sound waves. Oceans are not homogeneous and the contribution of each of these individual factors is extremely complex and interrelated. The physical characteristics that determine the sound's speed through the water will change with depth, season, geographic location, and with time of day (as a result, in actual sonar operations, crews will measure oceanic conditions, such as sea water temperature and depth, to calibrate models that determine the path the sonar signal will take as it travels through the ocean and how strong the sound signal will be at a given range along a particular transmission path). As sound travels through the ocean, the intensity associated with the wavefront diminishes, or attenuates. This decrease in intensity is referred to as propagation loss, also commonly called transmission loss.

Metrics Used in This Document

This section includes a brief explanation of the two sound measurements (sound pressure level (SPL) and sound exposure level (SEL)) frequently used in the discussions of acoustic effects in this document.

SPL

Sound pressure is the sound force per unit area, and is usually measured in microPa, where 1 Pa is the pressure resulting from a force of one newton exerted over an area of one square meter. SPL is expressed as the ratio of a measured sound pressure and a reference level. The commonly used reference pressure level in underwater acoustics is 1 µPa, and the units for SPLs are dB re: 1 µPa.

SPL (in dB) = 20 log (pressure/reference pressure)

SPL is an instantaneous measurement and can be expressed as the peak, the peak-peak, or the root mean square (rms). Root mean square, which is the square root of the arithmetic average of the squared instantaneous pressure values, is typically used in discussions of the effects of sounds on vertebrates and all references to SPL in this document refer to the root mean square. SPL does not take the duration of a sound into account. SPL is the applicable metric used in the risk continuum, which is used to estimate behavioral harassment takes (see Level B Harassment Risk Function (Behavioral Harassment) Section).

SEL

SEL is an energy metric that integrates the squared instantaneous sound pressure over a stated time interval. The units for SEL are dB re: 1 microPa^2-s.

SEL = SPL + 10 log(duration in seconds)

As applied to tactical sonar, the SEL includes both the SPL of a sonar ping and the total duration. Longer duration pings and/or pings with higher SPLs will have a higher SEL. If an animal is exposed to multiple pings, the SEL in each individual ping is summed to calculate the total SEL. The total SEL depends on the SPL, duration, and number of pings received. The thresholds that NMFS uses to indicate at what received level the onset of temporary threshold shift (TTS) and permanent threshold shift (PTS) in hearing are likely to occur are expressed in SEL.

Potential Impacts to Marine Mammal Species

The Navy considers that the Q-20 sonar testing activities in the Q-20 Study Area could potentially result in harassment to marine mammals. Although surface operations related to sonar testing involve ship movement in the vicinity of the Q-20 test area, NMFS considers it unlikely that ship strike could occur as analyzed in the Federal Register for the proposed IHA (77 FR 12010; February 28, 2012).

Anticipated impacts resulting from the Navy's Q-20 testing activities primary arise from underwater noise due to sonar operations, if marine mammals are in the vicinity of the action area. The following subsection provides a summary of the acoustic effects to marine mammals.

(1) Direct Physiological Effects

Based on the literature, there are two basic ways that Navy sonar might directly result in physical trauma or damage: Noise-induced loss of hearing sensitivity (more commonly-called "threshold shift") and acoustically mediated bubble growth. Separately, an animal's behavioral reaction to an acoustic exposure might lead to physiological effects that might ultimately lead to injury or death, which is discussed later in the Stranding section.

Threshold Shift (Noise-Induced Loss of Hearing)

When animals exhibit reduced hearing sensitivity (i.e., sounds must be louder for an animal to recognize them) following exposure to a sufficiently intense sound, it is referred to as a noise-induced threshold shift (TS). An animal can experience temporary threshold shift (TTS) or permanent threshold shift (PTS). TTS can last from minutes or hours to days (i.e., there is recovery), occurs in specific frequency ranges (e.g., an animal might only have a temporary loss of hearing sensitivity between the frequencies of 1 and 10 kHz)), and can be of varying amounts (for example, an animal's hearing sensitivity might be reduced by only 6 dB or reduced by 30 dB). PTS is permanent (i.e., there is no recovery), but also occurs in a specific frequency range and amount as mentioned in the TTS description.

The following physiological mechanisms are thought to play a role in inducing auditory TSs: Effects on sensory hair cells in the inner ear that reduce their sensitivity, modification of the chemical environment within the sensory cells, residual muscular activity in the middle ear, displacement of certain inner ear membranes, increased blood flow, and post-stimulatory reduction in both efferent and sensory neural output (Southall et al., 2007). The amplitude, duration, frequency, temporal pattern, and energy distribution of sound exposure all affect the amount of associated TS and the frequency range in which it occurs. As amplitude and duration of sound exposure increase, so, generally, does the amount of TS. For continuous sounds, exposures of equal energy (the same SEL) will lead to approximately equal effects. For intermittent sounds, less TS will occur than from a continuous exposure with the same energy (some recovery will occur between exposures) (Kryter et al., 1966; Ward, 1997). For example, one short but loud (higher SPL) sound exposure may induce the same impairment as one longer but softer sound, which in turn may cause more impairment than a series of several intermittent softer sounds with the same total energy (Ward, 1997). Additionally, though TTS is temporary, very prolonged exposure to sound strong enough to elicit TTS, or shorter-term exposure to sound levels well above the TTS threshold, can cause PTS, at least in terrestrial mammals (Kryter, 1985) (although in the case of Navy sonar, animals are not expected to be exposed to levels high enough or durations long enough to result in PTS).

PTS is considered auditory injury (Southall et al., 2007). Irreparable damage to the inner or outer cochlear hair cells may cause PTS, however, other mechanisms are also involved, such as exceeding the elastic limits of certain tissues and membranes in the middle and inner ears and resultant changes in the chemical composition of the inner ear fluids (Southall et al., 2007).

Although the published body of scientific literature contains numerous theoretical studies and discussion papers on hearing impairments that can occur with exposure to a loud sound, only a few studies provide empirical information on the levels at which noise-induced loss in hearing sensitivity occurs in nonhuman animals. For cetaceans, published data are limited to the captive bottlenose dolphin and beluga whale (Finneran et al., 2000, 2002b, 2005a; Schlundt et al., 2000; Nachtigall et al., 2003, 2004).

Marine mammal hearing plays a critical role in communication with conspecifics, and interpreting environmental cues for purposes such as predator avoidance and prey capture. Depending on the frequency range of TTS degree (dB), duration, and frequency range of TTS, and the context in which it is experienced, TTS can have effects on marine mammals ranging from discountable to serious (similar to those discussed in auditory masking, below). For example, a marine mammal may be able to readily compensate for a brief, relatively small amount of TTS in a non-critical frequency range that takes place during a time when the animal is traveling through the open ocean, where ambient noise is lower and there are not as many competing sounds present.

Alternatively, a larger amount and longer duration of TTS sustained during a time when communication is critical for successful mother/calf interactions could have more serious impacts. Also, depending on the degree and frequency range, the effects of PTS on an animal could range in severity, although it is considered generally more serious because it is a long term condition. Of note, reduced hearing sensitivity as a simple function of development and aging has been observed in marine mammals, as well as humans and other taxa (Southall et al., 2007), so we can infer that strategies exist for coping with this condition to some degree, though likely not without cost. There is no empirical evidence that exposure to Navy sonar can cause PTS in any marine mammals; instead the probability of PTS has been inferred from studies of TTS (see Richardson et al., 1995).

