NOAA's National Marine Fisheries Service
Endangered Species Act Section 7 Consultation

Biological and Conference Opinion

Agencies:	National Science Foundation-Division of Ocean Sciences and NOAA's National Marine Fisheries Service-Office of Protected Resources-Permits, Conservation, and Education Division
Activities Considered:	Seismic survey by the Scripps Institute of Oceanography in the western tropical North Pacific and issuance of an Incidental Harassment Authorization pursuant to section 101(a)(5)(D) of the Marine Mammal Protection Act (MMPA)
Consultation Conducted by:	NOAA's National Marine Fisheries Service-Office of Protected Resources-Endangered Species Division
Approved by:	
Date:	OCT 31 2011

Section 7(a)(2) of the Endangered Species Act (ESA)(16 U.S.C. 1531 *et seq.*) requires that each federal agency shall ensure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat of such species. When the action of a federal agency "may affect" a listed species or critical habitat designated for them, that agency is required to consult with either the NOAA's National Marine Fisheries Service (NMFS) or the U.S. Fish and Wildlife Service, depending upon the listed resources that may be affected. For the actions described in this document, the action agencies are the National Science Foundation (NSF), which proposes to fund the Scripps Institute of Oceanography (SIO) to conduct a seismic survey in the western tropical North Pacific near Wake Island from November to December of 2011 and the NMFS' Office of Protected Resources-Permits, Conservation, and Education Division (Permits Division), which proposes to authorize the NSF and SIO to "take" marine mammals incidental to those seismic surveys. The consulting agency for these proposals is the NMFS' Office of Protected Resources – Endangered Species Division (Endangered Species Division).

This document represents the NMFS' biological and conference opinion (Opinion) of the effects of the proposed actions on endangered and threatened species, as well as species proposed for listing, and designated critical habitat and has been prepared in accordance with section 7 of the ESA. This Opinion is based on information provided in the Incidental Harassment Authorization (IHA) application, draft IHA, environmental assessment, monitoring reports from similar activities, published and unpublished scientific information on endangered and threatened species and their surrogates, scientific and commercial information such as reports from government agencies and the peer-reviewed literature, Opinions on similar activities, and other sources of information.

Consultation history

On June 9, 2011, the NMFS' Endangered Species Division received a request for formal consultation from the NSF to incidentally harass marine mammals during a seismic survey cruise in the western tropical North Pacific. Information was deemed sufficient to initiate consultation on the same date. The following day, the Permits Division received an application from NSF for SIO to incidentally harass marine mammal species during a seismic survey cruise through the western tropical North Pacific.

On July 25, 2011, as a result of the NSFs application, the Endangered Species Division received a request for formal consultation from the Permits Division to authorize incidental harassment of marine mammals during a seismic survey cruise through the western tropical North Pacific. Information was determined to be sufficient to initiate consultation on this date.

On July 29, 2011, the Permits Division sent the application out to reviewers and published a notice in the Federal Register soliciting public comment on its intent to issue an IHA.

Description of the proposed actions

Section 7(a)(2) of the Endangered Species Act (ESA)(16 U.S.C. 1531 *et seq.*) requires that each federal agency shall ensure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat of such species.

The NSF proposes to fund the SIO to conduct a seismic survey in the western tropical North Pacific near Wake Island from roughly 5 November-17 December, 2011. It is possible that delays could occur due to weather, equipment malfunctions, or other unforeseen circumstances. Thus, the IHA is proposed to be effective until 31 January, 2011. The *R/V Thomas G. Thompson* (*Thompson*) would conduct the survey. The *Thompson* would deploy an array of two airguns as an energy source, an 800 m-long hydrophone streamer, and 50 passive acoustic sonobuoys. In addition, a multibeam echosounder and a sub-bottom profiler would continuously operate from the *Thompson* during the survey. An autonomous underwater vehicle would be towed behind the *Thompson*. The Permits Division proposes to issue an IHA for takes of marine mammals that would occur incidental to these studies, pursuant to section 101(a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. §1371 (a)(5)(D).

The purpose of the proposed activities is obtaining a better understanding of the variations in Earth's magnetic field during the Jurassic period.

