NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION
SCIENCE ADVISORY BOARD

FINAL REPORT

EVALUATION OF THE OBSERVED OR POTENTIAL IMPACTS TO OCEAN RESOURCES FROM UNDERWATER SEISMIC TESTING

March 5, 2020

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EVALUATION OF THE OBSERVED OR POTENTIAL IMPACTS TO OCEAN RESOURCES FROM UNDERWATER SEISMIC TESTING

FINAL REPORT

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A Report to the Scientific Advisory Board (SAB)
New Jersey Department of Environmental Protection

January 27, 2020

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Sections of this Report were Prepared by: Chuck Harman, Elizabeth Ravit, Dan Cooke, Nellie Tsipoura, Paul Bovitz; Editorial Review Provided by: Joseph Bilinski, Dan Millemann, Nick Procopio

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EXECUTIVE SUMMARY

For the New Jersey Department of Environmental Protection (NJDEP), the approval by the U.S. National Marine Fisheries Service (NMFS) of Incidental Harassment Authorizations (IHAs; pursuant to the Marine Mammal Protection Act (MMPA)) as they relate to proposed geophysical survey activities in Federal waters off the coast of New Jersey) has brought an immediacy to the need to understand the potential impacts from sound generated by seismic surveys. It is important to note that there can be a substantial difference in survey specifications (including airgun array size, total volume of airguns, and duration of activities) between those conducted exclusively for research by the National Science Foundation (NSF) and US Geological Survey (USGS) and for which only an IHA is granted and the activities conducted by industry, for which both an IHA is granted and Bureau of Ocean Energy Management (BOEM) must issue a permit. Applicants will conduct seismic surveys using sound generation devices to perform either two-dimensional or three-dimensional deep penetration surveys to acquire data regarding oil and gas deposits beneath the seafloor.

Seismic surveys use mechanically generated sound waves from an acoustic source that are used to map layers of the subsurface for various purposes (a broad range of power levels are generally considered as seismic surveys). Off the New Jersey coast, seismic survey activities using air guns are typically associated oil and gas development. The NJDEP's Coastal Zone Management Rules (N.J.A.C. 7:7) establish standards for these activities in the offshore environment within State's Waters (within three nautical miles of the shore), typically authorized under Waterfront Development Permits or through the Federal Consistency process. In order to assess the impact to other uses and resources, it is critical that the NJDEP understands the potential impacts of sound generation for seismic surveys.

The NJDEP has identified questions and concerns related to the use of sound generation devices in the marine environment as part of the completion of seismic surveys. The specific questions raised by the NJDEP as part of this charge include:

1. What are the actual or potential impacts of seismic testing on ocean resources?

2. What types and scales of seismic testing could have impacts on New Jersey's ocean and marine resources?

3. In the past few years, industry has proposed seismic testing programs as a precursor to more detailed searches for potential oil and gas drilling. Through the NJ Coastal Management Program, NJDEP can comment on, and potentially seek adjustment to, activities conducted or supported by federal agencies. What documentation (and potentially additional research) is needed to determine whether seismic testing off NJ shores has impacts on our marine species?

The Scientific Advisory Board, Ecological Processes Standing Committee (EPSC) was tasked with responding to these charge elements and providing the NJDEP with technical information enough to form a basis for future regulatory decisions and research options regarding the use of sound generation devices.

Seismic surveys are conducted using acoustic sources that emit sound into the marine environment and receivers that record the returning acoustic signals. The acoustic sources used in seismic surveys most commonly consist of air gun arrays, while the receivers consist of towed cables with hydrophones encased in plastic tubing called streamers. When an air gun array is activated, an acoustic energy pulse is emitted and reflected or refracted back from the seafloor and subsurface interfaces. These reflected/refracted acoustic signals create pressure fluctuations, which are detected and recorded by the streamers. Data collected by the streamers are then transferred and recorded in the vessel's initial data processing system. A ship tows both the array and the streamer below the sea surface along a predetermined trackline. A tail buoy marks the end of the gear, allowing the crew to monitor the location and direction of the streamers.

Responses to anthropogenic sound may be strongly related to circumstances specific to an individual animal (e.g., mother with calf) or an animal group (e.g., migrating pod). Nothing is yet known about long-term effects of seismic exposure or about effects related to cumulative exposures. Because auditory structures and auditory processes differ between various species and across taxonomic phyla, and sound propagation is not consistent under different environmental conditions, research findings cannot be reliably extrapolated from one species to another or from one set of environmental conditions to another. Review papers are available that discuss a variety of species/research studies.

A Web of Science literature search for the term "seismic testing" reveals over 25,000 peer-reviewed papers published between 1980 – 2019. When the term "seismic" is combined with "impact" or "whale" the number of Web of Science papers drops to 35 and 37, respectively. Combining the terms "seismic" and "fish" yields 17 papers and "seismic" combined with "invertebrate" produces 2 papers. These search results highlight the lack of replicable, peer-reviewed research papers and/or controlled experiments that can inform policies designed to address seismic air gun exploration in marine environments. In addition to peer-reviewed papers, there are non-peer reviewed papers and presentations published in conference proceedings, as well as a "gray literature" that consists of reports commissioned by various governments, agencies, and industry groups to determine appropriate regulatory actions related to seismic noise in the marine environment. There are also published anecdotal reports that attempt to connect seismic survey activity with negative environmental results, although demonstrating cause/effect has not been possible. Significant issues exist with obtaining reliable data in the wild: the difficulty/cost of establishing *in situ* controls; the challenges associated with eliminating effects attributable to the presence of a vessel; the challenges with obtaining significant sample sizes; and the limitations of visual observations at a distance. However, there are governments that have chosen to follow the Precautionary Principal and ban seismic activity during breeding or migration seasons.

While there are significant uncertainties, including a paucity of reproducible experimental data, authors were able to speculate on possible seismic effects or lack thereof. It is important to note that there is a broad range of possible "effects" that stem from exposure to seismic air gun arrays.

Mitigation for biological impacts associated with seismic testing are required, or under consideration, in several geographic area, including the U.S., Russia, and Latin America. The mitigation approach required for a typical project reflects the size, scope, geographic location, and timing of the proposed seismic survey project.

There is a standard set of mitigation procedures for seismic surveys, as initially implemented by the regulator for Gulf of Mexico surveys by industry ("permitted" by BOEM). All IHA holders now follow those standard mitigation procedures for seismic surveys. These mitigation procedures can be found in numerous documents prepared in consultation with the regulator.

Mitigation measures that will be adopted during the planned surveys include (1) Vessel-based visual mitigation monitoring; (2) Vessel-based passive acoustic monitoring; (3) Establishment of an exclusion zone; (4) Power down procedures; (5) Shutdown procedures; (6) Ramp-up procedures; and (7) Vessel strike avoidance measures.

The EPSC has reviewed an extensive body of research that has been published regarding the impacts of sound generated by air guns used as a component of seismic surveys. In general, the identified impacts are negative, with direct impacts being both physical (in terms of physical damage to auditory structures) and behavioral (changes in life activities). While not all of the impacts are believed to be permanent, the research has not demonstrated any underwater noise generation activity from air guns that is considered to have no effect or a positive influence.

As the NJDEP has the potential to review more plans for seismic surveys, the Department should consider the development of a stronger regulatory program to manage the needs of the companies to conduct the surveys. Some of the elements of the regulatory considerations would be:

- Continuous monitoring should be required as a component of the survey;
- Drones and other advanced technology be considered as part of monitoring activities;
- Time of year restrictions to ensure that sensitive elements of the aquatic community such as the North Atlantic right whale are protected;
- Restriction of sensitive breeding areas and/or habitat from seismic survey;
- More widespread use of marine mammal observers and more comprehensive observation protocols to ensure better field protection for marine mammals;
- More comprehensive use of mitigation measures;
- Better baseline documentation of potential marine mammals and other aquatic species found in a given area before approval of a survey effort; and

Additionally, the Department should consider better coordination with other states in the Mid-Atlantic region to coordinate the development of a baseline characterization of anthropogenic noise levels. The Department should also consider closer coordination with Federal agencies such as the National Marine Fisheries Service to ensure that the state concerns over seismic surveys are considered.

1.0 INTRODUCTION

Sound levels in the earth's oceans are a source of increasing concern. High intensity sounds associated with military activities, oil and gas exploration, pile driving, and seismic surveys have been shown to impact to varying degrees the marine organisms living in the sound's zone of influence. Though commercial shipping traffic has been shown to be the greatest source of marine noise, even low-level noise such as commercial and recreational boat traffic has been shown to be disruptive to marine organisms.

For the New Jersey Department of Environmental Protection (NJDEP), the approval by the U.S. National Marine Fisheries Service (NMFS) of Incidental Harassment Authorizations (IHAs; pursuant to the Marine Mammal Protection Act (MMPA)) as they relate to proposed geophysical survey activities in Federal waters off the coast of New Jersey) has brought an immediacy to the need to understand the potential impacts from sound generated by seismic surveys. It is important to note that there can be a substantial difference in survey specifications (including airgun array size, total volume of airguns, and duration of activities) between those conducted exclusively for research by the National Science Foundation (NSF) and US Geological Survey (USGS) and for which only an IHA is granted and the activities conducted by industry, for which both an IHA is granted and Bureau of Ocean Energy Management (BOEM) must issue a permit. Applicants will conduct seismic surveys using sound generation devices to perform either two-dimensional or three-dimensional deep penetration surveys to acquire data regarding oil and gas deposits beneath the seafloor.

Seismic surveys use mechanically generated sound waves from an acoustic source that are used to map layers of the subsurface for various purposes (a broad range of power levels are generally considered as seismic surveys). Off the New Jersey coast, seismic survey activities using air guns are typically associated oil and gas development. The NJDEP's Coastal Zone Management Rules (N.J.A.C. 7:7) establish standards for these activities in the offshore environment within State's Waters (within three nautical miles of the shore), typically authorized under Waterfront Development Permits or through the Federal Consistency process. In order to assess the impact to other uses and resources, it is critical that the NJDEP understands the potential impacts of sound generation for seismic surveys.

Charge

The NJDEP has identified questions and concerns related to the use of sound generation devices in the marine environment as part of the completion of seismic surveys. The specific questions raised by the NJDEP as part of this charge include:

4. What are the actual or potential impacts of seismic testing on ocean resources?

5. What types and scales of seismic testing could have impacts on New Jersey's ocean and marine resources?

6. In the past few years, industry has proposed seismic testing programs as a precursor to more detailed searches for potential oil and gas drilling. Through the NJ Coastal Management Program, NJDEP can comment on, and potentially seek adjustment to, activities conducted or supported by federal agencies. What documentation (and potentially additional research) is needed to determine whether seismic testing off NJ shores has impacts on our marine species?

The Scientific Advisory Board, Ecological Processes Standing Committee (EPSC) was tasked with responding to these charge elements and providing the NJDEP with technical information enough to form a basis for future regulatory decisions and research options regarding the use of sound generation devices.

Following are the findings of the EPSC with respect to the charge.

2.0 SOUND GENERATION FROM SEISMIC SURVEYS

Seismic surveys are conducted using acoustic sources that emit sound into the marine environment and receivers that record the returning acoustic signals. The acoustic sources used in seismic surveys most commonly consist of air gun arrays, while the receivers consist of towed cables with hydrophones encased in plastic tubing called streamers. When an air gun array is activated, an acoustic energy pulse is emitted and reflected or refracted back from the seafloor and subsurface interfaces. These reflected/refracted acoustic signals create pressure fluctuations, which are detected and recorded by the streamers. Data collected by the streamers are then transferred and recorded in the vessel's initial data processing system. A ship tows both the array and the streamer below the sea surface along a predetermined trackline (Figure 2-1). A tail buoy marks the end of the gear, allowing the crew to monitor the location and direction of the streamers.

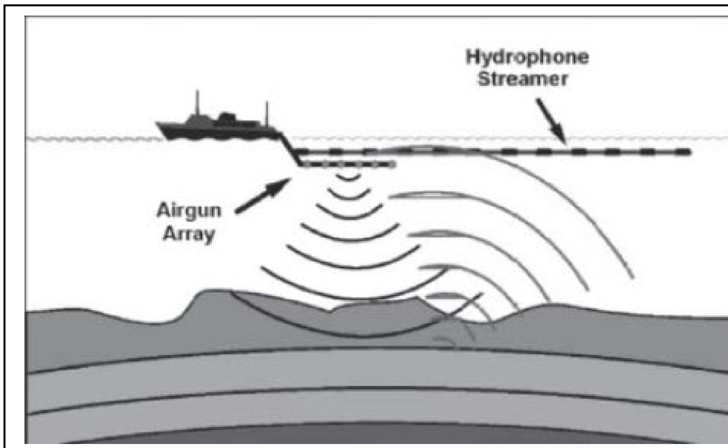

Figure 2-1 From NMFS ESA Section 7 Biological Opinion (2018)

Noise can be characterized by four factors: frequency, intensity, duration, and distance:

Frequency: Sound travels in waves, and the frequency of a sound is the number of wave cycles per second, measured in hertz (Hz). High frequency sounds have many cycles per second, while low frequency sounds have fewer. The wavelength (the distance sound travels in one cycle) can be calculated by dividing the speed of sound underwater by the frequency of the sound. For example, the speed of sound in seawater is approximately 1,500 meters per second (m/s), meaning a sound wave with a frequency of 100 Hz will have a wavelength of 1,500/100 = 15 meters.

A sound wave is a pressure disturbance, traveling molecule to molecule. As one molecule is vibrated, it vibrates adjacent molecules and the sound energy is transported through the water. The speed of sound is how fast (e.g., m/s), and the frequency refers to the number of vibrations an individual molecule creates per second.

Marine species are sensitive to a wide range of frequencies, with different species exhibiting varying sensitivities to differing frequencies. Seismic air guns create an intense, broadband, impulsive sound that can propagate several kilometers (km) from the source, though the potential impacts of the sound must be considered against the baseline value of background noise. The sound perceived by a marine animal will be limited to the range that the species can hear.

Intensity: Noise intensity is the power (average energy per unit time) transmitted through a unit area in a specific direction. Sound intensity (i.e., loudness) is measured in decibels (dB). The dB is a relative unit of measure describing the logarithm of the ratio of a sound's intensity to a reference intensity. The decibel scale is logarithmic and each 10-decibel rise corresponds to a ten-fold increase in intensity. Therefore, a sound of 130 dB is considered ten times more intense than a 120 dB, a sound of 140 dB is 100 times more intense, and a sound of 150 dB is 1,000 times more intense (Richardson et al., 1995).

Measurements of dB in water are not directly comparable to dB in air because different reference intensities are used for the different media. A sound wave pressure of 1.0 microPascal (μPa) is normally used as the underwater reference intensity. When reporting sound intensity in water, it is noted as decibels relative to 1 μPa, or "dB re 1 μPa".

Duration: The duration of a sound affects its potential impact. Generally, long-term sounds are considered more harmful than short bursts of sound. "Masking" occurs when the pressure of a sound masks a sound of interest, by being equal or greater power. For marine animals, a low-level sound of long duration might mask sounds of interest such as prey and inter- and intra-species communication.