Acoustically Mediated Bubble Growth

One theoretical cause of injury to marine mammals is rectified diffusion (Crum and Mao, 1996), the process of increasing the size of a bubble by exposing it to a sound field. This process could be facilitated if the environment in which the ensonified bubbles exist is supersaturated with gas. Repetitive diving by marine mammals can cause the blood and some tissues to accumulate gas to a greater degree than is supported by the surrounding environmental pressure (Ridgway and Howard, 1979). The deeper and longer dives of some marine mammals (for example, beaked whales) are theoretically predicted to induce greater supersaturation (Houser et al., 2001). If rectified diffusion were possible in marine mammals exposed to high-level sound, conditions of tissue supersaturation could theoretically speed the rate and increase the size of bubble growth. Subsequent effects due to tissue trauma and emboli would presumably mirror those observed in humans suffering from decompression sickness.

It is unlikely that the short duration of sonar pings would be long enough to drive bubble growth to any substantial size, if such a phenomenon occurs. Recent work conducted by Crum et al. (2005) demonstrated the possibility of rectified diffusion for short duration signals, but at sound exposure levels and tissue saturation levels that are improbable to occur in a diving marine mammal. However, an alternative but related hypothesis has also been suggested: Stable bubbles could be destabilized by high-level sound exposures such that bubble growth then occurs through static diffusion of gas out of the tissues. In such a scenario the marine mammal would need to be in a gas-supersaturated state for a long enough period of time for bubbles to become of a problematic size. Yet another hypothesis (decompression sickness) has speculated that rapid ascent to the surface following exposure to a startling sound might produce tissue gas saturation sufficient for the evolution of nitrogen bubbles (Jepson et al., 2003; Fernandez et al., 2005). In this scenario, the rate of ascent would need to be sufficiently rapid to compromise behavioral or physiological protections against nitrogen bubble formation. Collectively, these hypotheses can be referred to as "hypotheses of acoustically mediated bubble growth."

Although theoretical predictions suggest the possibility for acoustically mediated bubble growth, there is considerable disagreement among scientists as to its likelihood (Piantadosi and Thalmann, 2004; Evans and Miller, 2003). Crum and Mao (1996) hypothesized that received levels would have to exceed 190 dB in order for there to be the possibility of significant bubble growth due to supersaturation of gases in the blood (i.e., rectified diffusion). More recent work conducted by Crum et al. (2005) demonstrated the possibility of rectified diffusion for short duration signals, but at SELs and tissue saturation levels that are highly improbable to occur in diving marine mammals. To date, Energy Levels (ELs) predicted to cause in vivo bubble formation within diving cetaceans have not been evaluated (NOAA, 2002). Although it has been argued that traumas from some recent beaked whale strandings are consistent with gas emboli and bubble-induced tissue separations (Jepson et al., 2003), there is no conclusive evidence of this (Hooker et al., 2011). However, Jepson et al. (2003, 2005) and Fernandez et al. (2004, 2005) concluded that in vivo bubble formation, which may be exacerbated by deep, long duration, repetitive dives may explain why beaked whales appear to be particularly vulnerable to sonar exposures. A recent review of evidence for gas-bubble incidence in marine mammal tissues suggest that diving mammals vary their physiological responses according to multiple stressors, and that the perspective on marine mammal diving physiology should change from simply minimizing nitrogen loading to management of the nitrogen load (Hooker et al., 2011). This suggests several avenues for further study, ranging from the effects of gas bubbles at molecular, cellular and organ function levels, to comparative studies relating the presence/absence of gas bubbles to diving behavior. More information regarding hypotheses that attempt to explain how behavioral responses to Navy sonar can lead to strandings is included in the Behaviorally Mediated Bubble Growth section, after the summary of strandings.

(2) Acoustic Masking

Marine mammals use acoustic signals for a variety of purposes, which differ among species, but include communication between individuals, navigation, foraging, reproduction, and learning about their environment (Erbe and Farmer, 2000; Tyack, 2000; Clark et al., 2009). Masking, or auditory interference, generally occurs when sounds in the environment are louder than, and of a similar frequency to, auditory signals an animal is trying to receive. Masking is a phenomenon that affects animals that are trying to receive acoustic information about their environment, including sounds from other members of their species, predators, prey, and sounds that allow them to orient in their environment. Masking these acoustic signals can disturb the behavior of individual animals, groups of animals, or entire populations.

The extent of the masking interference depends on the spectral, temporal, and spatial relationships between the signals an animal is trying to receive and the masking noise, in addition to other factors. In humans, significant masking of tonal signals occurs as a result of exposure to noise in a narrow band of similar frequencies. As the sound level increases, though, the detection of frequencies above those of the masking stimulus also decreases. This principle is also expected to apply to marine mammals because of common biomechanical cochlear properties across taxa.

Richardson et al. (1995) argued that the maximum radius of influence of an industrial noise (including broadband low frequency sound transmission) on a marine mammal is the distance from the source to the point at which the noise can barely be heard. This range is determined by either the hearing sensitivity of the animal or the background noise level present. Industrial masking is most likely to affect some species' ability to detect communication calls and natural sounds (i.e., surf noise, prey noise, etc.; Richardson et al., 1995).

The echolocation calls of odontocetes (toothed whales) are subject to masking by high frequency sound. Human data indicate low-frequency sound can mask high-frequency sounds (i.e., upward masking). Studies on captive odontocetes by Au et al. (1974, 1985, 1993) indicate that some species may use various processes to reduce masking effects (e.g., adjustments in echolocation call intensity or frequency as a function of background noise conditions). There is also evidence that the directional hearing abilities of odontocetes are useful in reducing masking at the high frequencies these cetaceans use to echolocate, but not at the low-to-moderate frequencies they use to communicate (Zaitseva et al., 1980).

As mentioned previously, the functional hearing ranges of mysticetes (baleen whales) and odontocetes (toothed whales) all encompass the frequencies of the sonar sources used in the Navy's Q-20 test activities. Additionally, almost all species' vocal repertoires span across the frequencies of the sonar sources used by the Navy. The closer the characteristics of the masking signal to the signal of interest, the more likely masking is to occur. However, because the pulse length and duty cycle of the Navy sonar signals are of short duration and would not be continuous, masking is unlikely to occur as a result of exposure to these signals during the Q-20 test activities in the designated Q-20 Study Area.

In addition to making it more difficult for animals to perceive acoustic cues in their environment, anthropogenic sound presents separate challenges for animals that are vocalizing. When they vocalize, animals are aware of environmental conditions that affect the "active space" of their vocalizations, which is the maximum area within which their vocalizations can be detected before it drops to the level of ambient noise (Brenowitz, 2004; Brumm et al., 2004; Lohr et al., 2003). Animals are also aware of environmental conditions that affect whether listeners can discriminate and recognize their vocalizations from other sounds, which are more important than detecting a vocalization (Brenowitz, 1982; Brumm et al., 2004; Dooling, 2004; Marten and Marler, 1977; Patricelli et al., 2006). Most animals that vocalize have evolved an ability to make vocal adjustments to their vocalizations to increase the signal-to-noise ratio, active space, and recognizability of their vocalizations in the face of temporary changes in background noise (Brumm et al., 2004; Patricelli et al., 2006). Vocalizing animals will make one or more of the following adjustments to their vocalizations: Adjust the frequency structure; adjust the amplitude; adjust temporal structure; or adjust temporal delivery.