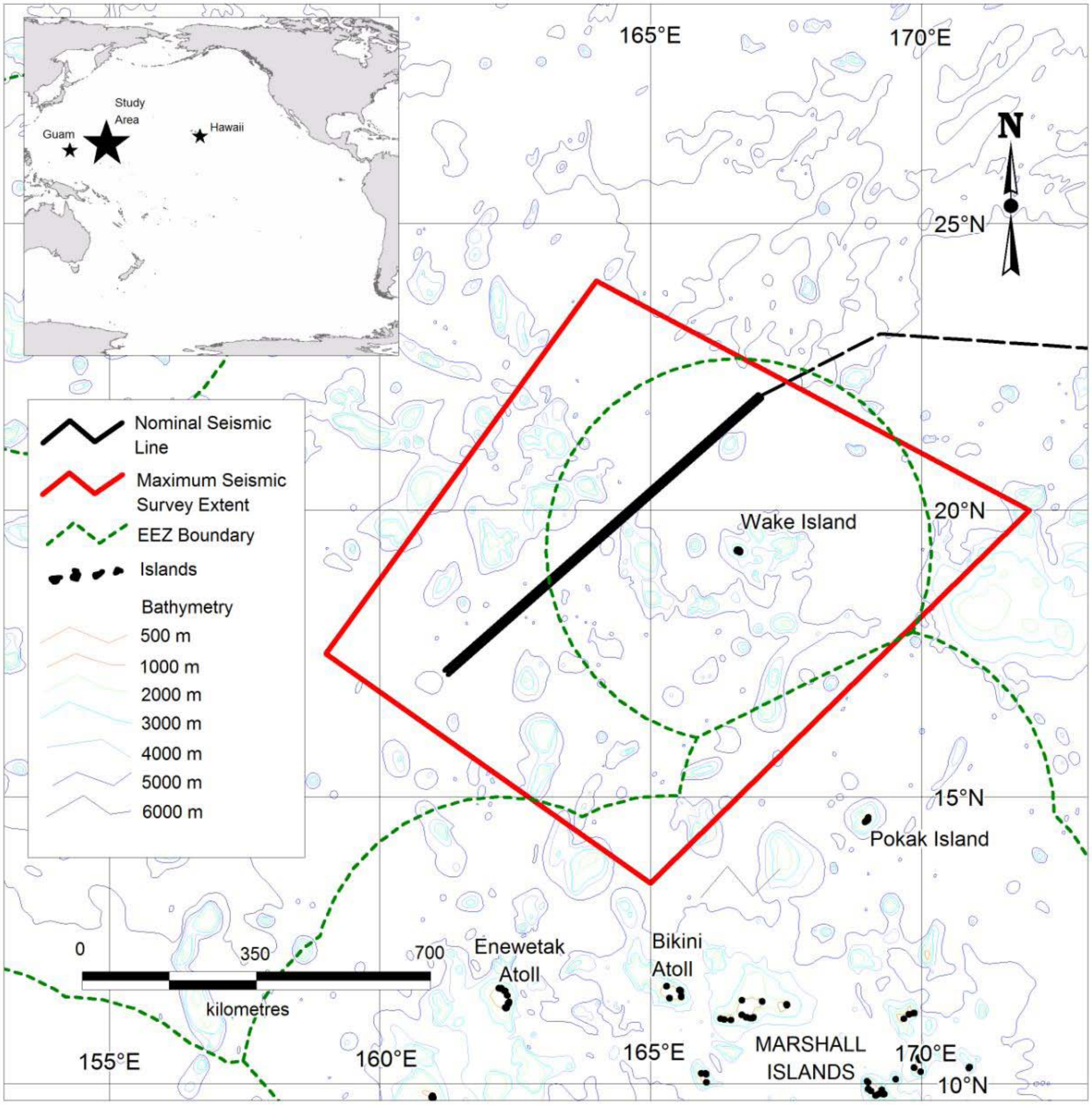

Figure 1. Study area and proposed seismic transit lines near Wake Island for the SIO survey planned for November through December 2011.

The survey would occur in the U.S. Exclusive Economic Zone and could enter that of the Republic of the Marshall Islands. All planned geophysical data acquisition activities would be conducted by SIO with on-board assistance of the scientists who have proposed the study.

The planned seismic survey would consist of ~1,600 km of survey lines in water depths >1,000 m.

Schedule

The *Thompson* is scheduled to depart Honolulu, Hawaii on or about 5 November 2011 for the study area (Figure 1). Once there, the *Thompson* would shoot the seismic survey over 16 days.

The *Thompson* would be due in Apra Harbor, Guam on roughly 17 December 2011.

Source vessel specifications

The *Thompson* would tow the two-airgun array along predetermined lines (Figure 1). The operating speed during seismic acquisition is typically 7.4 km/h. When not towing seismic survey gear, the *Thompson* cruises at 22 km/h. The *Thompson* would also serve as the platform from which marine mammal observers (MMOs) would watch for animals.

Airgun description

The airgun array would consist of two airguns, with a total volume of 90-210 in^3, including Sercel GI airguns. The airguns would be towed in a line 21 m behind the *Thompson* at a depth of 3 m. The airgun array would fire every 5-10 s. During firing, a brief (~0.1 s) pulse of sound would be emitted, but be silent during the intervening periods.

Two-airgun array specifications

• Energy source	2-105 in^3
• Source output (downward)	0-pk is 5.5 bar-m (234.4 dB re 1 μPa·m); pk-pk is 9.8 bar·m (239.8 dB)
• Air discharge volume	~90-210 in^3
• Dominant frequency components	0–188 Hz

Because the actual source originates from two airguns rather than a single point source, the highest sound levels measurable at any location in the water is less than the nominal source level. In addition, the effective source level for sound propagating in near-horizontal directions would be substantially lower than the nominal source level applicable to downward propagation because of the directional nature of the sound from the airgun array.