Distance: In the ocean, sound radiates in all directions in a spherical pattern from the source in the near field. As the sound radiates, the pressure wave increases in size and the power of the wave dissipates. When the spherical sound pattern reaches the water surface or the sea floor, the sound continues to travel, but in a cylindrical pattern. The intensity of the sound is also reduced by absorption of the water molecules, reflection off underwater features, refraction if traveling through varying water temperatures or densities, and scattering off particles in the water column.

There are two methods of acoustic sound detection under water: pressure fluctuations within the medium or particle motion due to the back and forth motion of the medium. All marine mammals and some fish species detect sound pressure, which is easily measured using available equipment; however, particle motion, which is much harder to measure and rarely reported, is the hearing source for fishes and invertebrates (Hawkins *et al.*, 2015). Particle motion shortens the distance that sound can be perceived and limits the detectable frequency to a few hundred Hz (Kunc *et al.*, 2016). Species relying on sound pressure detect changes over large distances and may be more vulnerable to noise than species relying on only particle motion (Kunc *et al.*, 2016).

Measuring particle motion, and therefore sound exposure, is an ongoing challenge under experimental conditions. This limitation is especially important when exposing captive caged animals to a sound source. Accurate particle motion measurements can only be obtained when measured at a distance from reflecting boundaries and acoustic discontinuities, and so the acoustic field in a laboratory tank or *in situ* cage differs greatly from a natural environment acoustic field (Gordon *et al.*, 2003/4; Hawkins & Popper 2017). There are also bathymetric conditions where the magnitude of particle motion is greater for a given sound pressure, such as in shallow waters or close to the water surface (Hawkins & Popper 2017). Seismic energy sent into the seabed may create substrate vibrations that affect sound in shallow waters (Hawkins *et al.*, 2015). Therefore, caged behaviors do not indicate how unrestrained animals would react in the wild or respond to seismic sounds at a feeding or breeding site, and so *in situ* experiments are needed to verify results obtained under caged and/or laboratory experimental conditions (Popper & Hastings 2009).

There are an estimated 100 species of marine mammals, 32,000 species of fishes and a greater number of aquatic invertebrates (Hawkins & Popper 2017). Hearing thresholds have been determined for approximately 100 species (Popper & Hastings 2009; BOEM 2014 and references therein), and only a limited number of species have been studied after exposure to seismic sound sources. Differences in marine animal responses to various sound intensities, the duration and characteristics of biological sounds produced by different species, and gender differences in sound production have been observed (Croll et al., 2002; Nieukirk et al., 2004) Therefore, the measured responses and hearing thresholds are probably not representative of all species.

Responses to anthropogenic sound may be strongly related to circumstances specific to an individual animal (e.g., mother with calf) or an animal group (e.g., migrating pod). Nothing is yet known about long-term effects of seismic exposure or about effects related to cumulative exposures (Popper & Hastings 2009). Because auditory structures and auditory processes differ between various species and across taxonomic phyla, and sound propagation is not consistent under different environmental conditions, research findings cannot be reliably extrapolated from one species to another or from one set of environmental conditions to another (Kunc *et al.*, 2016). Review papers are available that discuss a variety of species/research studies. The findings in these papers are included in this review.

2.1 Regulatory Criteria for Sound

Under the MMPA (US Code, Title 16, Chapter 31, as amended December 18, 2018), a Level A harassment is defined as "…*any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild*". Level B harassment is defined as "…*any act of pursuit, torment, or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering.*" In the case of scientific research, the Level B harassment definition is qualified as, "…*to a point where such behavioral patterns are abandoned or significantly altered*".

The NMFS has published sound exposure level (SEL) guidelines for determining acoustic harassment thresholds for marine mammals (NMFS, 2018). The SELs were derived for impulsive sounds (sharp, near-instantaneous) and non-impulsive sounds (continuous, varying, or intermittent) to develop SEL thresholds that may potentially result in Level A harassment (Level B harassment was not examined by NMFS).

As noted above, a sound wave is a pressure disturbance traveling through the water. Prior to this guidance, NMFS used an interim sound pressure level (SPL) threshold for Level A harassment of 180 dB re 1 μPa for cetaceans, and 190 dB re 1 μPa for pinnipeds. These interim guidelines considered instantaneous SPL at a given receiver location and were designed to protect all marine species from high SPLs at any discrete frequency across the entire frequency spectrum. They did not take species-specific hearing capabilities into account.

The SELs are frequency-weighted SPLs for the onset of either temporary threshold shift (TTS) in hearing or permanent threshold shift (PTS), that were developed because animals are not equally sensitive to noise at all frequencies. The frequency-dependent effects of noise were addressed by using auditory weighting functions to emphasize frequencies where animals are more susceptible and to de-emphasize frequencies where animals are less susceptible (NMFS 2018).

NMFS developed six "hearing groups" (shown in **Table 2-1**) which combine species that hear low-frequency sounds (group LF: mysticetes), mid-frequency sounds (group MF: delphinids, beaked whales, sperm whales), and high-frequency sounds (group HF: porpoises, river dolphins), along with sirenians (group SI: manatees), phocids in water (group PW: true seals), and otariids in water (group OW: sea lions, walruses, otters, polar bears). NMFS developed SELs for PTS for each group (NMFS, 2018).

Table 2-1. Summary of PTS Onset Thresholds (adapted from NMFS 2018)

		PTS Onset Thresholds (received level)	
Hearing Group	**Generalized Hearing Range***	**Impulsive Sound****	**Non-Impulsive Sound**
LF: Low-Frequency cetaceans (baleen whales)	7 Hz to 35 kHz	PK: 219 dB SEL_{cum}: 183 dB	SEL_{cum}: 199 dB
MF: Mid-Frequency cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)	150 Hz to 160 kHz	PK: 230 dB SEL_{cum}: 185 dB	SEL_{cum}: 198 dB
HF: High-Frequency cetaceans (true porpoises, river dolphins)	275 Hz to 160 kHz	PK: 202 dB SEL_{cum}: 155 dB	SEL_{cum}: 173 dB
PW: Phocid Pinnipeds (true seals) (underwater)	50 Hz to 86 kHz	PK: 218 dB SEL_{cum}: 185 dB	SEL_{cum}: 201 dB
OW: Otariid Pinnipeds (sea lions and fur seals) (underwater)	60 Hz to 39 kHz	PK: 232 dB SEL_{cum}: 203 dB	SEL_{cum}: 219 dB

*Generalized hearing range for the entire group as a composite of all species in the group
**Dual impulsive thresholds: use the one that results in the largest effect distance.
PK = peak sound pressure level
SEL_{cum} = indicates SEL incorporating auditory frequency weighting functions

2.2 Seismic Air Guns

Seismic air guns are the most widely used source of impulsive sound for marine geophysical imaging. Air guns release a specific volume of air under high pressure, creating a sound pressure wave from the expansion and contraction of the released air bubble. The sound frequency of a seismic air gun is controlled by the air gun volume, the air pressure used, and the towing depth. The sound frequencies of interest for seismic surveys are less than 100 Hz (Gisiner, 2016). Large-volume air guns generate more low-frequency sound than smaller-volume air guns. Seismic surveys generally require lower-frequency sound to penetrate below the sediment surface, as the higher frequencies tend to be attenuated in the subsurface depths and can only be used for shallower subsurface surveys (Breitzke *et al.*, 2008).

Air gun arrays are designed to produce a low frequency impulse sound centered around 50 Hz, though the inherently broadband nature of a transient sound source with a high-power source gives rise to a very broad frequency spectrum (Hermannsen *et al.*, 2015). This predominantly low-frequency, high-power sound creates long range propagation (DOSITS 2019).

The sound produced is a function of the volume, size, air pressure, and the shape of the air gun ports through which air is released, as well as tow depth. The amplitude of the sound increases with the cube root of the volume of the air gun, meaning that to double the amplitude obtained from a 1,000 cubic inch chamber would require an 8,000 cubic inch chamber (Gisiner, 2016). Rather than use increasingly large air guns to yield high sound pressure, multiple air guns are fired with precise timing to produce a pulse of sound.

Oil industry air gun arrays typically involve 12 to 48 (occasionally higher) individual guns operating at a pressure of 2,000 pounds per square inch (psi) (ranging from 1,500 to 3,000 psi), arranged in a rectangular array, towed approximately 200 meters behind a ship. The planar array directs the added energy from the multiple air guns primarily downward. The air gun array will typically be towed at a speed of about five knots, making a series of parallel passes through the target area, firing the air guns every ten seconds, though it is more common in current surveys to fire based on a preset distance (Gisiner, 2016). Near field maximum pressure levels can be 230 dB re 1 µPa, in the 5 Hz to 300 Hz frequency range (Hildebrand, 2005). As shown in **Table 2-1**, this peak sound pressure is at or above the PTS threshold for all marine mammals.

A “receive array” streamer is towed along with the seismic air gun array, with a streamer typically 4 to 12 kilometers in length, with 300 to 1,000 receive modules (each composed of a hydrophone, accelerometer, and depth sensor) (Gisiner, 2016). It is occasional practice is to use repeated seismic surveys in the same area to develop “time lapse” monitoring of producing oil fields, called “4-D” surveys (Hildebrand, 2005).

3.0 POTENTIAL RECEPTORS

Potential receptor species which may be impacted by seismic activities off the coast of New Jersey include the species that live in or migrate through those waters. Receptor classes include marine mammals (whales, dolphins, seals), marine reptiles (sea turtles), fish, macroinvertebrates (shellfish), zooplankton (including larval stages of fish and macroinvertebrates), and phytoplankton. In addition to the aquatic marine species, bird species could potentially be impacted by seismic activity, both through direct impacts (physical damage or fright) and through indirect impacts (e.g., impact to food sources).

3.1 Marine Mammals and Reptiles

NJDEP’s Division of Fish and Wildlife (DFW) webpage lists 28 marine mammals and five sea turtle species that live in or pass through waters offshore of New Jersey during the year (**Table 3-1**). Additionally, the New Jersey Marine Mammal Stranding Center (Brigantine, NJ) posts lists of marine mammals and turtles that have been found stranded in NJ; the species stranded during 2018 and early 2019 are also listed in **Table 3-1**.

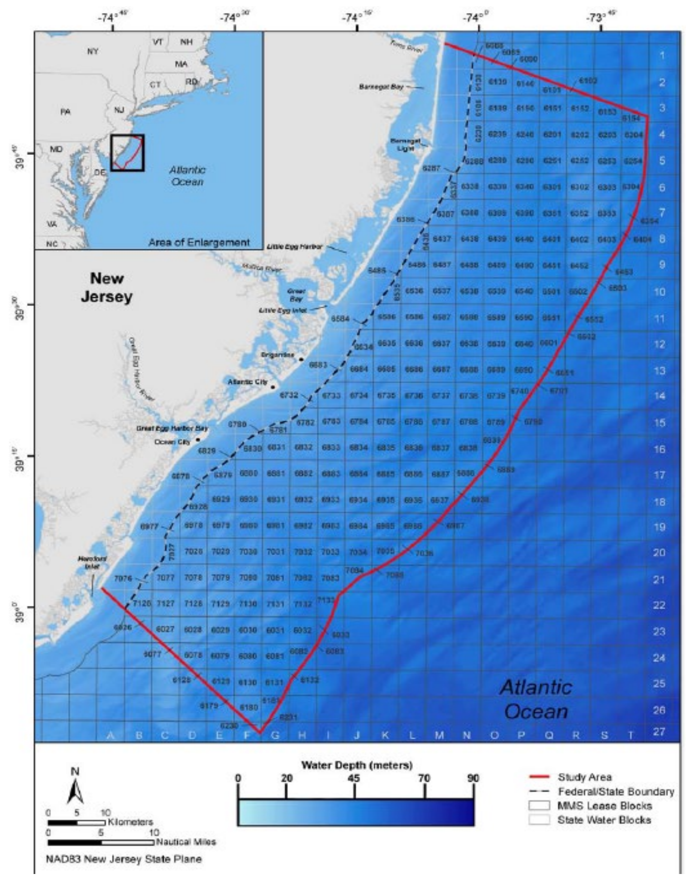

Figure 3-1. NJDEP Ocean/Wind Power Ecological Baseline Studies (Geo-Marine 2010)

As part of NJDEP's preparation for wind energy leases off the New Jersey coast, a two-year series of studies was performed to determine the wildlife receptors that could potentially be impacted by the necessary geophysical surveys, construction work, and long-term maintenance associated with offshore energy development (Geo-Marine, 2010). The lease area surveyed extended to 37 kilometers (km; ~20 nautical miles or 23 statute miles) offshore and was bounded on the north by Seaside Park and on the south by Stone Harbor, a total area of approximately 4,665 square km (1,800 square miles) along the southern half of the NJ coastline (**Figure 3-1**). The studies included surveys of birds, fish, marine mammals and reptiles, benthic invertebrates, and essential habitats. The marine mammals and reptiles observed during the surveys are listed in **Table 3-1**.

Marine mammals are regularly observed in NJ coastal waters, and some are quite common. Harp seals, harbor seals, and grey seals can be found on shore during the winter months. There are documented seal haul-outs, where seals regularly come onto land, in Great Bay (the largest haul-out in NJ with up to 150 harbor seals sighted at one time), Sandy Hook (the second largest haul-out in NJ with up to 95 harbor seals sighted at one time), and Barnegat Light (CWF 2019). Seals may also haul out at numerous other locations in smaller numbers.

Table 3-1. Marine Mammals and Turtles Observed in Coastal NJ

Receptor Species	Scientific Name	Source
Whales		
Atlantic Killer Whale	*Orcinus orca*	c
Beluga Whale	*Delphinapterus leucas*	c
Black Right Whale	*Balaena glacialis*	c
Blainville's Beaked Whale	*Mesoplodon densirostris*	b

Receptor Species	Scientific Name	Source
Blue Whale	*Balaenoptera musculus*	c
Dense Beaked Whale	*Mesoplodon densirostris*	c
Dwarf Sperm Whale	*Kogia sima*	b, c
Fin Whale	*Balaenoptera physalus*	a, b, c
Gervais Beaked Whale	*Mesoplodon europaeus*	c
Goose-beaked Whale	*Ziphius cavirostris*	c
Humpback Whale	*Megaptera novaeangliae*	a, b, c
Long-finned Pilot Whale	*Globicephala melaena*	c
Minke Whale	*Balaenoptera acutorostrata*	a, b, c
North Atlantic Right Whale	*Eubalaena glacialis*	a, b
Pilot Whale	*Globicephala* sp.	b
Pygmy Sperm Whale	*Kogia breviceps*	b, c
Sei Whale	*Balaenoptera borealis*	b, c
Short-finned Pilot Whale	*Globicephala macrorhyncus*	c
Sperm Whale	*Physeter macrocephalus*	c
True's Beaked Whale	*Mesoplodon mirus*	c
Dolphins		
Bottlenose Dolphin	*Tursiops truncatus*	a, b, c
Bridled Spotted Dolphin	*Stenella frontalis*	c
Grampus/Risso's Dolphin	*Grampus griseus*	b, c
Harbor Porpoise	*Phocoena*	a, b, c
Short-beaked Common Dolphin	*Delphinus delphis*	a, b, c
Spotted Dolphin	*Stenella plagiodon*	c
Striped Dolphin	*Stenella coeruleoalba*	b, c
Pinnipeds		
Grey Seal	*Halichoerus grypus*	b, c
Harbor Seal	*Phoca vitulina concolor*	a, b, c
Harp Seal	*Pagophilus groenlandicus*	b, c
Hooded Seal	*Cystophora cristata*	c
Sea Turtles		
Green Turtle	*Chelonia mydas*	b
Hawksbill Turtle	*Eretmochelys imbricata*	b
Kemp's Ridley Turtle	*Lepidochelys kempii*	b
Leatherback Turtle	*Dermochelys coriacea*	a, b
Loggerhead Turtle	*Caretta*	a, b
Other		
Florida Manatee	*Trichechus manatus latirostris*	b
Unidentified		
whales, pinnipeds, and turtles	Observed but not identified	a, b

a: Geo-Marine 2010
b: NJ Marine Mammal Stranding Center 2018/2019 stranding records
c: NJDEP DFW Mammals of New Jersey

Bottlenose dolphins are commonly observed near the beach during the summer months. While these dolphins are abundant and distributed worldwide, the National Oceanic and Atmospheric Administration (NOAA) recognizes the population of dolphins that appear in NJ waters as the "northern coastal migratory stock", which is included in the larger coastal migratory stock of dolphins that the National Marine Fisheries Service (NMFS) has designated as "depleted" (NOAA 2019). Dolphins mate along the NJ coast, and use several inshore locations near Cape May (on both the Delaware Bay and Atlantic Ocean sides), and in the nearshore areas off the barrier islands of Atlantic City, Brigantine, and Long Beach Island to give birth (NJDEP unpublished data). The mothers and calves are particularly vulnerable to disturbance.