Many animals will combine several of these strategies to compensate for high levels of background noise. Anthropogenic sounds that reduce the signal-to-noise ratio of animal vocalizations, increase the masked auditory thresholds of animals listening for such vocalizations, or reduce the active space of an animal's vocalizations impair communication between animals. Most animals that vocalize have evolved strategies to compensate for the effects of short-term or temporary increases in background or ambient noise on their songs or calls. Although the fitness consequences of these vocal adjustments remain unknown, like most other trade-offs animals must make, some of these strategies probably come at a cost (Patricelli et al., 2006). For example, vocalizing more loudly in noisy environments may have energetic costs that decrease the net benefits of vocal adjustment and alter a bird's energy budget (Brumm, 2004; Wood and Yezerinac, 2006). Shifting songs and calls to higher frequencies may also impose energetic costs (Lambrechts, 1996).

(3) Stress Responses

Classic stress responses begin when an animal's central nervous system perceives a potential threat to its homeostasis. That perception triggers stress responses regardless of whether a stimulus actually threatens the animal; the mere perception of a threat is sufficient to trigger a stress response (Moberg, 2000; Sapolsky et al., 2005; Seyle, 1950). Once an animal's central nervous system perceives a threat, it mounts a biological response or defense that consists of a combination of the four general biological defense responses: behavioral responses, autonomic nervous system responses, neuroendocrine responses, or immune response.

In the case of many stressors, an animal's first and most economical (in terms of biotic costs) response is behavioral avoidance of the potential stressor or avoidance of continued exposure to a stressor. An animal's second line of defense to stressors involves the autonomic nervous system and the classical "fight or flight" response, which includes the cardiovascular system, the gastrointestinal system, the exocrine glands, and the adrenal medulla to produce changes in heart rate, blood pressure, and gastrointestinal activity that humans commonly associate with "stress." These responses have a relatively short duration and may or may not have significant long-term effects on an animal's welfare.

An animal's third line of defense to stressors involves its neuroendocrine or sympathetic nervous systems; the system that has received the most study has been the hypothalmus-pituitary-adrenal system (also known as the HPA axis in mammals or the hypothalamus-pituitary-interrenal axis in fish and some reptiles). Unlike stress responses associated with the autonomic nervous system, virtually all neuro-endocrine functions that are affected by stress—including immune competence, reproduction, metabolism, and behavior—are regulated by pituitary hormones. Stress-induced changes in the secretion of pituitary hormones have been implicated in failed reproduction (Moberg, 1987; Rivier, 1995) and altered metabolism (Elasser et al., 2000), reduced immune competence (Blecha, 2000) and behavioral disturbance. Increases in the circulation of glucocorticosteroids (cortisol, corticosterone, and aldosterone in marine mammals; Romano et al., 2004) have been equated with stress for many years.

The primary distinction between stress (which is adaptive and does not normally place an animal at risk) and distress is the biotic cost of the response. During a stress response, an animal uses glycogen stores that can be quickly replenished once the stress is alleviated. In such circumstances, the cost of the stress response would not pose a risk to the animal's welfare. However, when an animal does not have sufficient energy reserves to satisfy the energetic costs of a stress response, energy resources must be diverted from other biotic functions, which impair those functions that experience the diversion. For example, when mounting a stress response diverts energy away from growth in young animals, those animals may experience stunted growth. When mounting a stress response diverts energy from a fetus, an animal's reproductive success and its fitness will suffer. In these cases, the animals will have entered a pre-pathological or pathological state which is called ‘‘distress’’ (sensu Seyle, 1950) or “allostatic loading” (sensu McEwen and Wingfield, 2003). This pathological state will last until the animal replenishes its biotic reserves sufficient to restore normal function.

Relationships between these physiological mechanisms, animal behavior, and the costs of stress responses have also been documented fairly well through controlled experiments; because this physiology exists in every vertebrate that has been studied, it is not surprising that stress responses and their costs have been documented in both laboratory and free-living animals (for examples see, Holberton et al., 1996; Hood et al., 1998; Jessop et al., 2003; Krausman et al., 2004; Lankford et al., 2005; Reneerkens et al., 2002; Thompson and Hamer, 2000). Although no information has been collected on the physiological responses of marine mammals to exposure to anthropogenic sounds, studies of other marine animals and terrestrial animals would lead us to expect some marine mammals to experience physiological stress responses and, perhaps, physiological responses that would be classified as “distress” upon exposure to mid-frequency and low-frequency sounds.

For example, Jansen (1998) reported on the relationship between acoustic exposures and physiological responses that are indicative of stress responses in humans (for example, elevated respiration and increased heart rates). Jones (1998) reported on reductions in human performance when faced with acute, repetitive exposures to acoustic disturbance. Trimper et al. (1998) reported on the physiological stress responses of osprey to low-level aircraft noise while Krausman et al. (2004) reported on the auditory and physiology stress responses of endangered

Sonoran pronghorn to military overflights. Smith et al. (2004a, 2004b) identified noise induced physiological transient stress responses in hearing-specialist fish that accompanied short- and long-term hearing losses. Welch and Welch (1970) reported physiological and behavioral stress responses that accompanied damage to the inner ears of fish and several mammals.

Hearing is one of the primary senses cetaceans use to gather information about their environment and to communicate with conspecifics. Although empirical information on the relationship between sensory impairment (TTS, PTS, and acoustic masking) on cetaceans remains limited, it seems reasonable to assume that reducing an animal's ability to gather information about its environment and to communicate with other members of its species would be stressful for animals that use hearing as their primary sensory mechanism. Therefore, we assume that acoustic exposures sufficient to trigger onset PTS or TTS would be accompanied by physiological stress responses because terrestrial animals exhibit those responses under similar conditions (NRC, 2003). More importantly, marine mammals might experience stress responses at received levels lower than those necessary to trigger onset TTS. Based on empirical studies of the time required to recover from stress responses (Moberg, 2000), we also assume that stress responses are likely to persist beyond the time interval required for animals to recover from TTS and might result in pathological and pre-pathological states that would be as significant as behavioral responses to TTS.

(4) Behavioral Disturbance

Behavioral responses to sound are highly variable and context-specific. Exposure of marine mammals to sound sources can result in (but is not limited to) the following observable responses: Increased alertness; orientation or attraction to a sound source; vocal modifications; cessation of feeding; cessation of social interaction; alteration of movement or diving behavior;

habitat abandonment (temporary or permanent); and, in severe cases, panic, flight, stampede, or stranding, potentially resulting in death (Southall et al., 2007).

Many different variables can influence an animal's perception of and response to (nature and magnitude) an acoustic event. An animal's prior experience with a sound type affects whether it is less likely (habituation) or more likely (sensitization) to respond to certain sounds in the future (animals can also be innately pre-disposed to respond to certain sounds in certain ways) (Southall et al., 2007). Related to the sound itself, the perceived nearness of the sound, bearing of the sound (approaching vs. retreating), similarity of a sound to biologically relevant sounds in the animal's environment (i.e., calls of predators, prey, or conspecifics), and familiarity of the sound may affect the way an animal responds to the sound (Southall et al., 2007). Individuals (of different age, gender, reproductive status, etc.) among most populations will have variable hearing capabilities, and differing behavioral sensitivities to sounds that will be affected by prior conditioning, experience, and current activities of those individuals. Often, specific acoustic features of the sound and contextual variables (i.e., proximity, duration, or recurrence of the sound or the current behavior that the marine mammal is engaged in or its prior experience), as well as entirely separate factors such as the physical presence of a nearby vessel, may be more relevant to the animal's response than the received level alone.

There are only few empirical studies of behavioral responses of free-living cetaceans to military sonar being conducted to date, due to the difficulties in implementing experimental protocols on wild marine mammals.