Multibeam echosounder and sub-bottom profiler

Along with airgun operations, two additional acoustical data acquisition systems would operate during the survey. The multibeam echosounder and sub-bottom profiler systems would map the ocean floor during the survey. These sound sources would operate from the *Thompson* simultaneously with the airgun array.

The multibeam echosounder is a hull-mounted system operating at ~30 kHz. The beamwidth is 1, 2, or 4° fore–aft and 150° perpendicular to the ship's line of travel. The maximum source level is 237 dB re 1 μPa·m$_{rms}$. For deepwater operation, each "ping" consists of nine successive fan-shaped transmissions, each 5 ms in duration and each ensonifying a sector that extends 1, 2, or 4° fore–aft. The nine successive transmissions span an overall cross-track angular extent of about 150°.

The sub-bottom profiler provides information about the sedimentary features and the bottom topography that is being mapped simultaneously by the multibeam echosounder. The maximum output is 7 kW (221 re 1 μPa) at 3-6 kHz. The pulse duration is 1.5 to 24 ms and the interpulse interval is 3-8 seconds.

Autonomous underwater vehicle

The *Thompson* would deploy the tethered vehicle *Sentry* to acquire magnetic profiles along the sea floor. Along with a host of passive sensors, the *Sentry* has several active acoustic sensors. However, all sensors operate in a frequency range well above the hearing range of listed whales.

Proposed exclusion zones

Predicted sound levels vs. distance and depth. The Lamont-Doherty Earth Observatory has predicted received sound levels, in relation to distance and direction from two 105-in^3 airguns (Figure 2). Empirical data concerning 190, 180, and 160 dB re 1 µPa$_{rms}$ distances were acquired during acoustic verification studies of a large airgun array in the Gulf of Mexico in 2003. The down-scaling of the model for use in a two-airgun array likely overestimates the acoustic radii that would be produced by the *Thompson*'s airgun array in practice.

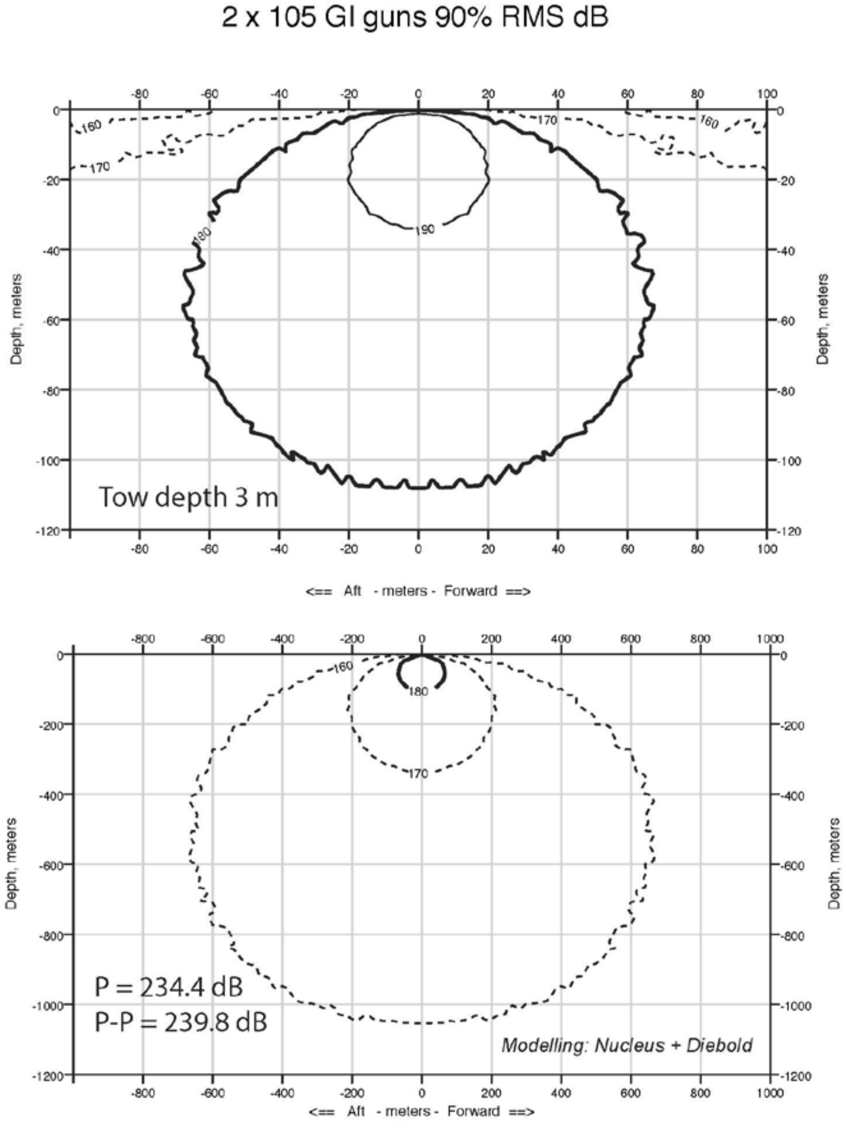
2 x 105 GI guns 90% RMS dB

Figure 2. Modeled received sound levels (SELs) from two 105-in^3 airguns operating in deep water. Received rms levels (SPLs) are likely ~10 dB higher.