3.2 Fish

New Jersey's fishery and aquaculture resources, with over 100 different species of finfish and shellfish, contribute more than $1 billion annually to the state's economy. New Jersey has six major commercial fishing ports, four of which are in the top 50 commercial ports around the country for economic value (NJ Sea Grant 2019). While commercial species have direct economic value, the other non-commercial species are linked in the complex food web and are also valuable resources. Additionally, there are endangered fish species in the NJ coastal zone, including both the Atlantic sturgeon (*Acipenser oxyrhynchus*) and the shortnose sturgeon (*Acipenser brevirostrum*).

The NJDEP's DFW webpage states that there are 336 marine finfish that live in or pass through NJ waters during the year. Those 336 species represent 116 families occurring from the coastal estuaries to the 200-meter (656-foot) depth contour at the edge of the continental shelf (GeoMarine 2010). A partial list of species that are important for both commercial and recreational fisheries is in **Table 3-2**. In addition to these fish, there are numerous smaller species that serve as food for the target fish and are also important recreational baitfish (e.g., mummichog, silversides, mossbunker, squid). There are also numerous large game fish that are routinely caught off the NJ shore, including tuna, sharks, swordfish, and marlin.

Table 3-2: Partial List of New Jersey Commercial and Recreational Fish

Receptor Species	Scientific Name	Source
American Eel	*Anguilla rostrata*	a, b
Atlantic Cod	*Gadus morhua*	a, b
Atlantic Mackerel	*Scomber scombrus*	b
Atlantic Menhaden	*Brevoortia tyrannus*	b
Black Drum	*Pogonias cromis*	a, b
Black Sea Bass	*Centropristis striata*	a, b
Bluefish	*Pomatomus saltatrix*	a, b
Blueline Tilefish	*Caulolatilus microps*	b
Cobia	*Rachycentron canadum*	a, b
Goosefish (Monkfish)	*Lophiidae*	a, b
Haddock	*Melanogrammus aeglefinus*	a, b
King Mackerel (Kingfish)	*Scomberomorus cavalla*	a, b

Receptor Species	Scientific Name	Source
Pollock	*Pollachius virens*	a, b
Red Drum	*Sciaenops ocellatus*	a, b
River Herring (Alewife)	*Alosa pseudoharengus*	a, b
Scup (Porgy)	*Stenotomus chrysops*	a, b
Shad	*Alosa sapidissima*	a, b
Shark	Multiple species	b
Spanish Mackerel	*Scomberomorus maculatus*	b
Striped Bass	*Morone saxatilis*	a, b
Summer Flounder (Fluke)	*Paralichthys dentatus*	a, b
Tautog	*Tautoga onitis*	a, b
Weakfish	*Cynoscion regalis*	b
Winter Flounder	*Pseudopleuronectes americanus*	a, b

a: NJDEP DFW 2019 Recreational Minimum Size, Possession Limits, and Seasons
b: NJDEP DFW 2019 Commercial Marine Fishing Regulations

Marine and estuarine fish can be classified as pelagic (open water), demersal (near the bottom), and benthic (bottom) fish. While all of the fish in coastal NJ may be exposed to the same noise, fish that are active in different parts of the water column and different distances from the source are impacted differently. The degree to which a fish is affected by noise is dependent on both the species and life stage of the fish, as well as environmental factors such as water depth, hydrodynamic regime, and substrate type. The presence of an air-filled swim bladder in finfish increases vulnerability to sound and sound pressure effects.

3.3 Marine Invertebrates

A partial list of commercially important marine macroinvertebrates is presented in **Table 3-3**. In addition to these invertebrates, there are numerous other species that serve as food for some of these species and are also important as bait for both commercial and recreational fishing (e.g., horseshoe crab, clams, grass shrimp, green crabs). While horseshoe crabs are not eaten by people, they are in high demand in NJ, and the population is in steady decline. They mate in late May or early June, and their eggs are a critical food source for the endangered red knot (*Calidris canutus*) on its migration from South America to the Arctic. The adults are valued by conch and eel fisherman as bait (though NJDEP placed a moratorium on horseshoe crab harvest in 2008). The blood of the horseshoe crab is also valuable for the pharmaceutical industry, where it is used to test for contamination of drugs and medical equipment.

Table 3-3. Partial List of Commercial and Recreational Invertebrates

Receptor Species	Scientific Name	Source
American Lobster	*Homarus americanus*	a, b
Bay Scallop	*Argopecten irradians*	c
Blue Crab	*Calinectes sapidus*	a, b

Receptor Species	Scientific Name	Source
Conch (whelk)	*Busycon carica gmelin*	b
Hard Clam	*Mercenaria*	a, b
Horseshoe Crab	*Limulus polyphemus*	
Jonah Crab	*Cancer borealis*	a, b
Oyster	*Crassostrea virginica*	b
Soft Shell Clam	*Mya arenaria*	
Surf Clam	*Spisula solidissima*	b

a: NJDEP DFW 2019 Recreational Minimum Size, Possession Limits, and Seasons
b: NJDEP DFW 2019 Commercial Marine Fishing Regulations
c: NJDEP DFW 2006

Marine invertebrates produce sound primarily through stridulation (rubbing two body parts together to produce acoustic vibrations) to communicate. Some crabs and shrimp drum two body parts together or hit a hard substrate with a claw. Some species can be identified by the frequency and time interval of their sounds. Mussels can produce sound with their byssal threads (the structures used to adhere to hard substrates) by stretching and breaking them to produce a snapping sound.

Little is known about how marine invertebrates use sound to feed, though they can detect vibrations that may alert them to potential food sources. Unlike vertebrates, invertebrates hear by using external sensory hairs or internal statocysts (a sac-like structure containing a mineralized statolith and numerous sensory cells) to sense vibrations and movements associated with sound production. Some invertebrates detect vibrations transmitted through the substrate with sensory organs in their walking legs. Once alerted to a potential food source, the invertebrates may be able to use chemical cues to locate the food (URI 2019).

3.4 Zooplankton and Phytoplankton

Zooplankton is composed of heterotrophic animals that drift with the currents. They range from microscopic to almost eight inches in length. Some zooplankton (holoplankton) remain planktonic for their entire life cycle, while other zooplankton (meroplankton) are actually larval forms of fish and invertebrates that will eventually outgrow this size class. Phytoplankton is composed of autotrophic microalgae that form the base of the ocean food chain. Impacts to the plankton cause impacts on fish and invertebrate populations by killing larval fish and invertebrates, and by reducing a primary food source for adult fish and invertebrates.

3.5 Birds

During the two-year Ocean Wind Power Baseline Study (GeoMarine 2010), a total of 153 bird species were recorded, with 145 species recorded during shipboard offshore surveys and 82 species recorded during the small-boat coastal surveys. Fourteen federally listed species of concern and 16 state-classified endangered, threatened, and special concern species were observed. Avian densities were highest near shore in all seasons, though more pronounced in winter than in summer. This was likely because of the large numbers of coastal-breeding gulls and terns, and waterfowl.

Some aquatic birds have adaptations to hear underwater. Murres and auks (both observed in NJ) have a structure that creates a barrier over their ear openings. The northern gannet has extra air spaces in its head and neck, and a thicker tympanic membrane than similar-sized birds. Some in-water hearing threshold work has been performed on cormorants, gannets, loons, and auks, but further studies are needed to assess sensitivities to anthropogenic noise (URI 2019). Penguins have been shown to avoid their preferred foraging areas during seismic activities (Pichegru *et al.,* 2017).

Though the direct impacts of seismic air guns on birds are yet unknown, the indirect impacts could include changes to and temporary loss of local food sources (requiring more energy to find alternate food sources).

4.0 IMPACTS FROM SEISMIC SURVEYS

A Web of Science literature search for the term "seismic testing" reveals over 25,000 peer-reviewed papers published between 1980 – 2019. When the term "seismic" is combined with "impact" or "whale" the number of Web of Science papers drops to 35 and 37, respectively. Combining the terms "seismic" and "fish" yields 17 papers and "seismic" combined with "invertebrate" produces 2 papers. These search results highlight the lack of replicable, peer-reviewed research papers and/or controlled experiments that can inform policies designed to address seismic air gun exploration in marine environments. In addition to peer-reviewed papers, there are non-peer reviewed papers and presentations published in conference proceedings, as well as a "gray literature" that consists of reports commissioned by various governments, agencies, and industry groups to determine appropriate regulatory actions related to seismic noise in the marine environment. There are also published anecdotal reports that attempt to connect seismic survey activity with negative environmental results, although demonstrating cause/effect has not been possible (Castellote & Llorens 2016). Significant issues exist with obtaining reliable data in the wild: the difficulty/cost of establishing *in situ* controls; the challenges associated with eliminating effects attributable to the presence of a vessel; the challenges with obtaining significant sample sizes; and the limitations of visual observations at a distance (Gordon *et al.,* 2003/4). However, there are governments that have chosen to follow the Precautionary Principal and ban seismic activity during breeding or migration seasons (Engel et al., 2004).

Marine mammals and reptiles have been shown to be sensitive to noise, and behavior alterations have been observed during seismic survey activity. Marine mammal avoid areas were seismic activities are occurring (Richardson et al., 1999), and may modify non-seismic migratory patterns through small course deviations (Malme et al., 1983). Some of the effects of exposure to loud noise can be characterized by the following range of responses (Richardson *et al.*, 1995):

1. <u>Behavioral reactions</u> – Range from brief startle responses to changes or interruptions in feeding, diving, or respiratory patterns, to cessation of vocalizations, to temporary or permanent displacement from habitat.

2. Masking – Reduction in the ability to detect communication or other relevant sound signals due to elevated levels of background noise.
3. Temporary Threshold Shift (TTS) – Temporary, fully recoverable reduction in hearing sensitivity caused by exposure to sound.
4. Permanent Threshold Shift (PTS) – Permanent, irreversible reduction in hearing sensitivity due to damage or injury to ear structures caused by prolonged exposure to sound or temporary exposure to very intense sound.
5. Non-auditory physiological effects – Effects of sound exposure on tissues in non-auditory systems either through direct exposure or as a consequence of changes in behavior (e.g., resonance of respiratory cavities or growth of gas bubbles in body fluids).

Richardson *et al*. (1995) also defines four zones of noise influence for marine species depending on the distance between a strong noise source and the animal. Starting from the closest to the source:

1. Zone of Hearing Loss – The area closest to the noise source, where the sound pressure is high enough to cause tissue damage either temporarily or permanently. More severe physical damage (including death) is possible depending on the strength of the noise.
2. Zone of Responsiveness – The area in which the noise is strong enough to elicit behavioral and/or physiological responses from the animal. Such responses include alarm movements or area avoidance.
3. Zone of Masking – The area in which noise is strong enough to interfere with the detection of other sounds (e.g., communication signals and echolocation clicks).
4. Zone of Audibility – The farthest from the source, and extends to the limits of hearing, until the sound is lost to ambient background noise.

While there are significant uncertainties, including a paucity of reproducible experimental data, authors were able to speculate on possible seismic effects or lack thereof. It is important to note that there is a broad range of possible "effects" that stem from exposure to seismic air gun arrays. The following discussion of impacts contains divergent scientific findings. A listing of references used to compile this report is included in **Appendix A**.

Depending on the length of exposure (acute for a brief time period or chronic over a repetitive and cumulative time period) and distance from the air gun source (**Figure 4-1**), a short-term direct effect may or may not reach the level of an "impact". Hawkins and Popper (2017) defined an impact as an effect that rises

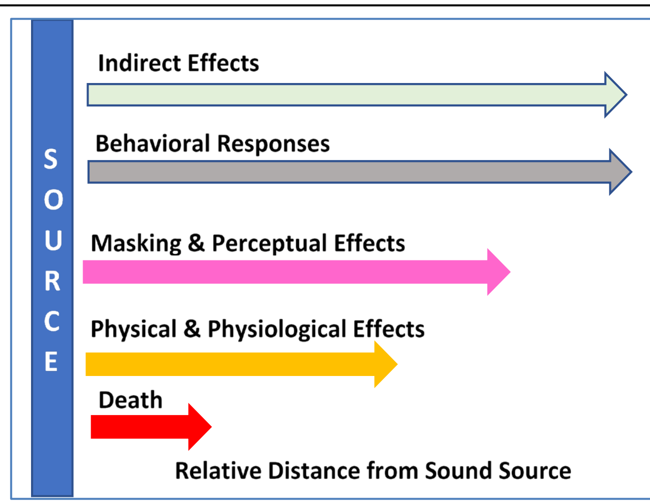

Figure 4-1. Possible Effects related to seismic air gun exposure (After Hawkins & Popper 2017 and Gordon *et al*., 2003/4)

to the level of "*deleterious ecological significance*" that affects a species, population or ecological community. However, the literature does attribute impacts to *individuals* within a population from exposure to both acute and chronic exposure (BOEM 2014). The International Whaling Commission reports that repeated and persistent acoustic events over a large area should be considered enough to cause population level impacts (IWC 2005). There may also be secondary, indirect effects that are the result of seismic air gun activity, such as a food source moving away from an area where the animal of concern normally feeds, resulting in reduced feeding rates (Gordon *et al.*, 2003/4).

4.1 Direct Impacts

Based on a review of the scientific literature, the following direct impacts have been identified from the use of sound generation devices for seismic surveys in the marine environment.

Marine Mammals

Marine mammals use acoustic signals for communication, social interactions, foraging, and navigation, and all marine mammals produce sound (Erbe *et al.*, 2016). Marine mammal auditory systems vary in structure and function depending on the species. Hearing acuity may decrease with age. As noted in Section 2.1, the NMFS has developed six "hearing groups" for marine mammals, depending on the both the generalized frequency range of their hearing and the received levels of sound that may cause the onset of Permanent Threshold Shift (PTS). **Table 2-1** shows that the frequency range encompassing all six hearing groups is 7 Hz to 160 kHz, with a peak impulsive sound pressure of 202 to 232 dB re 1 μPa causing the onset of PTS (NMFS 2018). The near-field maximum pressure levels from seismic surveys can be 230 dB re 1 μPa, in the 5 Hz to 300 Hz frequency range (Hildebrand, 2005).