An opportunistic observation was made on a tagged Blainville's beaked whale (Mesoplodon densirostris) before, during, and after a multi-day naval exercises involving tactical mid-frequency sonars within the U.S. Navy's sonar testing range at the Atlantic Undersea Test and Evaluation Center (AUTEC), in the Tongue of the Ocean near Andros Island in the Bahamas (Tyack et al., 2011). The adult male whale was tagged with a satellite transmitter tag on May 7, 2009. During the 72 hrs before the sonar exercise started, the mean distance from whale to the center of the AUTEC range was approximately 37 km. During the 72 hrs sonar exercise, the whale moved several tens of km farther away (mean distance approximately 54 km). The received sound levels at the tagged whale during sonar exposure were estimated to be 146 dB re 1 μPa at the highest level. The tagged whale slowly returned for several days after the exercise stopped (mean distance approximately 29 km) from 0 – 72 hours after the exercise stopped (Tyack et al., 2011).

In the past several years, controlled exposure experiments (CEE) on marine mammal behavioral responses to military sonar signals using acoustic tags have been started in the Bahamas, the Mediterranean Sea, southern California, and Norway. These behavioral response studies (BRS), though still in their early stages, have provided some preliminary insights into cetacean behavioral disturbances when exposed to simulated and actual military sonar signals.

In 2007 and 2008, two Blainville's beaked whales were tagged in the AUTEC range and exposed to simulated mid-frequency sonar signals, killer whale (Orcinus orca) recordings (in 2007), and pseudo-random noise (PRN, in 2008) (Tyack et al., 2011). For the simulated mid-frequency exposure BRS, the tagged whale stopped clicking during its foraging dive after 9 minutes when the received level reached 138 dB SPL, or a cumulative SEL value of 142 dB re 1 μPa^2-s. Once the whale stopped clicking, it ascended slowly, moving away from the sound source. The whale surfaced and remained in the area for approximately 2 hours before making another foraging dive (Tyack et al., 2011).

The same beaked whale was exposed to a killer whale sound recording during its subsequent deep foraging dive. The whale stopped clicking about 1 minute after the received level of the killer whale sound reached 98 dB SPL, just above the ambient noise level at the whale. The whale then made a long and slow ascent. After surfacing, the whale continued to swim away from the playback location for 10 hours (Tyack et al., 2011).

In 2008, a Blainville's beaked was tagged and exposed with PRN that has the same frequency band as the simulated mid-frequency sonar signal. The received level at the whale ranged from inaudible to 142 dB SPL (144 dB cumulative SEL). The whale stopped clicking less than 2 minutes after exposure to the last transmission and ascended slowly to approximately 600 m. The whale appeared to stop at this depth, at which time the tag unexpectedly released from the whale (Tyack et al., 2011).

During CEEs of the BRS off Norway, social behavioral responses of pilot whales and killer whales to tagging and sonar exposure were investigated. Sonar exposure was sampled for 3 pilot whale (Globicephala spp.) groups and 1 group of killer whales. Results show that when exposed to sonar signals, pilot whales showed a preference for larger groups with medium-low surfacing synchrony, while starting logging, spyhopping and milling. Killer whales showed the opposite pattern, maintaining asynchronous patterns of surface behavior: decreased surfacing synchrony, increased spacing, decreased group size, tailslaps and loggings (Visser et al., 2011).

Although the small sample size of these CEEs reported here is too small to make firm conclusions about differential responses of cetaceans to military sonar exposure, none of the results showed that whales responded to sonar signals with panicked flight. Instead, the beaked whales exposed to simulated sonar signals and killer whale sound recording moved in a well oriented direction away from the source towards the deep water exit from the Tongue of the

Ocean (Tyack et al., 2011). In addition, different species of cetaceans exhibited different social behavioral responses towards (close) vessel presence and sonar signals, which elicit different, potentially tailored and species-specific responses (Visser et al., 2011).

Much more qualitative information is available on the avoidance responses of free-living cetaceans to other acoustic sources, like seismic airguns and low-frequency active sonar, than mid-frequency active sonar. Richardson et al., (1995) noted that avoidance reactions are the most obvious manifestations of disturbance in marine mammals.

Behavioral Responses

Southall et al., (2007) reports the results of the efforts of a panel of experts in acoustic research from behavioral, physiological, and physical disciplines that convened and reviewed the available literature on marine mammal hearing and physiological and behavioral responses to man-made sound with the goal of proposing exposure criteria for certain effects. This compilation of literature is very valuable, though Southall et al. note that not all data is equal, some have poor statistical power, insufficient controls, and/or limited information on received levels, background noise, and other potentially important contextual variables—such data were reviewed and sometimes used for qualitative illustration, but were not included in the quantitative analysis for the criteria recommendations.

In the Southall et al., (2007) report, for the purposes of analyzing responses of marine mammals to anthropogenic sound and developing criteria, the authors differentiate between single pulse sounds, multiple pulse sounds, and non-pulse sounds. HFAS/MFAS sonar is considered a non-pulse sound. Southall et al., (2007) summarize the reports associated with low-, mid-, and high-frequency cetacean responses to non-pulse sounds (there are no pinnipeds in the

Gulf of Mexico (GOM)) in Appendix C of their report (incorporated by reference and summarized in the three paragraphs below).

The reports that address responses of low-frequency cetaceans to non-pulse sounds include data gathered in the field and related to several types of sound sources (of varying similarity to HFAS/MFAS) including: Vessel noise, drilling and machinery playback, low frequency M-sequences (sine wave with multiple phase reversals) playback, low frequency active sonar playback, drill vessels, Acoustic Thermometry of Ocean Climate (ATOC) source, and non-pulse playbacks. These reports generally indicate no (or very limited) responses to received levels in the 90 to 120 dB re 1 μPa range and an increasing likelihood of avoidance and other behavioral effects in the 120 to 160 dB range. As mentioned earlier, however, contextual variables play a very important role in the reported responses and the severity of effects are not linear when compared to received level. Also, few of the laboratory or field datasets had common conditions, behavioral contexts or sound sources, so it is not surprising that responses differ.

The reports that address responses of mid-frequency cetaceans to non-pulse sounds include data gathered both in the field and the laboratory and related to several different sound sources (of varying similarity to HFAS/MFAS) including: Pingers, drilling playbacks, vessel and ice-breaking noise, vessel noise, Acoustic Harassment Devices (AHDs), Acoustic Deterrent Devices (ADDs), HFAS/MFAS, and non-pulse bands and tones. Southall et al. were unable to come to a clear conclusion regarding these reports. In some cases, animals in the field showed significant responses to received levels between 90 and 120 dB, while in other cases these responses were not seen in the 120 to 150 dB range. The disparity in results was likely due to contextual variation and the differences between the results in the field and laboratory data (animals responded at lower levels in the field).

The reports that address the responses of high-frequency cetaceans to non-pulse sounds include data gathered both in the field and the laboratory and related to several different sound sources (of varying similarity to HFAS/MFAS) including: acoustic harassment devices, Acoustical Telemetry of Ocean Climate (ATOC), wind turbine, vessel noise, and construction noise. However, no conclusive results are available from these reports. In some cases, high frequency cetaceans (harbor porpoises) are observed to be quite sensitive to a wide range of human sounds at very low exposure RLs (90 to 120 dB). All recorded exposures exceeding 140 dB produced profound and sustained avoidance behavior in wild harbor porpoises (Southall et al., 2007).