Table 1 shows the distances at which three root mean squared (rms) sound levels are expected to be received from the two airgun array. The 190 dB re 1 µPa$_{rms}$ distance is the safety criteria as specified by NMFS (1995) and is applicable to cetaceans. Airguns would shut down if this boundary is or is about to be crossed by any marine mammal. The 180 dB distance would also be used as the exclusion zone for marine mammals, as required by the NMFS during most other recent seismic projects (Holst and Beland 2008; Holst and Smultea 2008b; Holst et al. 2005a; Holt 2008; Smultea et al. 2004). A breach of this boundary would entail a power down of the airgun array.

Table 1. Predicted distances to which sound levels ≥190, 180, and 160 dB re 1 μPa_{rms} could be received from the airgun array.

Source and volume	Tow depth (m)	Water depth	Predicted rms radii (m)		
			190 dB	180 dB	160 dB
Two-105 in^3 airguns	3	>1,000	20	70	670

Incidental Harassment Authorization

The NMFS' Permits Division is proposing to issue an IHA authorizing non-lethal "takes" by harassment of marine mammals incidental to the planned seismic survey, pursuant to section 101 (a)(5)(D) of the MMPA, 16 U.S.C. § 1371 (a)(5)(D). The IHA would be valid from 5 November through 31 January, 2011 and 2012, and would authorize the incidental harassment of the following endangered species (among other species): sei whales (*Balaenoptera borealis*) and sperm whales (*Physeter macrocephalus*), as well as other non-listed marine mammals. The proposed IHA identifies the following requirements that SIO must comply with as part of its authorization.

A. Establish a safety radius corresponding to the anticipated 180-dB isopleth for full (210 in^3) and single (105 in^3) airgun operations.

B. Use at least one, NMFS-approved, vessel-based MMOs to watch for and monitor marine mammals near the seismic source vessel during daytime airgun operations, start-ups of airguns at night, and while the seismic array is being deployed and retrieved. The vessel's crew will also assist in detecting marine mammals, when practical. Observers will have access to reticle binoculars (7 X 50 Fujinon), big-eye binoculars (25 X 150), and night vision devices. MMOs shifts will last no longer than 4 hours at a time. MMOs will also observe during daytime periods when the seismic system is not operating for comparisons of animal abundance and behavior, when feasible.

C. Record the following information when a marine mammal is sighted:

i. Species, group size, age/size/sex categories (if determinable), behavior when first sighted and after initial sighting, heading (if consistent), bearing and distance from seismic vessel, sighting cue, apparent reaction to the airguns or vessel (e.g., none, avoidance, approach, paralleling, etc., and including responses to ramp-up), and behavioral pace.

ii. Time, location, heading, speed, activity of the vessel (including number of airguns operating and whether in state of ramp-up or power-down), sea state, visibility, cloud cover, and sun glare.

iii. The data listed under ii. would also be recorded at the start and end of each observation watch and during a watch whenever there is a change in one or more of the variables.

D. Visually observe the entire extent of the safety radius using MMOs, for at least 30 minutes prior to starting the airgun (day or night). If the MMO finds a marine mammal within the safety zone, SIO must delay the seismic survey until the marine mammal has left the area. If the MMO sees a marine mammal that surfaces, then dives below the surface, the observer shall wait 30 minutes. If the MMO sees no marine mammals during that time, they should assume that the animal has moved beyond the safety zone. If for any reason the entire radius cannot be seen for the entire 30 minutes (i.e. rough seas, fog, darkness), or if marine mammals are near, approaching, or in the safety radius, the airguns may not be started up. If one airgun is already running at a source level of at least 180 dB, SIO may start subsequent guns without observing the entire safety radius for 30 minutes prior, provided no marine mammals are known to be near the safety radius.

E. Apply a “ramp-up” procedure when starting up at the beginning of seismic operations or anytime after the entire array has been shut-down for more than 15 minutes, which means start the smallest gun first and add airguns in a sequence such that the source level of the array will increase in steps not exceeding approximately 6 dB per 5-minute period. During ramp-up, the MMOs will monitor the safety radius, and if marine mammals are sighted, a course/speed alteration, power-down, or shut-down will occur as though the full array were operational.

F. Alter speed or course during seismic operations if a marine mammal, based on its position and relative motion, appears likely to enter the safety zone. If speed or course alteration is not safe or practical, or if after alteration the marine mammal still appears likely to enter the safety zone, further mitigation measures, such as power-down or shut-down, will be taken.