Gordon *et al.* (2003/4) note that there are several adverse effects that can be attributed to marine mammals being exposed to sound sources such as seismic survey air guns. Those include:

- Physical damage;
- Behaviorally-mediated damage and stranding; and
- Auditory damage, leading to noise-induced hearing loss, both temporary (TTS), or permanent (PTS).

The following sections summarize the potential impacts to various marine mammals.

Whales

With respect to marine noise, marine mammals, and particularly whales, are studied most frequently (Williams *et al.,* 2015). Studying captive species and observing individuals during field research is the primary source of experimental data. While the professional community infers that whales are impacted by the noise of seismic testing because of the sensitivity of their auditory structures, Gordon *et al.* (2003/4) report that there is no direct evidence of damage to the ears of marine mammals resulting from seismic sound sources because there have been no direct investigations of hearing threshold shifts in marine mammals. Auditory parameters are inferred from the frequency range of vocalizations, field observations, and physical characteristics of the inner ear.

Scientists usually make observations from shore (resulting in a reduced visibility distance) or from ships (making it difficult to separate the seismic effects from a response to the vessel's presence). Castellote and Llorens (2016 and references therein) reviewed reports of whale displacement and ten suspected whale mass strandings that could be linked to offshore seismic activity. They note that this work is "very controversial", some findings are contradictory, and a causal link was not established in any of their reported displacement events that occurred between 2004 and 2013. However, Castellote and Llorens specified that, "*This lack of evidence should not be considered conclusive but rather as reflecting the absence of a comprehensive analysis of the circumstances*".

Noise from ship traffic and commercial, research and military activities has increased greatly over the past century and has caused changes in the vocalizations and behaviors of many marine mammals, including beluga whales (*Delphinapterus leucas*) (Lesage *et al.*1999), manatees (*Trichechus manatus*) (Miksis-Olds and Tyack, 2009) and right whales (*Eubalaena glacialis*, *E. australis*) (Parks *et al*. 2007). Right whales respond to periods of increased noise by increasing the amplitude of their calls, which may help to maintain their communication range with conspecifics during periods of increased noise. This may be interpreted as an adaptive response. However, periods of high noise are increasing and have reduced the ability of right whales to communicate with each other by about two-thirds.

In a study of whale and dolphin responses to seismic exploration off the coast of Angola, Weir (2008) found that humpback and sperm whale sightings from a vessel did not differ significantly based on the volume of the air gun arrays (5,085 cubic inch [in^3] and 3,147 in^3 arrays). The mean distance to whale sightings was greater during seismic operations than when air guns were not in use, showing that the whales actively avoided the area regardless of the volume of the air gun array. Dolphins exhibited the most overt response to air guns in terms of sighting rates and distances from the boat; positive dolphin approach behavior was only observed when the air guns were not in use. Though delphinids will also approach a vessel using airguns and ride the bow wave or play near streamers. The regulator allows exceptions to shut down rules for delphinids that approach a vessel during seismic shooting unless the delphinids enter a small exclusion zone, triggering a shutdown.

Atlantic spotted dolphins showed a marked short-term and localized displacement from areas where air guns were actively being used. The whales and dolphins all appeared to stay far enough from the in-use air gun arrays to avoid potential injury. Weir (2008) did look at the potential for prolonged displacement as a result of air gun activity and noted that humpback whale sightings exhibited a significant decrease that the authors suggest was potentially related to seasonal migration patterns. However, during the ten-month period of seismic activity, no evidence of a prolonged or large-scale displacement of the cetaceans was found.

Cerchio *et al.* (2014), studying humpback whales off the coast of Angola at a Congo River outflow, recorded individual whales that vocalized during periods with higher levels of seismic survey pulses. The authors suggest that whales either stopped singing or moved to other areas. A series of General Additive Mixed Models[2] examined the effect of seismic activity. The authors concluded that there was a significant negative effect on the detectable number of singers. Further, they observed that singing activity declined with the increased presence and received levels of seismic survey pulses. The authors emphasized that this study documented disturbance of a breeding display on a breeding ground, with implied potential for impacts on mating behavior and success.

Nowacek *et al*. (2007) reviewed responses of cetaceans to noise and found three types of responses: behavioral, acoustic and physiological. Behavioral responses involve changes in surfacing, diving, and swimming patterns. Acoustic responses include changes in the timing or type of vocalizations. Physiological responses include shifts in auditory thresholds. In this study they documented responses of cetaceans to various noise sources but were concerned about the relative absence of knowledge about effects of noise sources such as commercial sonars, depth finders and acoustics gear used by fisheries. Romano *et al*. (2004) measured blood parameters of the beluga whale and bottlenose dolphin exposed to noise. Norepinephrine, epinephrine, and dopamine levels, neurotransmitters related to stress, increased with increasing sound levels, and were significantly higher after high-level sound exposures compared with low-level sound exposures or controls.

Migrating humpback whales off the coast of Australia (Dunlop *et al*., 2016) were exposed to vessels with seismic air gun arrays to test whether a slow ramp-up of sound from a small seismic array would potentially limit acoustic exposure of whales close to the source better than a full-power start. Ramp up, or "soft start" is an exposure mitigation method that slowly increases the sound pressure over 20 to 40 minutes. Scientists at land-based stations monitored dive time and progress south for groups of whales (1-3 individuals each) over 20 kilometers. During seismic activity, whale groups changed their course and speeds, but not their surface behavior. The study found that humpback whales were likely to move away from the seismic source during ramp-up, and most whales appeared to avoid the source vessel at distances greater than the radius of most mitigation zones.

A second experiment conducted by this team (Dunlop *et al.*, 2017) compared the behavioral responses of humpback whales to a 3,130 cubic inch seismic air gun array with their baseline behavior during a seasonal southward migration. Responses ranged from no detectable response to small changes in the travel course, speed, and dive/respiration parameters. These responses varied widely and appeared to be determined by social context (adult groups versus mothers with calves), behavioral states, and individual variabilities. None of the observed behaviors were outside a normal repertoire, and no groups ceased navigation or social interactions. However, there was

[2] GAMM; to correlate non-linear responses to seismic activity, time of day, seasonality, or other variables

a reduced progression southward during air gun operations for some groups of whales, below typical migratory speeds, within 4 km of the source, at received SPL over 135 dB re 1 μPa.

Blackwell *et al.* (2013) assessed effects of air gun sounds on bowhead whale (*Balaena mysticetus*) calling behavior during the autumn migration. At the onset of air gun use, calls dropped significantly at sites near the air guns, but remained unchanged at sites distant from the air guns. This drop could result from a cessation of calling, deflection of whales around seismic activities, or both. Di Iorio and Clark (2009) investigated blue whale vocal behavior during a seismic survey and found that whales consistently called more on seismic exploration days and during periods when the air gun was operating. This increase was observed for the calls that are emitted during social encounters and feeding. The authors felt this response represents a compensatory behavior from the elevated noise from seismic survey operations.

Seals

Thompson *et al.* (1998) performed detailed observations of behavioral and physiological responses of harbor and grey seals to seismic disturbances. The harbor seals were fitted with telemetry devices to show changes in movement, dive behavior, swim speeds, and heart rates in response to controlled exposure experiments with small air guns (215-224 dB re 1 μPa peak sound pressure). The seals showed heart rate fright responses that were short-lived, and exhibited strong avoidance behavior, swimming rapidly away from the sound source. Stomach temperature tags revealed that they ceased feeding during this time. Behavior returned to normal soon after the end of each trial. The grey seals were not fitted with these devices, but they exhibited similar avoidance response, changing from foraging dives to transiting dives and moving away from the source. Some grey seals hauled out (possibly to avoid the noise). Seals returned to normal behavior two hours after the air gun ceased firing.

Gordon *et al.* (2003/4) also reviewed a study by Kastak *et al.* (1999) using harbor seals, sea lions, and elephant seals exposed to 20-25 minutes of low power sound pressure (60-75 dB above hearing threshold at a frequency range of 100 Hz to 2 kHz). The pinnipeds all exhibited a TTS, from which they recovered after 24 hours. It was clear to the reviewers that hearing threshold changes could be induced in pinnipeds by exposure to intense short-tones and sounds of moderate intensity for extended periods.

Turtles

A review article by Weilgart *et al.* (2013) stated that marine turtles show a strong avoidance response to air gun arrays at SPL 175 dB re 1 μPa or higher. Additionally, turtles in enclosures were shown to have progressively lower responses to successive air gun shots, which may indicate reduced hearing sensitivity (TTS).

McCauley *et al.* (2000) carried out trials with captive green and loggerhead turtles being approached by a single air gun. The turtles increased their swimming activity at approximately 166 dB re 1 μPa; above 175 dB re 1 μPa their behavior became more erratic. This indicates agitation and suggests avoidance behavior. This study also estimated that a typical air gun array operating in 100-120-meter water depths could impact turtle behavior at a distance of two kilometers and cause them to avoid the source from one kilometer away.

Fish

Adverse seismic-related impacts on fishes depend on multiple factors, including sound frequency characteristics and durations, the relationship of the animal's location to the seismic sound source, and a species' sensitivity to and spectral range of hearing. Carroll *et al.* (2017) noted that there is currently a disparity between results obtained in the field, where biological responses can be difficult to pinpoint when combined natural environmental variability, and results obtained from the laboratory, where exposure treatments or behavioral responses may be unrealistic.

There is evidence to suggest that seismic air guns can damage fish ears extensively at distances of up to several kilometers from the source, depending upon source size, water depth, and type of bottom. Caged pink snapper (*Pagrus auratus*) were exposed to air gun pulses towed toward and away in Jervoise Bay, Western Australia (to mimic a passing seismic vessel). The fish were sacrificed after exposure to evaluate ear sensory hair cells (compared to a non-exposed control group). The air gun source level was 223 dB re 1 µPa, which was 25 dB above background at 100 meters from the source, with the highest energy in the 20 Hz to 1,000 Hz spectrum (McCauley *et al.*, 2003). Fish were sacrificed 18 hours and 58 days after exposure. There was significant damage to the hair cells that was worse at 58 days than at 18 hours. This was expected, because damage is generally not visible for one or more days after exposure to intense sound. Approximately 15% of the hair cells were missing, and no recovery was apparent 58 days after exposure. It is unknown whether the remaining intact hair cells were still fully functional.

Trials with captive fish showed an "alarm" response of swimming faster, swimming toward the bottom, and tightening school structure at an estimated two to five kilometers from a seismic source. Captive fish exposed to short range air gun signals also showed damaged hearing structures (McCauley *et al.*, 2000). The studies included behavioral, physiological, and pathological measurements. Responses to air gun signals included:

- A greater startle response from small fish above 156-161 dB re 1 µPa, followed by a lessening of the severity of startle response with continued pulses (habituation);
- Increased use of the lower portion of the tank with a tendency for faster swimming and formation of tighter groups correlated to air gun use;
- Some evidence of damaged hearing in the form of ablated and damaged hair-cells; and
- Return to normal behavior within 30 minutes of firing the air gun.

Four categories of fish auditory capabilities have been proposed (BOEM 2014; Hawkins & Popper (2017):

1. Fish without a swim bladder – sensitive only to sound particle motion in a narrow band of frequencies (<400 Hz). Includes flatfishes (Pleuronectiformes), some gobies (Gobiiformes), and sharks, rays, and skates (Chondrichthyes)

2. Fish with a swim bladder that does not appear to have a role in hearing – sensitive only to particle motion in a narrow band of frequencies (<50 to 800-1,000 Hz). Includes salmonids (Salmonidae), some tunas (Scombridae), sturgeons (Acipenseriformes), and many other species.
3. Fish with a swim bladder that is close to, but not connected to the ear – sensitive to both particle motion and sound pressure with an extended hearing range (3,000+ Hz). Includes codfishes (Gadidae), eels (Anguilliformes), some drums and croakers (Sciaenidae), and possibly other species.
4. Fishes that have structures linking the swim bladder to the ear – sensitive primarily to sound pressure in the widest frequency range but may detect particle motion (>4 kHz; herring/shad 180 kHz). This group has a higher sensitivity to sound than the other three groups. Includes squirrelfishes (Holocentridae*),* drums and croakers (Sciaenidae), herrings and shad (Clupeidae), and the Otophysan fish (some marine catfish).

Carroll *et al.*, 2017 (and references therein) reported that much of the research on fish barotrauma due to low-frequency sound has focused on pile driving, which generates acute, high-intensity, low-frequency sound like seismic operations. Freshwater fishes that are exposed to pile driving show substantial damage to internal organs, including the swim bladder, liver, kidney and gonads.

Caged pallid sturgeon (*Scaphirhynchus albus*) and American paddlefish (*Polydon spathula*) exposed to a single air gun pulse from a small seismic air gun showed neither mortality nor lethal injury. In other caged experiments, teleost fish exhibited behavioral changes in response to seismic sound, such as startle and alarm responses, changes in schooling patterns and water column position, and swimming speeds. Startle and alarm responses have also been observed in captive fish several kilometers from a seismic sound source. The field depth distribution of free ranging whiting (*Merluccius bilinearis*) shifted downward to form a more compact layer at greater depth in response to an air gun. However, seismic effects on the distribution and abundance of pelagic herring were reported as insignificant, although blue whiting and mesopelagic species remained at a deeper depth during seismic exposure compared to their pre-exposure positions (Carroll *et al.*, 2017 and references therein).

Free ranging inshore reef fishes and invertebrates exposed to air guns in the 195-218 dB re 1 μPa range exhibited a startle response, but no species exhibited avoidance behaviors; coral reef fish (lane snapper (*Lutjanus synagris)*, schoolmaster snapper (*Lutjanus apodus)*, and Atlantic spadefish (*Chaetodipterus faber*)) produced less obvious startle responses after repeated exposures, as did *Pelates* species (Terapontidae) (Carroll *et al.*, 2017 and references therein). Reef fish behavior off the coast of North Carolina was evaluated *in situ* before, during, and after a seismic survey. Noise levels were estimated to exceed 170 dB re 1 μPa at the point closest to the reefs (0.7, 6.5, and 7.9 km from the survey vessel). Videos were obtained from one reef farthest from the sound source. Abundances remained low during the day of the seismic survey and fish occupying the reef during the evening declined by 78%.

TTS is a physical effect that has been observed in fish. There is a body of literature that reports anthropogenic sounds exceeding normal ambient noise may cause a temporary change in hearing sensitivity, which usually recovers within 24 hours post-exposure (Popper & Hastings 2009; BOEM 2014 and references therein). TTS tends to show up in species with specialized hearing (hearing sensitivity with a wide frequency range and a low hearing threshold). Three river species (lake chub (*Couesius plumbeus*), a hearing specialist, and northern pike (*Esox lucius*) and broad whitefish (*Coregonus nasus*), hearing non-specialists (hearing sensitivity with a low band width and high threshold)) placed in underwater mesh cages 30 to 40 centimeters (cm) from a speaker were exposed to 20 air gun shots over a 15-minute period (total volume of 730 in^3) (Popper *et al.*, 2005). The non-specialist whitefish and pike showed no significant TTS after 18 hours, but the lake chub demonstrated a TTS at 200 and 400 Hz, from which it recovered after 24 hours.