In addition to summarizing the available data, the authors of Southall et al. (2007) developed a severity scaling system with the intent of ultimately being able to assign some level of biological significance to a response. Following is a summary of their scoring system, a comprehensive list of the behaviors associated with each score may be found in the report:

- 0–3 (Minor and/or brief behaviors) includes, but is not limited to: No response; minor changes in speed or locomotion (but with no avoidance); individual alert behavior; minor cessation in vocal behavior; minor changes in response to trained behaviors (in laboratory).
- 4–6 (Behaviors with higher potential to affect foraging, reproduction, or survival) includes, but is not limited to: Moderate changes in speed, direction, or dive profile; brief shift in group distribution; prolonged cessation or modification of vocal behavior (duration > duration of sound); minor or moderate individual and/or group

avoidance of sound; brief cessation of reproductive behavior; or refusal to initiate trained tasks (in laboratory).

- 7–9 (Behaviors considered likely to affect the aforementioned vital rates) includes, but are not limited to: Extensive of prolonged aggressive behavior; moderate, prolonged or significant separation of females and dependent offspring with disruption of acoustic reunion mechanisms; long-term avoidance of an area; outright panic, stampede, stranding; threatening or attacking sound source (in laboratory).

In Table 2 we have summarized the scores that Southall et al. (2007) assigned to the papers that reported behavioral responses of low-frequency cetaceans, mid-frequency cetaceans, and high-frequency cetaceans to non-pulse sounds.

Table 4. Data compiled from three tables from Southall et al. (2007) indicating when marine mammals (low-frequency cetacean = L, mid-frequency cetacean = M, and high-frequency cetacean = H) were reported as having a behavioral response of the indicated severity to a non-pulse sound of the indicated received level. As discussed in the text, responses are highly variable and context specific.

	Received RMS Sound Pressure Level (dB re 1 microPa)											
Response Score	80 to <90	90 to < 100	100 to < 110	110 to <120	120 to < 130	130 to < 140	140 to < 150	150 to < 160	160 to < 170	170 to < 180	180 to < 190	190 to < 200
9												
8		M	M		M		M				M	M
7						L	L					
6	H	L/H	L/H	L/M/H	L/M/H	L	L/H	H	M/H	M		
5					M							
4			H	L/M/H	L/M		L					
3		M	L/M	L/M	M							
2			L	L/M	L	L	L					
1			M	M	M							
0	L/H	L/H	L/M/H	L/M/H	L/M/H	L	M				M	M

Potential Effects of Behavioral Disturbance

The different ways that marine mammals respond to sound are sometimes indicators of the ultimate effect that exposure to a given stimulus will have on the well-being (survival, reproduction, etc.) of an animal. There is little marine mammal data quantitatively relating the exposure of marine mammals to sound to effects on reproduction or survival, though data exists for terrestrial species to which we can draw comparisons for marine mammals.

Attention is the cognitive process of selectively concentrating on one aspect of an animal's environment while ignoring other things (Posner, 1994). Because animals (including humans) have limited cognitive resources, there is a limit to how much sensory information they can process at any time. The phenomenon called "attentional capture" occurs when a stimulus (usually a stimulus that an animal is not concentrating on or attending to) "captures" an animal's attention. This shift in attention can occur consciously or unconsciously (for example, when an animal hears sounds that it associates with the approach of a predator) and the shift in attention can be sudden (Dukas, 2002; van Rij, 2007). Once a stimulus has captured an animal's attention, the animal can respond by ignoring the stimulus, assuming a "watch and wait" posture, or treat the stimulus as a disturbance and respond accordingly, which includes scanning for the source of the stimulus or "vigilance" (Cowlishaw et al., 2004).

Vigilance is normally an adaptive behavior that helps animals determine the presence or absence of predators, assess their distance from conspecifics, or to attend cues from prey (Bednekoff and Lima, 1998; Treves, 2000). Despite those benefits, however, vigilance has a cost of time: when animals focus their attention on specific environmental cues, they are not attending to other activities such a foraging. These costs have been documented best in foraging animals, where vigilance has been shown to substantially reduce feeding rates (Saino, 1994; Beauchamp and Livoreil, 1997; Fritz et al., 2002).

Animals will spend more time being vigilant, which may translate to less time foraging or resting, when disturbance stimuli approach them more directly, remain at closer distances, have a greater group size (for example, multiple surface vessels), or when they co-occur with times that an animal perceives increased risk (for example, when they are giving birth or accompanied by a calf). Most of the published literature, however, suggests that direct approaches will increase the amount of time animals will dedicate to being vigilant. For example, bighorn sheep and Dall's sheep dedicated more time being vigilant, and less time resting or foraging, when aircraft made direct approaches over them (Frid, 2001; Stockwell et al., 1991).

Several authors have established that long-term and intense disturbance stimuli can cause population declines by reducing the body condition of individuals that have been disturbed, followed by reduced reproductive success, reduced survival, or both (Daan et al., 1996; Madsen, 1994; White, 1983). For example, Madsen (1994) reported that pink-footed geese (Anser brachyrhynchus) in undisturbed habitat gained body mass and had about a 46-percent reproductive success compared with geese in disturbed habitat (being consistently scared off the fields on which they were foraging), which did not gain mass and had a 17 percent reproductive success. Similar reductions in reproductive success have been reported for mule deer (Odocoileus hemionus) disturbed by all-terrain vehicles (Yarmoloy et al., 1988), caribou disturbed by seismic exploration blasts (Bradshaw et al., 1998), caribou disturbed by low-elevation military jetfights (Luick et al., 1996), and caribou disturbed by low-elevation jet flights (Harrington and Veitch, 1992). Similarly, a study of elk (Cervus elaphus) that were disturbed experimentally by pedestrians concluded that the ratio of young to mothers was inversely related to disturbance rate (Phillips and Alldredge, 2000).

The primary mechanism by which increased vigilance and disturbance appear to affect the fitness of individual animals is by disrupting an animal's time budget and, as a result, reducing the time they might spend foraging and resting (which increases an animal's activity rate and energy demand). For example, a study of grizzly bears (Ursus horribilis) reported that bears disturbed by hikers reduced their energy intake by an average of 12 kcal/min (50.2 × 103kJ/min), and spent energy fleeing or acting aggressively toward hikers (White et al., 1999).

On a related note, many animals perform vital functions, such as feeding, resting, traveling, and socializing, on a diel cycle (24-hr cycle). Substantive behavioral reactions to noise exposure (such as disruption of critical life functions, displacement, or avoidance of important habitat) are more likely to be significant if they last more than one diel cycle or recur on subsequent days (Southall et al., 2007). Consequently, a behavioral response lasting less than one day and not recurring on subsequent days is not considered particularly severe unless it could directly affect reproduction or survival (Southall et al., 2007).

(5) Stranding and Mortality

When a live or dead marine mammal swims or floats onto shore and becomes "beached" or incapable of returning to sea, the event is termed a "stranding" (Geraci et al., 1999; Perrin and Geraci, 2002; Geraci and Lounsbury, 2005; NMFS, 2007). Marine mammals are known to strand for a variety of reasons, such as infectious agents, biotoxicosis, starvation, fishery interaction, ship strike, unusual oceanographic or weather events, sound exposure, or combinations of these stressors sustained concurrently or in series. However, the cause or causes of most stranding are unknown (Geraci et al., 1976; Eaton, 1979, Odell et al., 1980; Best, 1982).