G. Shut-down or power-down the airguns upon marine mammal detection within, approaching, or entering the safety radius. A power-down means shutting-down one or more airguns and reducing the safety radius to the degree that the animal is outside of it. Following a power-down, if the marine mammal approaches the smaller designated safety radius, the airguns must completely shut-down. Airgun activity will not resume until the marine mammal has cleared the safety radius, which means it was visually observed to have left the safety radius, or has not been seen within the radius for 15 minutes (small odontocetes) or 30 minutes (mysticetes and large odontocetes).

H. Emergency shutdown. In the unanticipated event that any taking of a marine mammal in a manner prohibited by the proposed IHA occurs, such as an injury, serious injury or mortality, and is judged to result from these activities, SIO will immediately cease operating all authorized sound sources and report the incident to the Chief of the Permits, Conservation, and Education Division, Office of Protected Resources, NMFS, at 301-427-8401. SIO will postpone the research activities until NMFS is able to review the circumstances of the take. NMFS will work with SIO to determine whether modifications in the activities are appropriate and necessary, and notify SIO that they may resume the seismic survey operations.

I. In the unanticipated event that any cases of marine mammal injury or mortality are judged to result from these activities, SIO will cease operating seismic airguns and report the incident to the Office of Protected Resources, NMFS, immediately. Airgun operation will then be postponed until NMFS is able to review the circumstances and work with SIO to determine whether modifications in the activities are appropriate and necessary.

J. Conduct seismic operations during daylight hours where possible.

K. SIO is required to comply with the Terms and Conditions of the Opinion's Incidental Take Statement issued to both the NSF and the NMFS' Office of Protected Resources.

In addition, the proposed IHA requires SIO to adhere to the following reporting requirements:

A. The Holder of this Authorization is required to submit a report on all activities and monitoring results to the Office of Protected Resources, NMFS, within 90 days after the expiration of the IHA. This report must contain and summarize the following information:

  i. Dates, times, locations, heading, speed, weather, and associated activities during all seismic operations;

  ii. Species, number, location, distance from the vessel, and behavior of any marine mammals, as well as associated seismic activity (number of power-downs and shut-downs), observed throughout all monitoring activities.

  iii. An estimate of the number (by species) of marine mammals that:

    a. are known to have been exposed to the seismic activity (visual observation) at received levels greater than or equal to 160 dB re 1 μPa_{rms} and/or 180 dB re 1 μPa_{rms} for cetaceans with a discussion of any specific behaviors those individuals exhibited and

    b. may have been exposed (modeling results) to the seismic activity at received levels greater than or equal to 160 dB re 1 μPa_{rms} and/or 180 dB re 1 μPa_{rms} for cetaceans with a discussion of the nature of the probable consequences of that exposure on the individuals that have been exposed.

  iv. A description of the implementation and effectiveness of the;

    a. terms and conditions of the Opinion's Incidental Take Statement, and

    b. mitigation measures of the IHA. For the Opinion, the report will confirm the implementation of each term and condition and describe the effectiveness, as well as any conservation measures, for minimizing the adverse effects of the action on listed whales.

Approach to the assessment

The NMFS approaches its section 7 analyses of agency actions through a series of steps. The first step identifies those aspects of proposed actions that are likely to have direct or indirect physical, chemical, and biotic effects on listed species or on the physical, chemical, and biotic environment of an action area. As part of this step, we identify the spatial extent of these direct or indirect effects, including changes in that spatial extent over time. The result of this step includes defining the *Action area* for the consultation. The second step of our analyses identifies the listed resources that are likely to co-occur with these effects in space and time and the nature of that co-occurrence (these represent our *Exposure analyses*). In this step of our analyses, we try to identify the number, age (or life stage), gender, as well as behavioral and nutritional states of the individuals that are likely to be exposed to an action's effects and the populations or subpopulations those individuals represent. Once we identify which listed resources are likely to be exposed to an action's effects and the nature of that exposure, we examine the scientific and commercial data available to determine whether and how those listed resources are likely to respond given their exposure (these represent our *Response analyses*).

The final steps of our analyses – establishing the risks those responses pose to listed resources – are different for listed species and designated critical habitat (these represent our *Risk analyses*). Our jeopardy determinations must be based on an action's effects on the continued existence of threatened or endangered species as those "species" have been listed, which can include true biological species, subspecies, or distinct population segments of vertebrate species. The continued existence of these "species" depends on the fate of the populations that comprise them. Similarly, the continued existence of populations are determined by the fate of the individuals that comprise them – populations grow or decline as the individuals that comprise the population live, die, grow, mature, migrate, and reproduce (or fail to do so).

Our risk analyses reflect these relationships between listed species, the populations that comprise that species, and the individuals that comprise those populations. Our risk analyses begin by identifying the probable risks actions pose to listed individuals that are likely to be exposed to an action's stressors. Our analyses then integrate those individual risks to identify consequences to the populations those individuals represent. Our analyses conclude by determining the consequences of those population-level risks to the species those populations comprise.