This temporary reduction in hearing sensitivity may affect fish communications, predator or prey detection, or the ability to assess the environment. However, the exposure level and duration causing such a temporary hearing loss varies widely, and is affected by the number of seismic repetitions, the frequency and duration of the sounds, the sound pressure level, and the health of the exposed animal (Carroll *et al.*, 2017 and references therein).

Although catch rates have been included in some seismic impact studies, results are inconsistent; as a result, both negative and no impact effects of seismic air guns on fish catch rates and abundances have been reported. Streever *et al.* (2016) studied the effects of air guns used in oil industry seismic surveys on fish catch per unit effort (CPUE). Catch rates were generally within the range of those found in 27 previous sampling seasons. The effect of air guns on eight species was assessed using a modified Before-After/Control-Impact analysis. Historical data and data from 2014 comprised the Before-After components of the analysis, and days without and with air gun activity comprised the Control-Impact components. Results showed significant changes associated with air guns in catch rates at one or more nets at $p < 0.1$ for all eight species and at $p < 0.05$ for seven of the eight. Changes included both increased and decreased catch rates, with nets closest to the air gun array showing a decrease in CPUE, perhaps reflecting displacement of fish in response to air gun sounds throughout the study area. Engas et al., (1996) found trawl catches of haddock and cod decreased seventy percent within a seismic shooting area, affecting large (over 60 cm) fish more than small fish. Abundances and catch rates did not return to pre-seismic levels during the 5-day post-seismic period.

Behavioral aspects are the response most studied, although very little is known about *in situ* behavioral effects during seismic survey activity (BOEM 2014 and references therein). A recent study off the coast of Australia attempted to assess the effects of seismic studies on catch rates by monitoring acoustically tagged sharks released in experimental (seismic activity) and control zones (Bruce *et al.*, 2018). Acoustic tag data showed that 65% of the tagged sharks left the survey area immediately upon release, but some returned to the study area sporadically throughout the seismic activity. Approximately one-third of the gummy sharks and swell sharks (*Cephaloscyllium* spp.) were present in the seismic area two days after the survey, suggesting that some of the animals moved out of the area to avoid the noise but came back when it ceased. Tiger flathead sharks increased swimming speed during the survey and changed diel movement patterns after the survey ended. The study showed an increase in catch rate after the survey for six species including tiger flathead (*Neoplatycephalus richardsoni*); goatfish (*Upeneichthys* spp); elephant fish

(*Allorhynchus milii*); broad nose shark (*Notorynchus cepedianus*) and school shark (*Galeorhinus galeus*); as well as a decrease for three species (gummy shark [*Mustelus antarcticus*], red gurnard [*Chelidonichthys kumu*], saw shark [*Pristiophorus* spp]). Catch rates showed an inconsistent relationship with seismic activity, and appear to be species specific (Bruce *et al.*, 2018).

Marine Invertebrates

Carroll *et al.*, 2017 (and references therein) concluded that, while research on the topic is limited, exposure to near-field, low-frequency sound may cause anatomical damage. Without more subtle anatomical studies on marine invertebrates after exposure to acute low-frequency sound, mortality may be the most useful indicator of barotrauma in these animals.

Carroll *et al.* (2017, and references therein) noted that, in field studies using air guns, they did not observe any reduction in abundance or catch rates after seismic exposure in snow crabs (12 days post-exposure), shrimp (two days post-exposure) or lobsters (weeks to years' post-exposure). Exposure to air guns did resulted in damaged statocysts in rock lobsters up to a year post-exposure, but no effects were detected in snow crabs after exposure to 200 air gun shots at 17 – 31 Hz (Carroll *et al.*, 2017 and references therein). Under field conditions, researchers found no evidence of increased mortality after seismic exposure in lobster (eight months post-exposure), clams (two days post-exposure), or scallops (ten months post-exposure), although dose-dependent mortality was observed in scallops transplanted to nets four months after air gun exposure (Carroll *et al.*, 2017 and references therein). However, a Fisheries and Oceans Canada study found hemorrhaging and membrane detachment in snow crab livers and ovaries and larval development delays when caged crabs were exposed to two blasts of a seismic airgun (Draft Habitat Status Report 2004).

Aguilar de Soto, *et al.* (2013) performed an experiment in a small tank (1.3m x 2m). They placed a transducer that emitted a 200 Hz – 22 kHz pulse every three seconds, with a SPL of 160 dB re 1 μPa, nine centimeters from scallop (*Pecten novaezelandiae*) larvae. While the control larvae were normal, 46% of the larvae exposed to sound exhibited malformations. The experiment focused on near-field exposure (in a laboratory tank)., Although the larvae were exposed to the same SPL as *in-situ* far-field, the proximity of the sound source means that the larvae likely experienced higher particle motion than would be anticipated in the far-field.

Roberts et al. (2015) investigated sound detection of blue mussels, M*ytilus edulis,* also using valve closure as an indicator of sound perception. They studied the impact of loud substrate-borne vibrations, like pile driving and blasting, and established the threshold sensitivity of mussels on a sand and gravel bottom. They found that responses were relatively constant from 5–90 Hz but showed a sharp decrease in sensitivity at 210 Hz.

Charifi et al. (2017) examined responses of oysters*, Crassostrea gigas*, to different levels of noise. At high enough acoustic energy, oysters closed their shells in response to frequencies in the range of 10 to <1000 Hz, with maximum sensitivity from 10 to 200 Hz. This response could be maladaptive since oysters need their valves to be open in order to feed and respire, so their health can depend on how much time they spend with their valves open. Day et al. (2017) studied physiological and behavioral effects of air gun noise on the scallop, *Pecten fumatus*. Following exposure to air-gun noise in the field, scallops had significantly increased mortality, disrupted behaviors and reflex responses, both during and after exposure to the noise, as well as changed hemolymph biochemistry, physiology, and osmoregulation.

4.2 Indirect Impacts

Relationships between members of an ecological community are classified within two broad categories, direct effects and indirect effects. Direct effects deal with a direct impact on an individual that is not mediated or transmitted through another individual. Indirect effects are defined as the impact on one organism or species that is mediated or transmitted by another species (Moon *et al.*, 2010). One example of an indirect impact is interaction modification, which occurs when a species alters some attribute, such as behavior. For example, if a prey species feels threatened and modifies their normal behaviors (e.g., foraging, breeding, habitat) in ways that make them unavailable to natural predators, the predator populations could be negatively affected. Indirect effects are much harder to measure (and to correlate with seismic activity) than are direct physical injuries, loss of hearing and/or visible behavior changes in marine mammals, fish, and invertebrates.

4.3 Cumulative Impacts

The effects of cumulative exposure to sound in the marine environment, the way in which effects from single exposures accumulate, and the potential for recovery between repeated exposures are poorly understood (Erbe 2012). Published research exists from recent ongoing efforts to predict through modeling cumulative levels received by animals from multiple sources, from moving sources, and from multiple exposures over long durations and large areas (Erbe and King 2009; Breitzke and Bohlen 2012; Erbe 2012; Ellison et al. 2016).

"Soundscape" monitoring through remote acoustic sensors, such as the NOAA/National Park Service (NPS) Ocean Noise Reference Station Network (Haver *et al.* 2018) can provide information on existing conditions that can be taken into consideration in determining overall cumulative effects of noise in the marine environment (Wiggins *et al.* 2016; Heenehan 2019). However, even though at least 30 global sites or networks are routinely collecting data on ocean noise, monitoring stations typically are set up to perform specific functions. A variety of sensor designs, and data collection and transmission protocols have been used and there is no central repository for data (Hawkins *et al.* 2015).

Many anthropogenic maritime activities may temporally and spatially coincide, including seismic testing, oil and gas extraction, wind energy development, shipping, navigational dredging, and commercial fishing. Effects such as habitat changes, pollution, sedimentation, direct mortality, or noise and vibration created by each of these activities may compound or otherwise interact and potentially result in cumulative impacts. These impacts can be additive, synergistic or antagonistic, and need to be taken into consideration when addressing the effects of seismic testing. However, while the importance of understanding cumulative effects is clear, there are many challenges inherent in developing quantitative and qualitive measurements of cumulative impacts on ocean resources and a rich scientific literature addressing these limitations.

Willsteed *et al*. (2016) reviewed cumulative effects assessment efforts, identified a multitude of approaches and research, and discussed key considerations and challenges relevant to assessing the cumulative effects of energy development and other activities on marine ecosystems. They recommend an approach that shifts away from the current reliance on disparate environmental impact assessments, and a move towards establishing a common system of coordinated data and research relative to ecologically meaningful areas.

Several published papers outline steps for assessing underwater noise and evaluating cumulative impacts that include: 1) determining which stressors must be included in an assessment, along with how much to lump versus split groups of stressors; 2) transforming and normalizing stressors so that highly different kinds of stressors (e.g., milligrams per liter of pollutant from land-based pollution, tons of fish caught by fisheries, degrees heating from climate change) can be compared to each other; 3) identifying receptors and noise exposure criteria; and 4) understanding how a species, habitat, or ecosystem responds to a particular stressor (Halpern and Fujita 2013; Faulkner *et al*. 2018).

Much of the initial and continued interest in understanding cumulative impacts is motivated by the assumption that synergies exist that would make the whole greater than the sum of the parts (Halpern and Fujita 2013). This can be challenging because these assumptions have typically not been tested and their validity is not known. In addition, stressor impacts may not always be additive, so it is critical to understand the specific response of the specific target to this stressor. For example, indirect effects of a stressor like spatial and temporal displacement may be additive, while direct effects such as injury and direct mortality may not be. Assessing the effects of cumulative and aggregate exposure has implications both in terms of dose/response relationships and more broadly in terms of designing mitigation measures. For example, it is critical to know if there is full recovery of function after damage and what is an adequate period of healing between sound exposures (Hawkins *at al*. 2015).

To improve assessment and more efficiently limit the cumulative impacts of numerous projects should be reviewed collectively and well in advance of the proposed activities so that they can be revised if necessary. However, the projects must be considered in terms of the background noise generated by commercial vessel traffic. Aggregated impact assessments that simultaneously consider multiple projects, cross-company collaborations and a better incorporation of uncertainty into decision making could also help limit, if not reduce, cumulative impacts of multiple human activities (Wright and Kyhn 2015).

5.0 MITIGATION MEASURES

Mitigation for biological impacts associated with seismic testing are required, or under consideration, in several geographic area, including the U.S., Russia, and Latin America. The mitigation approach required for a typical project reflects the size, scope, geographic location, and timing of the proposed seismic survey project.

There is a standard set of mitigation procedures for seismic surveys, as initially implemented by the regulator for Gulf of Mexico surveys by industry ("permitted" by BOEM). All IHA holders now follow those standard mitigation procedures for seismic surveys. These mitigation procedures can be found in numerous documents prepared in consultation with the regulator.

Mitigation measures that will be adopted during the planned surveys include (1) Vessel-based visual mitigation monitoring; (2) Vessel-based passive acoustic monitoring; (3) Establishment of an exclusion zone; (4) Power down procedures; (5) Shutdown procedures; (6) Ramp-up procedures; and (7) Vessel strike avoidance measures. Further details of what goes into a mitigation plan can be found in **Appendix B**, which is information extracted from a mitigation plan from a research study for which an IHA was granted in 2018 is included as Appendix B.

Mitigation measures that have been suggested by the environmental community including:

- Requiring and maintaining safety zones visually and with passive acoustic monitoring around the seismic array, to reduce the risk of injury to marine mammals and other species;

- Implementing other operational restrictions as necessary (such as reducing the number of air guns);

- Limiting periods of exposure to certain time of year windows for species of concern;

- Requiring use of alternative technologies and engineering modifications, such as baffling to eliminate unneeded higher-frequency output from the array

- Restricting seismic air gun operation in and near sensitive environmental areas, such as marine mammal feeding and breeding areas.

Other suggestions have included:

- Prohibiting redundant seismic surveys in the same area by encouraging data sharing. While this certainly has merit it is unlikely that two private corporations would do so if involved with petroleum exploration. However, if nothing were found in the first survey that information might be more readably shared.

- Cap the number and duration of seismic surveys allowed each year by region.

It can be concluded that there is insufficient information at present to evaluate whether mitigation measures are effective for all species.

6.0 ADDITIONAL STUDIES

Based on the research studies reviewed as part of the development of this paper, the need for additional studies into the impacts of sound generated as part of seismic surveys and potential mitigation approaches to the protection of aquatic species from sound waves generated by those surveys (Gordon *et al.*, 2003/4; Popper and Hawkins, 2016; and Rosenbaum and Southall, 2017). Those suggested studies are as follows:

- Development of baseline noise levels for marine life in the Mid-Atlantic area (currently lacking);
- Research into the impacts of air gun noise on zooplankton, the base of the aquatic food chain;
- Direct research with marine mammals as opposed to reliance on observations in the wild;
- More research on sea turtles, which are underrepresented in the scientific literature;
- More research into cumulative impacts of air guns. Specifically, the impacts of air guns over and above base noise levels of shipping areas and other areas of high ambient noise levels; and
- Conduct research into development of quieter survey methods;

7.0 CONCLUSIONS/RECOMMENDATIONS

The EPSC has reviewed an extensive body of research that has been published regarding the impacts of sound generated by air guns used as a component of seismic surveys. In general, the identified impacts are negative, with direct impacts being both physical (in terms of physical damage to auditory structures) and behavioral (changes in life activities). While not all of the impacts are believed to be permanent, the research has not demonstrated any underwater noise generation activity from air guns that is considered to have no effect or a positive influence.

As the NJDEP has the potential to review more plans for seismic surveys, the Department should consider the development of a stronger regulatory program to manage the needs of the companies to conduct the surveys. Some of the elements of the regulatory considerations would be:

- Continuous monitoring should be required as a component of the survey;
- Drones and other advanced technology be considered as part of monitoring activities;
- Time of year restrictions to ensure that sensitive elements of the aquatic community such as the North Atlantic right whale are protected;
- Restriction of sensitive breeding areas and/or habitat from seismic survey;
- More widespread use of marine mammal observers and more comprehensive observation protocols to ensure better field protection for marine mammals;
- More comprehensive use of mitigation measures;

- Better baseline documentation of potential marine mammals and other aquatic species found in a given area before approval of a survey effort; and

Additionally, the Department should consider better coordination with other states in the Mid-Atlantic region to coordinate the development of a baseline characterization of anthropogenic noise levels. The Department should also consider closer coordination with Federal agencies such as the National Marine Fisheries Service to ensure that the state concerns over seismic surveys are considered.