Several sources have published lists of mass stranding events of cetaceans during attempts to identify relationships between those stranding events and military sonar (Hildebrand, 2004; IWC, 2005; Taylor et al., 2004). For example, based on a review of stranding records between 1960 and 1995, the International Whaling Commission (IWC, 2005) identified 10 mass stranding events of Cuvier's beaked whales that had been reported and one mass stranding of four Baird's beaked whales (Berardius bairdii). The IWC concluded that, out of eight stranding events reported from the mid-1980s to the summer of 2003, seven had been associated with the use of mid-frequency sonar, one of those seven had been associated with the use of low frequency sonar, and the remaining stranding event had been associated with the use of seismic airguns. None of the strandings has been associated with high frequency sonar such as the Q-20 sonar proposed to be tested in this action. Therefore, NMFS does not consider it likely that the proposed Q-20 testing activity would cause marine mammals to strand.

Effects on Marine Mammal Habitat

There are no areas within the NSWC PCD that are specifically considered as important physical habitat for marine mammals.

The prey of marine mammals are considered part of their habitat. The Navy's Final Environmental Impact Statement and Overseas Environmental Impact Statement (FEIS) on the research, development, test and evaluation activities in the NSWC PCD study area contains a detailed discussion of the potential effects to fish from HFAS/MFAS. These effects are the same as expected from the proposed Q-20 sonar testing activities within the same area.

The extent of data, and particularly scientifically peer-reviewed data, on the effects of high intensity sounds on fish is limited. In considering the available literature, the vast majority of fish species studied to date are hearing generalists and cannot hear sounds above 500 to 1,500 Hz (depending upon the species), and, therefore, behavioral effects on these species from higher frequency sounds are not likely. Moreover, even those fish species that may hear above 1.5 kHz, such as a few sciaenids and the clupeids (and relatives), have relatively poor hearing above 1.5 kHz as compared to their hearing sensitivity at lower frequencies. Therefore, even among the species that have hearing ranges that overlap with some mid- and high frequency sounds, it is likely that the fish will only actually hear the sounds if the fish and source are very close to one another. Finally, since the vast majority of sounds that are of biological relevance to fish are below 1 kHz (e.g., Zelick et al., 1999; Ladich and Popper, 2004), even if a fish detects a mid-or high frequency sound, these sounds will not mask detection of lower frequency biologically relevant sounds. Based on the above information, there will likely be few, if any, behavioral impacts on fish.

Alternatively, it is possible that very intense mid- and high frequency signals could have a physical impact on fish, resulting in damage to the swim bladder and other organ systems. However, even these kinds of effects have only been shown in a few cases in response to explosives, and only when the fish has been very close to the source. Such effects have never been indicated in response to any Navy sonar. Moreover, at greater distances (the distance clearly would depend on the intensity of the signal from the source) there appears to be little or no impact on fish, and particularly no impact on fish that do not have a swim bladder or other air bubble that would be affected by rapid pressure changes.

Mitigation Measures

In order to issue an incidental take authorization (ITA) under Section 101(a)(5)(D) of the MMPA, NMFS must set forth the “permissible methods of taking pursuant to such activity, and other means of effecting the least practicable adverse impact on such species or stock and its habitat, paying particular attention to rookeries, mating grounds, and areas of similar significance.” The National Defense Authorization Act (NDAA) of 2004 amended the MMPA as it relates to military-readiness activities and the ITA process such that "least practicable adverse impact" shall include consideration of personnel safety, practicality of implementation, and impact on the effectiveness of the "military readiness activity." The Q-20 sonar testing activities described in the Navy's IHA application are considered military readiness activities.

For the proposed Q-20 sonar testing activities in the GOM, NMFS worked with the Navy to develop mitigation measures. The following mitigation measures are required in the IHA issued to the Navy to take marine mammals incidental to its Q-20 testing activities.

<u>Personnel Training</u>

Marine mammal mitigation training for those who participate in the active sonar activities is a key element of the protective measures. The goal of this training is for key personnel onboard Navy platforms in the Q-20 Study Area to understand the protective measures and be competent to carry them out. The Marine Species Awareness Training (MSAT) is provided to all applicable participants, where appropriate. The program addresses environmental protection, laws governing the protection of marine species, Navy stewardship, and general observation information including more detailed information for spotting marine mammals. Marine mammal observer training will be provided before active sonar testing begins.

Marine observers would be aware of the specific actions to be taken based on the RDT&E platform if a marine mammal is observed. Specifically, the following requirements for personnel training would apply:

- All marine observers onboard platforms involved in the Q-20 sonar test activities will review the NMFS-approved MSAT material prior to use of active sonar.
- Marine Observers shall be trained in marine mammal recognition. Marine Observer training shall include completion of the Marine Species Awareness Training, instruction

on governing laws and policies, and overview of the specific Gulf of Mexico species present, and observer roles and responsibilities.

- Marine observers will be trained in the most effective means to ensure quick and effective communication within the command structure in order to facilitate implementation of mitigation measures if marine species are spotted.

Range Operating Procedures

The following procedures would be implemented to maximize the ability of Navy personnel to recognize instances when marine mammals are in the vicinity.

(1) Observer Responsibilities

- Marine observers will have at least one set of binoculars available for each person to aid in the detection of marine mammals.
- Marine observers will conduct monitoring for at least 15 minutes prior to the initiation of and for at least 15 minutes after the cessation of Q-20 testing activities.
- Marine observers will scan the water from the ship to the horizon and be responsible for all observations in their sector. In searching the assigned sector, the lookout will always start at the forward part of the sector and search aft (toward the back). To search and scan, the lookout will hold the binoculars steady so the horizon is in the top third of the field of vision and direct the eyes just below the horizon. The lookout will scan for approximately five seconds in as many small steps as possible across the field seen through the binoculars. They will search the entire sector in approximately five-degree steps, pausing between steps for approximately five seconds to scan the field of view. At the end of the sector search, the glasses will be lowered to allow the

eyes to rest for a few seconds, and then the lookout will search back across the sector with the naked eye.

- Observers will be responsible for informing the Test Director of any marine mammal that may need to be avoided, as warranted.
- These procedures would apply as much as possible during RMMV operations. When an RMMV is operating over the horizon, it is impossible to follow and observe it during the entire path. An observer will be located on the support vessel or platform to observe the area when the system is undergoing a small track close to the support platform.

(2) Operating Procedures

- Test Directors will, as appropriate to the event, make use of marine species detection cues and information to limit interaction with marine species to the maximum extent possible, consistent with the safety of the ship.
- During Q-20 sonar activities, personnel will utilize all available sensor and optical system (such as Night Vision Goggles) to aid in the detection of marine mammals.
- Navy aircraft participating will conduct and maintain, when operationally feasible, required, and safe, surveillance for marine species of concern as long as it does not violate safety constraints or interfere with the accomplishment of primary operational duties.
- Marine mammal detections by aircraft will be immediately reported to the Test Director. This action will occur when it is reasonable to conclude that the course of the ship will likely close the distance between the ship and the detected marine mammal.

- Special conditions applicable for dolphins only: If, after conducting an initial maneuver to avoid close quarters with dolphins, the Test Director or the Test Director’s designee concludes that dolphins are deliberately closing to ride the vessel’s bow wave, no further mitigation actions are necessary while the dolphins or porpoises continue to exhibit bow wave riding behavior.
- Sonar levels (generally)—Navy will operate sonar at the lowest practicable level, except as required to meet testing objectives.

Clearance Procedures

When the test platform (surface vessel or aircraft) arrives at the test site, an initial evaluation of environmental suitability will be made. This evaluation will include an assessment of sea state and verification that the area is clear of visually detectable marine mammals and indicators of their presence. For example, large flocks of birds and large schools of fish are considered indicators of potential marine mammal presence.