We measure risks to listed individuals using the individuals' "fitness," or the individual's growth, survival, annual reproductive success, and lifetime reproductive success. In particular, we examine the scientific and commercial data available to determine if an individual's probable lethal, sub-lethal, or behavioral responses to an action's effect on the environment (which we identify during our response analyses) are likely to have consequences for the individual's fitness.

When individual, listed plants or animals are expected to experience reductions in fitness in response to an action, those fitness reductions are likely to reduce the abundance, reproduction, or growth rates (or increase the variance in these measures) of the populations those individuals represent (see Stearns 1992). Reductions in at least one of these variables (or one of the variables we derive from them) is a *necessary* condition for reductions in a population's viability, which is itself a *necessary* condition for reductions in a species' viability. As a result, when listed plants or animals exposed to an action's effects are *not* expected to experience reductions in fitness, we would not expect the action to have adverse consequences on the viability of the populations those individuals represent or the species those populations comprise (e.g., Anderson 2000; Brandon 1978; Mills and Beatty 1979; Stearns 1992). As a result, if we conclude that listed plants or animals are *not* likely to experience reductions in their fitness, we would conclude our assessment.

Although reductions in fitness of individuals is a *necessary* condition for reductions in a population's viability, reducing the fitness of individuals in a population is not always *sufficient* to reduce the viability of the population(s) those individuals represent. Therefore, if we conclude that listed plants or animals are likely to experience reductions in their fitness, we determine whether those fitness reductions are likely to reduce the viability of the populations the individuals represent (measured using changes in the populations' abundance, reproduction, spatial structure and connectivity, growth rates, variance in these measures, or measures of extinction risk). In this step of our analyses, we use the population's base condition (established in the *Environmental baseline* and *Status of listed resources* sections of this Opinion) as our point of reference. If we conclude that reductions in individual fitness are not likely to reduce the viability of the populations those individuals represent, we would conclude our assessment.

Reducing the viability of a population is not always *sufficient* to reduce the viability of the species those populations comprise. Therefore, in the final step of our analyses, we determine if reductions in a population's viability are likely to reduce the viability of the species those populations comprise using changes in a species' reproduction, numbers, distribution, estimates of extinction risk, or probability of being conserved. In this step of our analyses, we use the species' status (established in the *Status of listed resources* section of this Opinion) as our point of reference. If information on a given species is lacking, we consider the use of surrogate species where appropriate (Favreau et al. 2006; Hitt and Frissell 2004). Our final determinations are based on whether threatened or endangered species are likely to experience reductions in their viability and whether such reductions are likely to be appreciable.

To conduct these analyses, we rely on all of the evidence available to us. This evidence consists of monitoring reports submitted by past and present permit holders; reports from NMFS Science Centers; reports prepared by natural resource agencies in States and other countries; reports from non-governmental organizations involved in marine conservation issues; the information provided by the Permits Division when it initiates formal consultation; and the general scientific literature.

We supplement this evidence with reports and other documents – environmental assessments, environmental impact statements, and monitoring reports – prepared by other federal and state agencies like the Bureau of Ocean Energy Management, Regulation, and Enforcement, U.S. Coast Guard, and U.S. Navy whose operations extend into the marine environment.

During the consultation, we conducted electronic searches of the general scientific literature using search engines, including Agricola, Ingenta Connect, Aquatic Sciences and Fisheries Abstracts, JSTOR, Conference Papers Index, First Search (Article First, ECO, and WorldCat), Web of Science, Oceanic Abstracts, Google Scholar, and Science Direct.

We supplemented these searches with electronic searches of doctoral dissertations and master's theses. These searches specifically try to identify data or other information that supports a particular conclusion (for example, a study that suggests whales will exhibit a particular response to acoustic exposure or close vessel approach) as well as data that do not support that conclusion. When data were equivocal or when faced with substantial uncertainty, our decisions are designed to avoid the risks of incorrectly concluding that an action would not have an adverse effect on listed species when, in fact, such adverse effects are likely (i.e., Type II error).

In this particular assessment, we identified the stressors associated with the action and evaluate which had a significant possibility of occurring based upon previous seismic surveys. Of the probable stressors, we identified the species that were expected to co-occur with the effects of the action, particularly the acoustic isopleths of the airgun and other sound sources. Utilizing survey data from previous years, density estimates per unit area of listed whales were multiplied by the area to be ensonified where effects were expected.

In the process of this assessment, we were required to make several assumptions where data were insufficient to support conclusions regarding the specific species and actions at hand. These included:

- Baleen whales can generally hear low-frequency sound better than high frequencies, as the former is the primary range in which they vocalize. Toothed whales (such as sperm whales) are better adapted to hear mid- and high-frequency sound for the same reason (although this species also responds to low-frequency sound and is considered to hear at low-, mid-, and high frequencies). Sperm whales are also assumed to have similar hearing qualities as other, better studied, toothed whales.
- Species for which little or no information on response to sound will respond similarly to their close taxonomic or ecological relatives (i.e., baleen whales respond similarly to each other).
- Although we may not know why individuals occur in a specific location, we assume that the individuals have located themselves in particular locations to maximize their survival and/or reproductive potential. Individuals displaced from these locations may or may not have secondary locations that are capable of meeting the individual's biological needs. Even if available, these habitats may not offer equivalent potential for survival and reproduction of the displaced location.