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Appendix A

Additional References Cited in Section 4

ADDITIONAL REFERENCES CITED IN SECTION 4

Author(s)	Title	Type	Species/ Location	Seismic Exp.	Funder/Assoc.	Website
André et al.	Low frequency sounds induce acoustic trauma in cephalopods	Caged	*Voligo vulgaris, Sepia officinalis, Octopus vulgaris, Illex coindetti*	5-400 Hz via loudspeaker for 2 hours, Animals in 2 L or 200 L cages	Spanish Ministry of the Environment	https://www.esa.org/pdfs/Andre.pdf
Aquilar de Soto et al.	Anthropogenic noise causes body malformations and delays development in marine larvae	Caged tank	New Zealand Scallop	200 Hz - 22 kHz every 3 sec., transducer placed 9 cm from larvae	EU 7th Frame Program, Marie Curie Actions	https://www.nature.com › scientific reports › articles
BOEM	Fish hearing and sensitivity to acoustic impacts - Appendix J	Government Report	Multiple Fishes		U.S. Bureau of Ocean Energy Management	https://www.cbd.int/doc/meetings/.../mcbem-2014-01-submission-boem-01-en.pdf

Bruce et al.	Quantifying fish behavior and commercial catch rates in relation to a marine seismic survey	Field and Desktop	Gummy shark, Tiger flathead shark, Swell shark and multiple fishes	40 Hz & 80 Hz 100 meters from sound source;	National Earth & Marine Obserations Branch, Geoscience Australia (CSIRO)	https://www.sciencedirect.com/science/article/pii/S0141113618300904
Carroll et al.	A critical review of the potential impacts of marine seismic surveys on fish and invertebrates	Review	Multiple		Australian government National CO_2 Infrastructure Program	https://www.sciencedirect.com/science/article/pii/S0025326X16309584
Castellote, M., Llorens, C.	Review of the effects of offshore seismic surveys in Cetaceans: Are mass strandings a possibility?	Review	Whales		NOAA, Seattle; Spanish Navy	https://www.ncbi.nlm.nih.gov/pubmed/26610953
Cerchio, S., Strindberg, S., Collins, T., Bennett, C., RosenbauM, H.	Seismic surveys negatively affect humpback whale singing activity off northern Angola	Field observations	Whales and Seismic survey vessel off the Angola coast	449 hour periods over 50 days; 10-11 sec apart; 0-500 Hz.	Cornell Bioacoustic Research, Wildlife Conservations Society, American Museum of Natural History	https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0086464

Dalen, J.	Effects of seismic surveys on fish, fish catches, and sea mammals	Government Report	Multiple		DNV Energy Cooperation Group - Fishery Industry and Petroleum Industry	https://pdfs.semanticscholar.org/1a6a/112c08b1a631250cb76add10eb34e155f50f.pdf
Day et al.	Exposure to seismic air gun signals causes physiological harm and alters behavior in scallop *Pecten fumatus*	Caged field	Scallop	One air gun simulated an array: 1,2,4 passes with pulses every 11.6 sec; 1 km from scallops	Australian Fisheries Research and Development Corp, Origin Energy, Carbon Net Project, Victorian Department of Economic Development, Jobs, Transport, and Resources	https://www.pnas.org/content/114/40/E8537
Dunlop et al.	The behavioral response of migrating humpback whales to a full seismic airgun array	Field land-based observations	Whale southward migration, east coast of Australia	Full commercial seismic air gun array	Joint Industry Programme on E&P Sound and Marine Life, International Association of Oil & Gas Producers	https://www.ncbi.nlm.nih.gov/pubmed/29237853
Dunlop et al.	Response of humpback whales (*Megaptera novaeanglise*) to ramp-up of a small	Field land-based observations	Whale southward migration, east coast of Australia	6 air guns at 4 levels of increasing dB with 1 constant source	Joint Industry Programme on E&P Sound and Marine Life (IOGP)	https://www.sciencedirect.com/science/article/pii/S0025326X15302435

	experimental air gun array					
Erbe et al.	Communication masking in marine mammals: A review and research strategy	Review	Multiple	Audiograms and masking	International Association of Oil & Gas Producers	https://www.sciencedirect.com/science/article/pii/S0025326X15302125
Gordon et al.	A Review of the effects of seismic survey on marine mammals	Review	Multiple		N/A	citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.472.128&rep=rep1...pdf
Hawkins, A.D., Popper, A.N.	A sound approach to assessing the impact of underwater noise on marine fishes and invertebrates	Review	Multiple		Aquatic Noise Trust, Scotland University of Maryland	https://academic.oup.com/icesjms/article-abstract/74/3/635/2739034
Hawkins, Pembroke, & Popper	Information gaps in understanding the effects of noise on fishes and invertebrates	Review	Multiple		University of Maryland	https://link.springer.com/article/10.1007/s11160-014-9369-3

Kunc et al.	Aquatic noise pollution: implications for individuals, populations, and ecosystems	Review	Multiple		Department of Agriculture, Environment, and Rural Affairs (DAERA)	https://royalsocietypublishing.org/doi/10.1098/rspb.2016.0839
McCauley et al.	High intensity anthropogenic sound damages fish ears	Cage Study	Pink snapper	6 pulses per min., 222.6 dB peak to peak, 5-15 to 400-800 meters from cages	Australian Petroleum Production and Exploration Association, U.S. Minerals Management Service	https://www.awionline.org/sites/default/files/.../McCauley-1238105863-10165.pdf
McCauley et al.	Widely used marine seismic survey air gun operations negatively impact zooplankton	Field	Zooplankton - 34 taxa	Single airgun with volume equal to 25 arrays, 120 kHz	Curtin University, Australia	https://www.nature.com › nature ecology & evolution › articles › article

Nelms et al.	Seismic surveys and marine turtles: An underestimated global threat?	Review	Multiple		Natural Environment Research Council and the Darwin Initiative	https://www.sciencedirect.com/science/article/pii/S0006320715301452
Paxton et al.	Seismic survey noise disrupted fish use of a temperate reef	*In situ* seismic survey	Multiple reef species	181 dB when closest to reefs	BOEM, NSF, NOAA	https://www.sciencedirect.com/science/article/pii/S0308597X16307382
Popper & Hastings	The effects of anthropogenic sources of sound on fishes	Review	Multiple Fishes		University of Maryland The Pennsylvania State University	https://www.ncbi.nlm.nih.gov/pubmed/20738551

Popper et al.	Effects of exposure to seismic air gun use on hearing of three fish species	Cage Study	Northern pike, Broad whitefish, Lake club	5-20 air gun shots in 1.9 m of water	University of Maryland Fisheries and Oceans Canada, Dept. of Indian Affairs and Northern Development, Inuvialuit Fisheries Joint Management Committee, WesternGeco	https://www.ncbi.nlm.nih.gov/pubmed/16018498
Przeslawski et al.	Multiple field-based methods to assess the potential impacts of seismic surveys on scallops	Field	Scallop	Single 2,530 in^3 array (16 air guns), 0-1 km from animals	Fisheries Research and Development Corporation, CSIRO, Geoscience Australia	https://www.sciencedirect.com/science/article/pii/S0025326X17309128
Solé, et al.	Offshore exposure experiments on cuttlefish indicate received sound pressure and particle motion levels associated with acoustic trauma	Caged	Cuttlefish	2 hour exposure at 7, 12, and 17 meters from 315-400 Hz sound source	European Union	https://www.nature.com › scientific reports › articles

Streever et al.	Changes in fish catch rates in the presence of air gun sounds in Prudhoe Bay, Alaska	Field Study	8 species in near shore waters	Frequency < 1kHz; Pressure 237 - 243 dB	BP Exploration Alaska, Inc.	https://tethys.pnnl.gov/sites/default/files/publications/Streever-et-al-2016.pdf
Weir, C.R.	Overt responses of humpback whales (*Megaptera novaeanglise*), sperm whales (*Physeter macrocephalus*) and Atlantic spotted dolphins (*Stenalla frontalis*) to seismic exploration off Angola	Field observations	Whales, dolphin and Seismic survey vessel off the Angola coast	10 months Array total volumes: 5,085 in^3 and 3,147 in^3	BP Exploration (Angola) Ltd.	https://www.aquaticmammalsjournal.org/index.php?...overt-responses-of-humpback-...
Williams, R. et al.	Impacts of anthropogenic noise on marine life: Publication patterns, new discoveries, and future directions in	Case Study Review			UK Department for Environment, Food, and Rural Affairs	https://www.sciencedirect.com/science/article/pii/S096456911500160X

	research and management					

Appendix B

Mitigation Requirements

EXAMPLE MITIGATION PLAN FOR SEISMIC SURVEY

Mitigation measures that will be adopted during the planned surveys include (1) Vessel-based visual mitigation monitoring; (2) Vessel-based passive acoustic monitoring; (3) Establishment of an exclusion zone; (4) Power down procedures; (5) Shutdown procedures; (6) Ramp-up procedures; and (7) Vessel strike avoidance measures. Note that additional measures have been included in the final IHA that were not contained in the proposed IHA. These measures are described in the following sections.

Vessel-Based Visual Mitigation Monitoring

Visual monitoring requires the use of trained observers (herein referred to as visual PSOs) to scan the ocean surface visually for the presence of marine mammals. The area to be scanned visually includes primarily the exclusion zone, but also the buffer zone. The buffer zone means an area beyond the exclusion zone to be monitored for the presence of marine mammals that may enter the exclusion zone. During pre-clearance monitoring (*i.e.,* before ramp-up begins), the buffer zone also acts as an extension of the exclusion zone in that observations of marine mammals within the buffer zone would also prevent airgun operations from beginning (*i.e.,* ramp-up). The buffer zone encompasses the area at and below the sea surface from the edge of the 0-500 meter exclusion zone, out to a radius of 1,000 meters from the edges of the airgun array (500-1,000 meters). Visual monitoring of the exclusion zones and adjacent waters is intended to establish and, when visual conditions allow, maintain zones around the sound source that are clear of marine mammals, thereby reducing or eliminating the potential for injury and minimizing the potential for more severe behavioral reactions for animals occurring close to the vessel. Visual monitoring of the buffer zone is intended to (1) provide additional protection to naïve marine mammals that may be in the area during pre-clearance, and (2) during airgun use, aid in establishing and maintaining the exclusion zone by alerting the visual observer and crew of marine mammals that are outside of, but may approach and enter, the exclusion zone. Note that L-DEO must monitor the Level B harassment zone beyond 1,000 meters and enumerate any takes beyond this buffer zone.

L-DEO must use at least five dedicated, trained, NMFS-approved Protected Species Observers (PSOs). The PSOs must have no tasks other than to conduct observational effort, record observational data, and communicate with and instruct relevant vessel crew with regard to the presence of marine mammals and mitigation requirements. PSO resumes shall be provided to NMFS for approval.

At least one of the visual and two of the acoustic PSOs aboard the vessel must have a minimum of 90 days at-sea experience working in those roles, respectively, during a deep penetration (*i.e.,* "high energy") seismic survey, with no more than 18 months elapsed since the conclusion of the at-sea experience. One visual PSO with such experience shall be designated as the lead for the entire protected species observation team. The lead PSO shall serve as primary point of contact for the vessel operator and ensure all PSO requirements per the IHA are met. To the maximum extent practicable, the experienced PSOs should be scheduled to be on duty with those PSOs with appropriate training but who have not yet gained relevant experience.

During survey operations (*e.g.,* any day on which use of the acoustic source is planned to occur, and whenever the acoustic source is in the water, whether activated or not), a minimum of two visual PSOs must be on duty and conducting visual observations at all times during daylight hours (*i.e.,* from 30 minutes prior to sunrise through 30 minutes following sunset) and 30 minutes prior to and during nighttime ramp-ups of the airgun array. Visual monitoring of the exclusion and buffer zones must begin no less than 30 minutes prior to ramp-up and must continue until one hour after use of the acoustic source ceases or until 30 minutes past sunset. Visual PSOs shall coordinate to ensure 360° visual coverage around the vessel from the most appropriate observation posts, and shall conduct visual observations using binoculars and the naked eye while free from distractions and in a consistent, systematic, and diligent manner. PSOs shall establish and monitor the exclusion and buffer zones. These zones shall be based upon the radial distance from the edges of the acoustic source (rather than being based on the center of the array or around the vessel itself). During use of the acoustic source (*i.e.,* anytime airguns are active, including ramp-up), occurrences of marine mammals within the buffer zone (but outside the exclusion zone) shall be communicated to the operator to prepare for the potential shutdown or powerdown of the acoustic source.

During use of the airgun (*i.e.,* anytime the acoustic source is active, including ramp-up), occurrences of marine mammals within the buffer zone (but outside the exclusion zone) should be communicated to the operator to prepare for the potential shutdown or powerdown of the acoustic source. Visual PSOs will immediately communicate all observations to the on duty acoustic PSO(s), including any determination by the PSO regarding species identification, distance, and bearing and the degree of confidence in the determination. Any observations of marine mammals by crew members shall be relayed to the PSO team. During good conditions (*e.g.,* daylight hours; Beaufort sea state (BSS) 3 or less), visual PSOs shall conduct observations when the acoustic source is not operating for comparison of sighting rates and behavior with and without use of the acoustic source and between acquisition periods, to the maximum extent practicable. Visual PSOs may be on watch for a maximum of two consecutive hours followed by a break of at least one hour between watches and may conduct a maximum of 12 hours of observation per 24-hour period. Combined observational duties (visual and acoustic but not at same time) may not exceed 12 hours per 24-hour period for any individual PSO.
For the final IHA, NMFS had added the requirement L-DEO must make a good faith effort to schedule their surveys to maximize the amount of seismic activity that takes place during daylight hours within the defined ranges of the Kohala resident stock of melon-headed whale and the Main Hawaiian Islands insular stock of fales killer whales. This will greatly assist PSOs in their efforts to effectively monitor these species. Furthermore, L-DEO must implement shutdown procedures if a melon-headed whale or group of melon-headed whales is observed in the Kohala resident stock's range.

Passive Acoustic Monitoring

Acoustic monitoring means the use of trained personnel (sometimes referred to as passive acoustic monitoring (PAM) operators, herein referred to as acoustic PSOs) to operate PAM equipment to acoustically detect the presence of marine mammals. Acoustic monitoring involves acoustically detecting marine mammals regardless of distance from the source, as localization of animals may not always be possible. Acoustic monitoring is intended to further support visual monitoring (during daylight hours) in maintaining an exclusion zone around the sound source that is clear of marine mammals. In cases where visual monitoring is not effective (*e.g.,* due to weather, nighttime), acoustic monitoring may be used to allow certain activities to occur, as further detailed below.

PAM would take place in addition to the visual monitoring program. Visual monitoring typically is not effective during periods of poor visibility or at night, and even with good visibility, if PSOs are unable to detect marine mammals when they are below the surface or beyond visual range. Acoustical monitoring can be used in addition to visual observations to improve detection, identification, and localization of cetaceans. The acoustic monitoring would serve to alert visual PSOs when vocalizing cetaceans are detected. It is only useful when marine mammals call, but it can be effective either by day or by night, and does not depend on good visibility. It would be monitored in real time so that the visual observers can be advised when cetaceans are detected.
The *R/V Langseth* will use a towed PAM system, which must be monitored by at a minimum one on duty acoustic PSO beginning at least 30 minutes prior to ramp-up and at all times during use of the acoustic source. Acoustic PSOs may be on watch for a maximum of four consecutive hours followed by a break of at least one hour between watches and may conduct a maximum of 12 hours of observation per 24-hour period. Combined observational duties (acoustic and visual but not at same time) may not exceed 12 hours per 24-hour period for any individual PSO.
Survey activity may continue for 30 minutes when the PAM system malfunctions or is damaged, while the PAM operator diagnoses the issue. If the diagnosis indicates that the PAM system must be repaired to solve the problem, operations may continue for an additional five hours without acoustic monitoring during daylight hours. In the proposed IHA, NMFS stated that only two hours of operations would be allowed without acoustic monitoring. However, L-DEO reported that approximately five hours are required to redeploy the spare PAM system if the primary PAM system fails. Note that operations may continue only under the following conditions:

- Sea state is less than or equal to BSS 4;
- No marine mammals (excluding delphinids) detected solely by PAM in the applicable exclusion zone in the previous two hours;
- NMFS is notified via email as soon as practicable with the time and location in which operations began occurring without an active PAM system; and
- Operations with an active acoustic source, but without an operating PAM system, do not exceed a cumulative total of five hours in any 24-hour period.