If the initial evaluation indicates that the area is clear, visual surveying will begin. The area will be visually surveyed for the presence of protected species and protected species indicators. Visual surveys will be conducted from the test platform before test activities begin. When the platform is a surface vessel, no additional aerial surveys will be required. For surveys requiring only surface vessels, aerial surveys may be opportunistically conducted by aircraft participating in the test.

Shipboard monitoring will be staged from the highest point possible on the vessel. The observer(s) will be experienced in shipboard surveys, familiar with the marine life of the area, and equipped with binoculars of sufficient magnification. Each observer will be provided with a two-way radio that will be dedicated to the survey, and will have direct radio contact with the

Test Director. Observers will report to the Test Director any sightings of marine mammals or indicators of these species, as described previously. Distance and bearing will be provided when available. Observers may recommend a "Go" / "No Go" decision, but the final decision will be the responsibility of the Test Director.

Post-mission surveys will be conducted from the surface vessel(s) and aircraft used for pre-test surveys. Any affected marine species will be documented and reported to NMFS. The report will include the date, time, location, test activities, species (to the lowest taxonomic level possible), behavior, and number of animals.

NMFS has carefully evaluated the Navy's proposed mitigation measures and considered a range of other measures in the context of ensuring that NMFS prescribes the means of effecting the least practicable adverse impact on the affected marine mammal species and stocks and their habitat. Our evaluation of potential measures included consideration of the following factors in relation to one another:

- the manner in which, and the degree to which, the successful implementation of the measure is expected to minimize adverse impacts to marine mammals
- the proven or likely efficacy of the specific measure to minimize adverse impacts as planned; and
- the practicability of the measure for applicant implementation, including consideration of personnel safety, practicality of implementation, and impact on the effectiveness of the military readiness activity.

Based on careful evaluation and assessing these measures, we have determined that the mitigation measures listed above provide the means of effecting the least practicable adverse impacts on marine mammals species or stocks and their habitat, paying particular attention to rookeries, mating grounds, and areas of similar significance, while also considering personnel safety, practicality of implementation, and impact on the effectiveness of the military readiness activity.

Monitoring Measures

In order to issue an ITA for an activity, section 101(a)(5)(D) of the MMPA states that NMFS must set forth "requirements pertaining to the monitoring and reporting of such taking." The MMPA implementing regulations at 50 CFR 216.104(a)(13) indicate that requests for LOAs must include the suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species and of the level of taking or impacts on populations of marine mammals that are expected to be present.

The RDT&E Monitoring Program, proposed by the Navy as part of its IHA application, is focused on mitigation-based monitoring. Main monitoring techniques include use of civilian personnel as marine mammal observers during pre-, during, and post-, test events.

Systematic monitoring of the affected area for marine mammals will be conducted prior to, during, and after test events using aerial and/or ship-based visual surveys. Observers will record information during the test activity. Data recorded will include exercise information (time, date, and location) and marine mammal and/or indicator presence, species, number of animals, their behavior, and whether there are changes in the behavior. Personnel will immediately report observed stranded or injured marine mammals to NMFS stranding response network and NMFS Regional Office. Reporting requirements are included in the Naval Surface Warfare Center Panama City Division (NSWC PCD) Mission Activities Final Environmental Impact Statement/Overseas Environmental Impact Statement Annual Activity report as required by its Final Rule (DON, 2009; NMFS, 2010d).

Ongoing Monitoring

The Navy has an existing Monitoring Plan that provides for site-specific monitoring for MMPA and Endangered Species Act (ESA) listed species, primarily marine mammals within the Gulf of Mexico, including marine water areas of the Q-20 Study Area (DON, 2009; NMFS, 2010d). This monitoring plan was initially developed in support of the NSWC PCD Mission Activities Final Environmental Impact Statement/Overseas Environmental Impact Statement and subsequent Final Rule by NMFS (DON, 2009; NMFS, 2010d). The primary goals of monitoring are to evaluate trends in marine species distribution and abundance in order to assess potential population effects from Navy training and testing events and determine the effectiveness of the Navy's mitigation measures. The monitoring plan, adjusted annually in consultation with NMFS, includes aerial- and ship-based visual observations, acoustic monitoring, and other efforts such as oceanographic observations.

Estimated Take by Incidental Harassment

As mentioned previously, with respect to military readiness activities, Section 3(18)(B) of the MMPA defines "harassment" as: (i) Any act that injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild [Level A Harassment]; or (ii) any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering, to a point where such behavioral patterns are abandoned or significantly altered [Level B Harassment].

A thorough analysis of the types of Level A and B harassments and the acoustic take criteria are provided in the Federal Register notice for the proposed IHA (77 FR 12010; February 28, 2012), and is not repeated here. Although analyses earlier in the document show that there are 22 species of marine mammals are found present in the vicinity of the proposed Q-20 testing area, due to the low density of many species and the small zones of influence resulted from the proposed sonar testing, only six species may be exposed to noise levels that constitute a "take". Based on the analysis and acoustical modeling, which can be found in Appendix A Supplemental Information for Underwater Noise Analysis of the Navy's IHA application, NSWC PCD's Q-20 sonar operations in non-territorial waters may expose up to six species to sound likely to result in Level B (behavioral) harassment (Table 1). They include the bottlenose dolphin (Tursiops truncatus), Atlantic spotted dolphin (Stenella frontalis), pantropical spotted dolphin (Stenella attenuata), striped dolphin (Stenella coeruleoalba), spinner dolphin (Stenella longirostris), and Clymene dolphin (Stenella clymene). No marine mammals would be exposed to levels of sound likely to result in TTS. The Navy requested that the take numbers of marine mammals for its IHA reflect the exposure numbers listed in Table 1.

Table 1. Estimates of Marine Mammal Exposures from Sonar in Non-territorial Waters per Year

Marine Mammal Species	Level A	Level B (TTS)	Level B (Behavioral)
Bottlenose dolphin (GOM oceanic)	0	0	399
Pantropical spotted dolphin	0	0	126
Atlantic spotted dolphin	0	0	315
Spinner dolphin	0	0	126
Clymene dolphin	0	0	42
Striped dolphin	0	0	42

Negligible Impact and Small Numbers Analysis and Determination

Pursuant to NMFS' regulations implementing the MMPA, an applicant is required to estimate the number of animals that will be "taken" by the specified activities (i.e., takes by harassment only, or takes by harassment, injury, and/or death). This estimate informs the analysis that NMFS must perform to determine whether the activity will have a "negligible impact" on the species or stock. Level B (behavioral) harassment occurs at the level of the individual(s) and does not assume any resulting population-level consequences, though there are known avenues through which behavioral disturbance of individuals can result in population-level effects. A negligible impact finding is based on the lack of likely adverse effects on annual rates of recruitment or survival (i.e., population-level effects). An estimate of the number of Level B harassment takes, alone, is not enough information on which to base an impact determination. In addition to considering estimates of the number of marine mammals that might be "taken" through behavioral harassment, NMFS must consider other factors, such as the likely nature of any responses (their intensity, duration, etc.), the context of any responses (critical reproductive time or location, migration, etc.), or any of the other variables mentioned in the first paragraph (if known), as well as the number and nature of estimated Level A takes, the number of estimated mortalities, and effects on habitat.

The Navy's specified activities have been described based on best estimates of the number of Q-20 sonar test hours that the Navy will conduct. Taking the above into account, considering the sections discussed below, and dependent upon the implementation of the mitigation measures, NMFS has determined that Navy's Q-20 sonar test activities in the non-territorial waters will have a negligible impact on the marine mammal species and stocks present in the Q-20 Study Area.