Action area

The proposed seismic survey should occur in a variety of water depths ranging from 2,000 m to 6,000 m in the western tropical North Pacific around Wake Island (Figure 1 on page 3). The seismic survey is planned from 5 November- 17 December 2011. Responses to seismic sound sources by listed species are expected to occur within the 160 dB isopleths (modeled to be 670 m from the *Thompson's* airgun array). This expands the action area beyond the seismic survey track lines (~1,600 km) to an ensonified region of 2,680 km^2.

Status of listed resources

The NMFS has determined that the actions considered in this Opinion may affect species listed in Table 2, which are provided protection under the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq*.).

Table 2. Listed species in the action area.

Common name (Distinct population segment, evolutionarily significant unit, or subspecies)	*Scientific name*	*Status*
Cetaceans		
Sei whale	*Balaenoptera borealis*	Endangered
Sperm whale	*Physeter macrocephalus*	Endangered
Marine Turtles		
Green sea turtle (Florida & Mexico's Pacific coast colonies)	*Chelonia mydas*	Endangered
Green sea turtle (All other areas)		Threatened
Hawksbill sea turtle	*Eretmochelys imbricate*	Endangered
Leatherback sea turtle	*Dermochelys coriacea*	Endangered
Loggerhead sea turtle	*Caretta caretta*	Threatened
Olive ridley sea turtle (Mexico's Pacific coast breeding colonies)	*Lepidochelys olivacea*	Endangered
Olive ridley sea turtle (All other areas)		Threatened
Proposed Species		
Loggerhead sea turtle-North Pacific DPS	*Caretta caretta*	Proposed endangered

Species not considered further in this Opinion

Leatherback, loggerhead, and olive ridley sea turtles have not been documented in the region, or have been found on very rare occasion. Perhaps the best regional information stems from the Northern Marianas Islands, where leatherback and olive ridley sea turtles occur only rarely, and loggerheads not at all (Eckert 1993; Eldredge 2003; Michael 2004; NMFS and USFWS 1998b; Pritchard 1977; Pritchard 1995; Wiles et al. 1995). None of these species nest in the vicinity. Several surveys in waters surrounding the Marianas Islands (which has received the best regional survey effort) have failed to detect any individual of these sea turtles species (Grimm and Farley 2008; Kolinski 2001; Kolinski et al. 1999; Pultz et al. 1999; Randall et al. 1975; SRS-Parsons et al. 2007; Stojkovich 1977; Vogt 2009). Leatherback satellite tracking data does support potential migration in the oceanic region around Wake Island (Benson et al. 2011). However, the timing of these migratory tracks is unlikely to bring leatherbacks near Wake Island during the time of the proposed survey (Scott Benson-NOAA, personal communication). We considered that these species are known to be wide-ranging and it is possible that currents can push individuals out of their normal range into local waters (Pickard and Emery 1982; Polovina et al. 2000) and that these species tend to travel or forage in deep oceanic waters (Eckert 1993; Kolinski 2001). However, given the lack of sightings, strandings, bycatch, or other detections, the probability of individual occurrence is low and leads us to discount the possibility of leatherbacks, loggerheads, or olive ridleys being exposed to actions associated with the proposed seismic survey. For these reasons, we conclude that the proposed activities may affect, but are not likely to adversely affect leatherback, loggerhead, and olive ridley sea turtles, and these species will not be considered in greater detail in the remainder of this Opinion.

Green and hawksbill sea turtles may be more regular inhabitants of nearshore waters of Wake Island. Green sea turtle nesting commonly occurs in some regional locations (such as the Marianas Islands), but hawksbill nesting is rare (Davis ; DON 2005; Franko's Maps 2005; Gutierrez 2004; Kolinski et al. 1999; NMFS 1998; NMFS and USFWS 1998a; Pritchard 1995; Pultz et al. 1999; Wiles et al. 1995). Both species typically forage in shallow, nearshore waters of the region (Abraham et al. 2004; DON 2003; Franko's Maps 2005; Wiles et al. 1995). This is consistent with life history trends found in other areas; both species feed in mangrove, seagrass, or coral reef habitats as juveniles and adults (Bjorndal and Bolten 2000; Bjorndal and Bolten 2010; Boyle and Limpus 2008; Cardona et al. 2009; Godley et al. 1998; Hatase et al. 2006; Hazel 2009; Heithaus et al. 2002; Musick and Limpus 1997; Parker and Balazs in press; Seminoff et al. 2002). Younger age classes (hatchlings to juveniles) do undergo an oceanic stage, but do so by associating with weedlines, *Sargassum* concentrations, or flotsam where they can be sheltered (Hornell 1927; Mellgren and Mann 1996; Mellgren et al. 1994; Musick and Limpus 1997; NMFS and USFWS 1998a). These features, frequently associated with frontal or current boundaries or gyre systems, are not a characteristic of the action area (Irene Kelly-NOAA, personal communication 2010). A recent survey through the offshore region near the Marianas Islands failed to find either species, although nearshore surveys routinely identified green and hawksbill sea turtles (SRS-Parsons et al. 2007). We considered that both species are wide-ranging (Musick and Limpus 1997; Plotkin 2003), but ultimately the action area is not habitat in which one would expect green or hawksbill sea turtles to occur. Therefore, we find that the probabilities of green or hawksbill sea turtle exposure to actions associated with the proposed seismic survey are discountable. These species will not be considered in greater detail in the remainder of this Opinion.