Establishment of an Exclusion Zone and Buffer Zone

An exclusion zone (EZ) is a defined area within which occurrence of a marine mammal triggers mitigation action intended to reduce the potential for certain outcomes, *e.g.,* auditory injury, disruption of critical behaviors. The PSOs would establish a minimum EZ with a 500 m radius for the 36 airgun array. The 500 m EZ would be based on radial distance from any element of the airgun array (rather than being based on the center of the array or around the vessel itself). With certain exceptions (described below), if a marine mammal appears within or enters this zone, the acoustic source would be shut down.

The 500 m EZ is intended to be precautionary in the sense that it would be expected to contain sound exceeding the injury criteria for all cetacean hearing groups, (based on the dual criteria of SELcum and peak SPL), while also providing a consistent, reasonably observable zone within which PSOs would typically be able to conduct effective observational effort. Additionally, a 500 m EZ is expected to minimize the likelihood that marine mammals will be exposed to levels likely to result in more severe behavioral responses. Although significantly greater distances may be observed from an elevated platform under good conditions, we believe that 500 m is likely regularly attainable for PSOs using the naked eye during typical conditions.

Pre-Clearance and Ramp-Up

Ramp-up (sometimes referred to as "soft start") means the gradual and systematic increase of emitted sound levels from an airgun array. Ramp-up begins by first activating a single airgun of the smallest volume, followed by doubling the number of active elements in stages until the full complement of an array's airguns are active. Each stage should be approximately the same duration, and the total duration should not be less than approximately 20 minutes. The intent of pre-clearance observation (30 minutes) is to ensure no protected species are observed within the buffer zone prior to the beginning of ramp-up. During pre-clearance is the only time observations of protected species in the buffer zone would prevent operations (*i.e.,* the beginning of ramp-up). The intent of ramp-up is to warn protected species of pending seismic operations and to allow sufficient time for those animals to leave the immediate vicinity. A ramp-up procedure, involving a step-wise increase in the number of airguns firing and total array volume until all operational airguns are activated and the full volume is achieved, is required at all times as part of the activation of the acoustic source. All operators must adhere to the following pre-clearance and ramp-up requirements:

- The operator must notify a designated PSO of the planned start of ramp-up as agreed upon with the lead PSO; the notification time should not be less than 60 minutes prior to the planned ramp-up in order to allow the PSOs time to monitor the exclusion and buffer zones for 30 minutes prior to the initiation of ramp-up (pre-clearance).
- Ramp-ups shall be scheduled so as to minimize the time spent with the source activated prior to reaching the designated run-in.
- One of the PSOs conducting pre-clearance observations must be notified again immediately prior to initiating ramp-up procedures and the operator must receive confirmation from the PSO to proceed.
- Ramp-up may not be initiated if any marine mammal is within the applicable exclusion or buffer zone. If a marine mammal is observed within the applicable exclusion zone or the buffer zone during the 30 minute pre-clearance period, ramp-up may not begin until the animal(s) has been observed exiting the zones or until an additional time period has elapsed with no further sightings (15 minutes for small odontocetes and 30 minutes for all other species).

- Ramp-up shall begin by activating a single airgun of the smallest volume in the array and shall continue in stages by doubling the number of active elements at the commencement of each stage, with each stage of approximately the same duration. Duration shall not be less than 20 minutes. The operator must provide information to the PSO documenting that appropriate procedures were followed.
- PSOs must monitor the exclusion and buffer zones during ramp-up, and ramp-up must cease and the source must be shut down upon observation of a marine mammal within the applicable exclusion zone. Once ramp-up has begun, observations of marine mammals within the buffer zone do not require shutdown or powerdown, but such observation shall be communicated to the operator to prepare for the potential shutdown or powerdown.
- Ramp-up may occur at times of poor visibility, including nighttime, if appropriate acoustic monitoring has occurred with no detections in the 30 minutes prior to beginning ramp-up. Acoustic source activation may only occur at times of poor visibility where operational planning cannot reasonably avoid such circumstances.

If the acoustic source is shut down for brief periods (*i.e.,* less than 30 minutes) for reasons other than that described for shutdown and powerdown (*e.g.,* mechanical difficulty), it may be activated again without ramp-up if PSOs have maintained constant visual and/or acoustic observation and no visual or acoustic detections of marine mammals have occurred within the applicable exclusion zone. For any longer shutdown, pre-clearance observation and ramp-up are required. For any shutdown at night or in periods of poor visibility (*e.g.,* BSS 4 or greater), ramp-up is required, but if the shutdown period was brief and constant observation was maintained, pre-clearance watch of 30 min is not required.

Testing of the acoustic source involving all elements requires ramp-up. Testing limited to individual source elements or strings does not require ramp-up but does require pre-clearance of 30 min.

Shutdown and Powerdown

The shutdown of an airgun array requires the immediate de-activation of all individual airgun elements of the array while a powerdown requires immediate de-activation of all individual airgun elements of the array except the single 40-in^3 airgun. Any PSO on duty will have the authority to delay the start of survey operations or to call for shutdown or powerdown of the acoustic source if a marine mammal is detected within the applicable exclusion zone. The operator must also establish and maintain clear lines of communication directly between PSOs on duty and crew controlling the acoustic source to ensure that shutdown and powerdown commands are conveyed swiftly while allowing PSOs to maintain watch. When both visual and acoustic PSOs are on duty, all detections will be immediately communicated to the remainder of the on-duty PSO team for potential verification of visual observations by the acoustic PSO or of acoustic detections by visual PSOs. When the airgun array is active (*i.e.,* anytime one or more airguns is active, including during ramp-up and powerdown) shutdown must occur under the following conditions:

- A marine mammal appears within or enters the applicable exclusion zone; and

- A marine mammal (other than delphinids, see below) is detected acoustically and localized within the applicable exclusion zone.
- The shutdown requirements described below have been added to the final IHA as they were not included in the proposed IHA. Under the following conditions L-DEO must implement shutdown:
- A marine mammal species, for which authorization was granted but the takes have been met, approaches the Level A or B harassment zones;
- A large whale with a calf or an aggregation of large whales is observed regardless of the distance from the *Langseth;*
- A melon-headed whale or group of melon-headed whales is observed in the range of the Kohala resident stock. This stock is found off the the Kohala Peninsula and west coast of Hawaii Island and at a depth of less than 2,500 m (Carretta *et al.* 2018). L-DEO will attempt to time their seismic operations along Trackline 1 so they will traverse the Kohala resident stock's range during daytime.
- A spinner or bottlenose dolphin or group of dolphins is observed approaching or is within the Level B harassment zone in the habitat of the specific MHI insular stock if the authorized takes have been met for any of these stocks.

When shutdown is called for by a PSO, the acoustic source will be immediately deactivated and any dispute resolved only following deactivation. Additionally, shutdown will occur whenever PAM alone (without visual sighting), confirms presence of marine mammal(s) in the EZ. If the acoustic PSO cannot confirm presence within the EZ, visual PSOs will be notified but shutdown is not required.

Following a shutdown, airgun activity would not resume until the marine mammal has cleared the 500 m EZ. The animal would be considered to have cleared the 500 m EZ if it is visually observed to have departed the 500 m EZ, or it has not been seen within the 500 m EZ for 15 min in the case of small odontocetes and pinnipeds, or 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales.

The shutdown requirement can be waived for small dolphins in which case the acoustic source shall be powered down to the single 40-in^3 airgun if an individual is visually detected within the exclusion zone. As defined here, the small delphinoid group is intended to encompass those members of the Family Delphinidae most likely to voluntarily approach the source vessel for purposes of interacting with the vessel and/or airgun array (*e.g.,* bow riding). This exception to the shutdown requirement would apply solely to specific genera of small dolphins including *Tursiops, Delphinus, Lagenodelphis, Lagenorhynchus, Lissodelphis, Stenella and Steno*. The acoustic source shall be powered down to 40-in^3 airgun if an individual belonging to these genera is visually detected within the 500 m exclusion zone. Note that when the acoustic source is powered down to the 40-in^3 airgun due to the presence of specified dolphins, a shutdown zone of 100 m and Level B harassment zone of 430 m will be in effect for species other than specified dolphin genera that may approach the survey vessel. This mitigation measure had not been included in the notice of proposed IHA.

Powerdown conditions shall be maintained until delphinids for which shutdown is waived are no longer observed within the 500 m exclusion zone, following which full-power operations may be resumed without ramp-up. Visual PSOs may elect to waive the powerdown requirement if delphinids for which shutdown is waived appear to be voluntarily approaching the vessel for the purpose of interacting with the vessel or towed gear, and may use best professional judgment in making this decision.

We include this small delphinoid exception because power-down/shutdown requirements for small delphinoids under all circumstances represent practicability concerns without likely commensurate benefits for the animals in question. Small delphinoids are generally the most commonly observed marine mammals in the specific geographic region and would typically be the only marine mammals likely to intentionally approach the vessel. As described above, auditory injury is extremely unlikely to occur for mid-frequency cetaceans (*e.g.,* delphinids), as this group is relatively insensitive to sound produced at the predominant frequencies in an airgun pulse while also having a relatively high threshold for the onset of auditory injury (*i.e.,* permanent threshold shift).

A large body of anecdotal evidence indicates that small delphinoids commonly approach vessels and/or towed arrays during active sound production for purposes of bow riding, with no apparent effect observed in those delphinoids (*e.g.,* Barkaszi *et al.,* 2012). The potential for increased shutdowns resulting from such a measure would require the Langseth to revisit the missed track line to reacquire data, resulting in an overall increase in the total sound energy input to the marine environment and an increase in the total duration over which the survey is active in a given area. Although other mid-frequency hearing specialists (*e.g.,* large delphinoids) are no more likely to incur auditory injury than are small delphinoids, they are much less likely to approach vessels. Therefore, retaining a power-down/shutdown requirement for large delphinoids would not have similar impacts in terms of either practicability for the applicant or corollary increase in sound energy output and time on the water. We do anticipate some benefit for a power-down/shutdown requirement for large delphinoids in that it simplifies somewhat the total range of decision-making for PSOs and may preclude any potential for physiological effects other than to the auditory system as well as some more severe behavioral reactions for any such animals in close proximity to the source vessel.

Visual PSOs shall use best professional judgment in making the decision to call for a shutdown if there is uncertainty regarding identification (*i.e.,* whether the observed marine mammal(s) belongs to one of the delphinid genera for which shutdown is waived or one of the species with a larger exclusion zone). If PSOs observe any behaviors in a small delphinid for which shutdown is waived that indicate an adverse reaction, then powerdown will be initiated immediately.
Upon implementation of shutdown, the source may be reactivated after the marine mammal(s) has been observed exiting the applicable exclusion zone (*i.e.,* animal is not required to fully exit the buffer zone where applicable) or following 15 minutes for small odontocetes and 30 minutes for all other species with no further observation of the marine mammal(s).

In the event of a live stranding (or near-shore atypical milling) event, L-DEO must adhere to recently established protocols, which were not contained in the proposed IHA. If the stranding event occurs within 50 km of the survey operations, where the NMFS stranding network is engaged in herding or other interventions to return animals to the water, the Director of OPR, NMFS (or designee) will advise the IHA-holder of the need to implement shutdown procedures for all active acoustic sources operating within 50 km of the stranding. Shutdown procedures for live stranding or milling marine mammals include the following:

- If at any time, the marine mammal(s) die or are euthanized, or if herding/intervention efforts are stopped, the Director of OPR, NMFS (or designee) will advise the IHA-holder that the shutdown around the animals' location is no longer needed.
- Otherwise, shutdown procedures will remain in effect until the Director of OPR, NMFS (or designee) determines and advises the IHA-holder that all live animals involved have left the area (either of their own volition or following an intervention).
- If further observations of the marine mammals indicate the potential for re-stranding, additional coordination with the IHA-holder will be required to determine what measures are necessary to minimize that likelihood (*e.g.,* extending the shutdown or moving operations farther away) and to implement those measures as appropriate.

Shutdown procedures are not related to the investigation of the cause of the stranding and their implementation is not intended to imply that the specified activity is the cause of the stranding. Rather, shutdown procedures are intended to protect marine mammals exhibiting indicators of distress by minimizing their exposure to possible additional stressors, regardless of the factors that contributed to the stranding.

Vessel Strike Avoidance

These measures apply to all vessels associated with the planned survey activity; however, we note that these requirements do not apply in any case where compliance would create an imminent and serious threat to a person or vessel or to the extent that a vessel is restricted in its ability to maneuver and, because of the restriction, cannot comply. These measures include the following:

- Vessel operators and crews must maintain a vigilant watch for all marine mammals and slow down, stop their vessel, or alter course, as appropriate and regardless of vessel size, to avoid striking any marine mammal. A single marine mammal at the surface may indicate the presence of submerged animals in the vicinity of the vessel; therefore, precautionary measures should be exercised when an animal is observed. A visual observer aboard the vessel must monitor a vessel strike avoidance zone around the vessel (specific distances detailed below), to ensure the potential for strike is minimized. Visual observers monitoring the vessel strike avoidance zone can be either third-party observers or crew members, but crew members responsible for these duties must be provided sufficient training to distinguish marine mammals from other phenomena and broadly to identify a marine mammal to broad taxonomic group (*i.e.,* as a large whale or other marine mammal).

- Vessel speeds must be reduced to 10 kn or less when mother/calf pairs, pods, or large assemblages of any marine mammal are observed near a vessel.
- All vessels must maintain a minimum separation distance of 100 m from large whales (*i.e.,* sperm whales and all baleen whales.
- All vessels must attempt to maintain a minimum separation distance of 50 m from all other marine mammals, with an exception made for those animals that approach the vessel.
- When marine mammals are sighted while a vessel is underway, the vessel should take action as necessary to avoid violating the relevant separation distance (*e.g.,* attempt to remain parallel to the animal's course, avoid excessive speed or abrupt changes in direction until the animal has left the area). If marine mammals are sighted within the relevant separation distance, the vessel should reduce speed and shift the engine to neutral, not engaging the engines until animals are clear of the area. This recommendation does not apply to any vessel towing gear.
- We have carefully evaluated the suite of mitigation measures described here and considered a range of other measures in the context of ensuring that we prescribe the means of effecting the least practicable adverse impact on the affected marine mammal species and stocks and their habitat. Based on our evaluation of the planned measures, NMFS has determined that the mitigation measures provide the means effecting the least practicable impact on the affected species or stocks and their habitat, paying particular attention to rookeries, mating grounds, and areas of similar significance.

Monitoring and Reporting

In order to issue an IHA 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 authorizations 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 in the action area. Effective reporting is critical both to compliance as well as ensuring that the most value is obtained from the required monitoring.
Monitoring and reporting requirements prescribed by NMFS should contribute to improved understanding of one or more of the following:

- Occurrence of marine mammal species or stocks in the area in which take is anticipated (*e.g.,* presence, abundance, distribution, density).
- Nature, scope, or context of likely marine mammal exposure to potential stressors/impacts (individual or cumulative, acute or chronic), through better understanding of: (1) Action or environment (*e.g.,* source characterization, propagation, ambient noise); (2) affected species (*e.g.,* life history, dive patterns); (3) co-occurrence of marine mammal species with the action; or (4) biological or behavioral context of exposure (*e.g.,* age, calving or feeding areas).