<u>Behavioral Harassment</u>

As discussed in the Potential Effects of Exposure of Marine Mammals to Sonar section and illustrated in the conceptual framework, marine mammals can respond to HFAS/MFAS in many different ways, a subset of which qualifies as harassment. One thing that the take estimates do not take into account is the fact that most marine mammals will likely avoid strong sound sources to one extent or another. Although an animal that avoids the sound source will likely still be taken in some instances (such as if the avoidance results in a missed opportunity to feed, interruption of reproductive behaviors, etc.), in other cases avoidance may result in fewer instances of take than were estimated or in the takes resulting from exposure to a lower received level than was estimated, which could result in a less severe response. The Navy proposes only 420 hours of high-frequency sonar operations per year for the Q-20 sonar testing activities, spread among 42 days with an average of 10 hours per day, in the Q-20 Study Area. There will be no powerful tactical mid-frequency sonar involved. Therefore, there will be no disturbance to marine mammals resulting from MFAS systems (such as 53C). The effects that might be expected from the Navy's major training exercises at the Atlantic Fleet Active Sonar Training (AFAST) Range, Hawaii Range Complex (HRC), and Southern California (SOCAL) Range Complex will not occur here. The source level of the Q-20 sonar is much lower than the 53C series MFAS system, and high frequency signals tend to have more attenuation in the water column and are more prone to lose their energy during propagation. Therefore, their zones of influence are much smaller, thereby making it easier to detect marine mammals and prevent adverse effects from occurring.

The Navy has been conducting monitoring activities since 2006 on its sonar operations in a variety of the Naval range complexes (e.g., AFAST, HRC, SOCAL) under the Navy's own protective measures and under the regulations and LOAs. Monitoring reports based on these major training exercises using military sonar have shown that no marine mammal injury or mortality has occurred as a result of the sonar operations (DoN, 2011a; 2011b).

<u>Diel Cycle</u>

As noted previously, many animals perform vital functions, such as feeding, resting, traveling, and socializing on a diel cycle (24-hr cycle). Substantive behavioral reactions to noise exposure (such as disruption of critical life functions, displacement, or avoidance of important habitat) are more likely to be significant if they last more than one diel cycle or recur on subsequent days (Southall et al., 2007). Consequently, a behavioral response lasting less than one day and not recurring on subsequent days is not considered particularly severe unless it could directly affect reproduction or survival (Southall et al., 2007).

In the previous section, we discussed the fact that potential behavioral responses to HFAS/MFAS that fall into the category of harassment could range in severity. By definition, the takes by behavioral harassment involve the disturbance of a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns (such as migration, surfacing, nursing, breeding, feeding, or sheltering) to a point where such behavioral patterns are abandoned or significantly altered. In addition, the amount of time the Q-20 sonar testing will occur is 420 hours per year in non-territorial waters, and is spread among 42 days with an average of 10 hours per day. Thus the exposure is expected to be sporadic throughout the year and is localized within a specific testing site.

TTS

Based on the Navy's model and NMFS analysis, it is unlikely that marine mammals would be exposed to sonar received levels that could cause TTS due to the lower source level (207-212 dB re 1 µPa at 1 m) and high attenuation rate of the HFAS signals (above 35 kHz).

Acoustic Masking or Communication Impairment

As discussed above, it is possible that anthropogenic sound could result in masking of marine mammal communication and navigation signals. However, masking only occurs during the time of the signal (and potential secondary arrivals of indirect rays), versus TTS, which occurs continuously for its duration. The Q-20 ping duration is in milliseconds and the system is relatively low-powered making its range of effect smaller. Therefore, masking effects from the Q-20 sonar signals are expected to be minimal. If masking or communication impairment were to occur briefly, it would be in the frequency range of above 35 kHz (the lower limit of the Q-20 signals), which overlaps with some marine mammal vocalizations; however, it would likely not mask the entirety of any particular vocalization or communication series because the pulse length, frequency, and duty cycle of the Q-20 sonar signal does not perfectly mimic the characteristics of any marine mammal's vocalizations.

PTS, Injury, or Mortality

Based on the Navy's model and NMFS analysis, it is unlikely that PTS, injury, or mortality of marine mammals would occur from the proposed Q-20 sonar testing activities. As discussed earlier, the lower source level (207-212 dB re 1 μPa at 1 m) and high attenuation rate of the HFAS signals (above 35 kHz) make it highly unlikely that any marine mammals in the vicinity would be injured (including PTS) or killed as a result of sonar exposure.

Based on the aforementioned assessment, NMFS determines that approximately 399 bottlenose dolphins, 126 pantropical spotted dolphins, 315 Atlantic spotted dolphins, 126 spinner dolphins, 42 Clymene dolphins, and 42 striped dolphins would be affected by Level B behavioral harassment as a result of the proposed Q-20 sonar testing activities. These numbers represent approximately 10.76%, 0.37%, 1.26%, 6.33%, and 0.64% of bottlenose dolphins (GOM oceanic stock), pantropical spotted dolphins, striped dolphins, spinner dolphins, and Clymene dolphins, respectively, of these species in the GOM region (calculation based on NMFS 2011 US Atlantic and Gulf of Mexico Marine Mammal Stock Assessment). The percentage of potentially affected

Atlantic spotted dolphin is unknown since there is no current population assessment of this species in the Gulf of Mexico region. However, based on the most recent abundance estimate published in NMFS Atlantic and GOM SARs conducted in the northern Gulf of Mexico outer continental shelf during fall 2000-2001 and oceanic waters during spring/summer 2003-2004, the population was estimated at 37,611 (NMFS 2011). Using this number, it is estimated that approximately 0.84% of Atlantic spotted dolphins would be taken by Level B behavioral harassment from the Navy’s proposed sonar test activities.

The supporting analyses suggest that no marine mammals will be killed, injured, or receive TTS as a result of the Q-20 sonar testing activities, and no more than a small number of any affected species will be taken in the form of short-term Level B behavioral harassment. In addition, since these impacts will likely not occur in areas and times critical to reproduction, NMFS has determined that the taking of these species as a result of the Navy’s Q-20 sonar test will have a negligible impact on the marine mammal species and stocks present in the Q-20 Study Area.

Subsistence Harvest of Marine Mammals

NMFS has determined that the total taking of marine mammal species or stocks from the Navy’s Q-20 sonar testing in the Q-20 Study Area would not have an unmitigable adverse impact on the availability of the affected species or stocks for subsistence uses, since there are no such uses in the specified area.

Endangered Species Act (ESA)

Based on the analysis of the Navy Marine Resources Assessment (MRA) data on marine mammal distributions, there is near zero probability that sperm whale will occur in the vicinity of the Q-20 test area. No other ESA-listed marine mammal is expected to occur in the vicinity of the test area. In addition, acoustic modeling analysis indicates the ESA-listed sperm whale would not be exposed to levels of sound constituting a "take" under the MMPA, due to the low source level and high attenuation rates of the Q-20 sonar signal. Therefore, NMFS has determined that ESA-listed species will not be affected as the result of the Navy's Q-20 testing activities.

National Environmental Policy Act (NEPA)

In 2009, the Navy prepared a Final Environmental Impact Statement / Overseas Environmental Impact Statement for the NSWC PCD Mission Activities (FEIS/OEIS), and NMFS subsequently adopted the FEIS/OEIS for its rule governing the Navy's RDT&E activities in the NSWC PCD Study Area. The currently proposed Q-20 sonar testing activities are similar to the sonar testing activities described in the FEIS/OEIS for NSWC PCD mission activities. NMFS prepared an Environmental Assessment analyzing the potential impacts of the additional Q-20 sonar test activities and reached a finding of no significant impact.

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