- Individual marine mammal responses (behavioral or physiological) to acoustic stressors (acute, chronic, or cumulative), other stressors, or cumulative impacts from multiple stressors.
- How anticipated responses to stressors impact either: (1) Long-term fitness and survival of individual marine mammals; or (2) populations, species, or stocks.
- Effects on marine mammal habitat (*e.g.,* marine mammal prey species, acoustic habitat, or other important physical components of marine mammal habitat).
- Mitigation and monitoring effectiveness.
- Vessel-Based Visual Monitoring

As described above, PSO observations would take place during daytime airgun operations and nighttime start ups (if applicable) of the airguns. During seismic operations, at least five visual PSOs would be based aboard the *Langseth.* Monitoring shall be conducted in accordance with the following requirements:

- The operator shall provide PSOs with bigeye binoculars (*e.g.,* 25 × 150; 2.7 view angle; individual ocular focus; height control) of appropriate quality (*i.e.,* Fujinon or equivalent) solely for PSO use. These shall be pedestal-mounted on the deck at the most appropriate vantage point that provides for optimal sea surface observation, PSO safety, and safe operation of the vessel.
- The operator will work with the selected third-party observer provider to ensure PSOs have all equipment (including backup equipment) needed to adequately perform necessary tasks, including accurate determination of distance and bearing to observed marine mammals. (c) PSOs must have the following requirements and qualifications:
- PSOs shall be independent, dedicated, trained visual and acoustic PSOs and must be employed by a third-party observer provider.
- PSOs shall have no tasks other than to conduct observational effort (visual or acoustic), collect data, and communicate with and instruct relevant vessel crew with regard to the presence of protected species and mitigation requirements (including brief alerts regarding maritime hazards),
- PSOs shall have successfully completed an approved PSO training course appropriate for their designated task (visual or acoustic). Acoustic PSOs are required to complete specialized training for operating PAM systems and are encouraged to have familiarity with the vessel with which they will be working.
- PSOs can act as acoustic or visual observers (but not at the same time) as long as they demonstrate that their training and experience are sufficient to perform the task at hand.
- NMFS must review and approve PSO resumes accompanied by a relevant training course information packet that includes the name and qualifications (*i.e.,* experience, training completed, or educational background) of the instructor(s), the course outline or syllabus, and course reference material as well as a document stating successful completion of the course.
- NMFS shall have one week to approve PSOs from the time that the necessary information is submitted, after which PSOs meeting the minimum requirements shall automatically be considered approved.

- PSOs must successfully complete relevant training, including completion of all required coursework and passing (80 percent or greater) a written and/or oral examination developed for the training program.
- PSOs must have successfully attained a bachelor's degree from an accredited college or university with a major in one of the natural sciences, a minimum of 30 semester hours or equivalent in the biological sciences, and at least one undergraduate course in math or statistics.
- The educational requirements may be waived if the PSO has acquired the relevant skills through alternate experience. Requests for such a waiver shall be submitted to NMFS and must include written justification. Requests shall be granted or denied (with justification) by NMFS within one week of receipt of submitted information. Alternate experience that may be considered includes, but is not limited to (1) secondary education and/or experience comparable to PSO duties; (2) previous work experience conducting academic, commercial, or government-sponsored protected species surveys; or (3) previous work experience as a PSO; the PSO should demonstrate good standing and consistently good performance of PSO duties.

For data collection purposes, PSOs shall use standardized data collection forms, whether hard copy or electronic. PSOs shall record detailed information about any implementation of mitigation requirements, including the distance of animals to the acoustic source and description of specific actions that ensued, the behavior of the animal(s), any observed changes in behavior before and after implementation of mitigation, and if shutdown was implemented, the length of time before any subsequent ramp-up of the acoustic source. If required mitigation was not implemented, PSOs should record a description of the circumstances. At a minimum, the following information must be recorded:

- Vessel names (source vessel and other vessels associated with survey) and call signs;
- PSO names and affiliations;
- Dates of departures and returns to port with port name;
- Dates and times (Greenwich Mean Time) of survey effort and times corresponding with PSO effort;
- Vessel location (latitude/longitude) when survey effort began and ended and vessel location at beginning and end of visual PSO duty shifts;
- Vessel heading and speed at beginning and end of visual PSO duty shifts and upon any line change;
- Environmental conditions while on visual survey (at beginning and end of PSO shift and whenever conditions changed significantly), including BSS and any other relevant weather conditions including cloud cover, fog, sun glare, and overall visibility to the horizon;
- Factors that may have contributed to impaired observations during each PSO shift change or as needed as environmental conditions changed (*e.g.,* vessel traffic, equipment malfunctions); and
- Survey activity information, such as acoustic source power output while in operation, number and volume of airguns operating in the array, tow depth of the array, and any

other notes of significance (*i.e.,* pre-clearance, ramp-up, shutdown, testing, shooting, ramp-up completion, end of operations, streamers, etc.).

- The following information should be recorded upon visual observation of any protected species:
- Watch status (sighting made by PSO on/off effort, opportunistic, crew, alternate vessel/platform);
- PSO who sighted the animal;
- Time of sighting;
- Vessel location at time of sighting;
- Water depth;
- Direction of vessel's travel (compass direction);
- Direction of animal's travel relative to the vessel;
- Pace of the animal;
- Estimated distance to the animal and its heading relative to vessel at initial sighting;
- Identification of the animal (*e.g.,* genus/species, lowest possible taxonomic level, or unidentified) and the composition of the group if there is a mix of species;
- Estimated number of animals (high/low/best);
- Estimated number of animals by cohort (adults, yearlings, juveniles, calves, group composition, etc.);
- Description (as many distinguishing features as possible of each individual seen, including length, shape, color, pattern, scars or markings, shape and size of dorsal fin, shape of head, and blow characteristics);
- Detailed behavior observations (*e.g.,* number of blows/breaths, number of surfaces, breaching, spyhopping, diving, feeding, traveling; as explicit and detailed as possible; note any observed changes in behavior);
- Animal's closest point of approach (CPA) and/or closest distance from any element of the acoustic source;
- Platform activity at time of sighting (*e.g.,* deploying, recovering, testing, shooting, data acquisition, other); and
- Description of any actions implemented in response to the sighting (*e.g.,* delays, shutdown, ramp-up) and time and location of the action.

If a marine mammal is detected while using the PAM system, the following information should be recorded:

- An acoustic encounter identification number, and whether the detection was linked with a visual sighting;
- Date and time when first and last heard;
- Types and nature of sounds heard (*e.g.,* clicks, whistles, creaks, burst pulses, continuous, sporadic, strength of signal);
- Any additional information recorded such as water depth of the hydrophone array, bearing of the animal to the vessel (if determinable), species or taxonomic group (if determinable), spectrogram screenshot, and any other notable information.

L-DEO will be required to shall submit a draft comprehensive report to NMFS on all activities and monitoring results within 90 days of the completion of the survey or expiration of the IHA, whichever comes sooner. The report must describe all activities conducted and sightings of protected species near the activities, must provide full documentation of methods, results, and interpretation pertaining to all monitoring, and must summarize the dates and locations of survey operations and all protected species sightings (dates, times, locations, activities, associated survey activities). The report must include estimates of the number and nature of exposures that occurred above the harassment threshold based on PSO observations, including an estimate of those on the trackline but not detected. The report must also include geo-referenced time-stamped vessel tracklines for all time periods during which airguns were operating. Tracklines should include points recording any change in airgun status (*e.g.,* when the airguns began operating, when they were turned off, or when they changed from full array to single gun or vice versa). GIS files must be provided in ESRI shapefile format and include the UTC date and time, latitude in decimal degrees, and longitude in decimal degrees. All coordinates shall be referenced to the WGS84 geographic coordinate system. In addition to the report, all raw observational data must be made available to NMFS. The report must summarize the information submitted in interim monthly reports as well as additional data collected as described above and the IHA. The draft report must be accompanied by a certification from the lead PSO as to the accuracy of the report, and the lead PSO may submit directly NMFS a statement concerning implementation and effectiveness of the required mitigation and monitoring. A final report must be submitted within 30 days following resolution of any comments on the draft report.

Reporting Injured or Dead Marine Mammals

NMFS has revised the standard protcols that apply when an injured or dead marine mammal is discovered and has included them here. These updated protocols were not described in the proposed IHA. In the event that personnel involved in survey activities covered by the authorization discover an injured or dead marine mammal, the IHA-holder shall report the incident to the Office of Protected Resources (OPR), NMFS and to the NMFS Pacific Islands Regional Stranding Coordinator as soon as feasible. The report must include the following information:

- Time, date, and location (latitude/longitude) of the first discovery (and updated location information if known and applicable);
- Species identification (if known) or description of the animal(s) involved;
- Condition of the animal(s) (including carcass condition if the animal is dead);
- Observed behaviors of the animal(s), if alive;
- If available, photographs or video footage of the animal(s); and
- General circumstances under which the animal was discovered.

Additional Information Requests—If NMFS determines that the circumstances of any marine mammal stranding found in the vicinity of the activity suggest investigation of the association with survey activities is warranted (example circumstances noted below), and an investigation into the stranding is being pursued, NMFS will submit a written request to the IHA-holder indicating that the following initial available information must be provided as soon as possible, but no later than 7 business days after the request for information.

- Status of all sound source use in the 48 hours preceding the estimated time of stranding and within 50 km of the discovery/notification of the stranding by NMFS; and
- If available, description of the behavior of any marine mammal(s) observed preceding (*i.e.,* within 48 hours and 50 km) and immediately after the discovery of the stranding.

Examples of circumstances that could trigger the additional information request include, but are not limited to, the following:

- Atypical nearshore milling events of live cetaceans;
- Mass strandings of cetaceans (two or more individuals, not including cow/calf pairs);
- Beaked whale strandings;
- Necropsies with findings of pathologies that are unusual for the species or area; or
- Stranded animals with findings consistent with blast trauma.
- In the event that the investigation is still inconclusive, the investigation of the association of the survey activities is still warranted, and the investigation is still being pursued, NMFS may provide additional information requests, in writing, regarding the nature and location of survey operations prior to the time period above.
- *Vessel Strike*—In the event of a ship strike of a marine mammal by any vessel involved in the activities covered by the authorization, L-DEO must shall report the incident to OPR, NMFS and to regional stranding coordinators as soon as feasible. The report must include the following information:
- Time, date, and location (latitude/longitude) of the incident;
- Species identification (if known) or description of the animal(s) involved;
- Vessel's speed during and leading up to the incident;
- Vessel's course/heading and what operations were being conducted (if applicable);
- Status of all sound sources in use;
- Description of avoidance measures/requirements that were in place at the time of the strike and what additional measures were taken, if any, to avoid strike;
- Environmental conditions (*e.g.,* wind speed and direction, Beaufort sea state, cloud cover, visibility) immediately preceding the strike;
- Estimated size and length of animal that was struck;
- Description of the behavior of the marine mammal immediately preceding and following the strike;
- If available, description of the presence and behavior of any other marine mammals immediately preceding the strike;
- Estimated fate of the animal (*e.g.,* dead, injured but alive, injured and moving, blood or tissue observed in the water, status unknown, disappeared); and
- To the extent practicable, photographs or video footage of the animal(s).

Negligible Impact Analysis and Determination

NMFS has defined negligible impact 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" (50 CFR 216.103). 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 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 harassment, NMFS considers other factors, such as the likely nature of any responses (*e.g.,* intensity, duration), the context of any responses (*e.g.,* critical reproductive time or location, migration), as well as effects on habitat, and the likely effectiveness of the mitigation. We also assess the number, intensity, and context of estimated takes by evaluating this information relative to population status. Consistent with the 1989 preamble for NMFS' implementing regulations (54 FR 40338; September 29, 1989), the impacts from other past and ongoing anthropogenic activities are incorporated into this analysis via their impacts on the environmental baseline (*e.g.,* as reflected in the regulatory status of the species, population size and growth rate where known, ongoing sources of human-caused mortality, or ambient noise levels).

To avoid repetition, our analysis applies to all species listed in Table 7 and 8, given that NMFS expects the anticipated effects of the planned seismic survey to be similar in nature. Where there are meaningful differences between species or stocks, or groups of species, in anticipated individual responses to activities, impact of expected take on the population due to differences in population status, or impacts on habitat, NMFS has identified species-specific factors to inform the analysis.

NMFS does not anticipate that serious injury or mortality would occur as a result of L-DEO's planned surveys, even in the absence of planned mitigation. As discussed in the *Potential Effects* section, non-auditory physical effects, stranding, and vessel strike are not expected to occur.

NMFS has authorized a limited number of instances of Level A harassment of 6 species and Level B harassment of 39 marine mammal species. However, we believe that any PTS incurred in marine mammals as a result of the activity would be in the form of only a small degree of PTS, not total deafness, and would be unlikely to affect the fitness of any individuals, because of the constant movement of both the *Langseth* and of the marine mammals in the project areas, as well as the fact that the vessel is not expected to remain in any one area in which individual marine mammals would be expected to concentrate for an extended period of time (*i.e.,* since the duration of exposure to loud sounds will be relatively short). We expect that the majority of takes would be in the form of short-term Level B behavioral harassment in the form of temporary avoidance of the area or decreased foraging (if such activity were occurring), reactions that are considered to be of low severity and with no lasting biological consequences (*e.g.,* Southall *et al.,* 2007).

Potential impacts to marine mammal habitat were discussed previously in this document (see *Potential Effects of the Specified Activity on Marine Mammals and their Habitat*). Marine mammal habitat may be impacted by elevated sound levels, but these impacts would be temporary. Feeding behavior is not likely to be significantly impacted, as marine mammals appear to be less likely to exhibit behavioral reactions or avoidance responses while engaged in feeding activities (Richardson *et al.,* 1995). Prey species are mobile and are broadly distributed throughout the project areas; therefore, marine mammals that may be temporarily displaced during survey activities are expected to be able to resume foraging once they have moved away from areas with disturbing levels of underwater noise. Because of the relatively short duration (up to 24 days for Hawaii survey) and temporary nature of the disturbance as well as the availability of similar habitat and resources in the surrounding area, the impacts to marine mammals and the food sources that they utilize are not expected to cause significant or long-term consequences for individual marine mammals or their populations.

The activity is expected to impact a small percentage of all marine mammal stocks that would be affected by L-DEO's planned survey (less than 15 percent percent of all species, including those taken by both surveys). Additionally, the acoustic “footprint” of the planned surveys would be small relative to the ranges of the marine mammals that would potentially be affected. Sound levels would increase in the marine environment in a relatively small area surrounding the vessel compared to the range of the marine mammals within the planned survey area.

The required mitigation measures are expected to reduce the severity of takes by allowing for detection of marine mammals in the vicinity of the vessel by visual and acoustic observers, and by minimizing the severity of any potential exposures via power downs and/or shutdowns of the airgun array. Based on previous monitoring reports for substantially similar activities that have been previously authorized by NMFS, we expect that the required mitigation will be effective in preventing at least some extent of potential PTS in marine mammals that may otherwise occur in the absence of the mitigation.