No critical habitat occurs in the action area.

Sei whale

Description of the species. The sei whale occurs in all oceans of the world except the Arctic. The migratory pattern of this species is thought to encompass long distances from high-latitude feeding areas in summer to low-latitude breeding areas in winter; however, the location of winter areas remains largely unknown (Perry et al. 1999). Sei whales are often associated with deeper waters and areas along continental shelf edges (Hain et al. 1985). This general offshore pattern is disrupted during occasional incursions into shallower inshore waters (Waring et al. 2004). The species appears to lack a well-defined social structure and individuals are usually found alone or in small groups of up to six whales (Perry et al. 1999). When on feeding grounds, larger groupings have been observed (Gambell 1985).

Population designations. The population structure of sei whales is unknown and populations herein assume (based upon migratory patterns) population structuring is discrete by ocean basin (north and south), except for sei whales in the Southern Ocean, which may form a ubiquitous population or several discrete ones.

North Atlantic. In the western North Atlantic, a major portion of the sei whale population occurs in northern waters, potentially including the Scotian Shelf, along Labrador and Nova Scotia, south into the U.S. EEZ, including the Gulf of Maine and Georges Bank (Mitchell and Chapman 1977; Waring et al. 2004). These whales summer in northern areas before migrating south to waters along Florida, in the Gulf of Mexico, and the northern Caribbean Sea (Gambell 1985; Mead 1977). Sei whales may range as far south as North Carolina. In the U.S. EEZ, the greatest abundance occurs during spring, with most sightings on the eastern edge of Georges Bank, in the Northeast Channel, and in Hydrographer Canyon (CETAP 1982). In 1999, 2000, and 2001, the NMFS aerial surveys found sei whales concentrated along the northern edge of Georges Bank during spring (Waring et al. 2004). Surveys in 2001 found sei whales south of Nantucket along the continental shelf edge (Waring et al. 2004). During years of greater prey abundance (e.g., copepods), sei whales are found in more inshore waters, such as the Great South Channel (1987 and 1989), Stellwagen Bank (1986), and the Gulf of Maine (Payne et al. 1990a; Schilling et al. 1992). In the eastern Atlantic, sei whales occur in the Norwegian Sea, occasionally occurring as far north as Spitsbergen Island, and migrate south to Spain, Portugal, and northwest Africa (Gambell 1985; Jonsgård and Darling 1977).

North Pacific. Some mark-recapture, catch distribution, and morphological research indicate more than one population may exist – one between 155°-175° W, and another east of 155° W (Masaki 1976; Masaki 1977). Sei whales have been reported primarily south of the Aleutian Islands, in Shelikof Strait and waters surrounding Kodiak Island, in the Gulf of Alaska, and inside waters of southeast Alaska and south to California to the east and Japan and Korea to the west (Leatherwood et al. 1982; Nasu 1974). Sightings have also occurred in Hawaiian waters (Smultea et al. 2010). Sei whales have been occasionally reported from the Bering Sea and in low numbers on the central Bering Sea shelf (Hill and DeMaster 1998). Whaling data suggest that sei whales do not venture north of about 55° N (Gregr et al. 2000). Masaki (1977) reported sei whales concentrating in the northern and western Bering Sea from July-September, although other researchers question these observations because no other surveys have reported sei whales in the northern and western Bering Sea. Horwood (1987) evaluated Japanese sighting data and concluded that sei whales rarely occur in the Bering Sea. Horwood (1987) reported that 75-85% of the North Pacific population resides east of 180°.

Historically, sei whales were common in the northern Gulf of Alaska (Calkins 1986b; Consiglieri et al. 1982; Fiscus and Braham 1976; Masaki 1976), but no individuals have been sighted during recent surveys (Wade et al. 2003; Waite 2003; Zerbini et al. 2006; Rone et al. 2009).

Southern Hemisphere. Sei whales occur throughout the Southern Ocean during the austral summer, generally between 40°-50° S (Gambell 1985). During the austral winter, sei whales occur off Brazil and the western and eastern coasts of southern Africa and Australia, although all of the 20 sightings off Argentina occurred in August or September (Iniguez et al. 2010). However, sei whales generally do not occur north of 30º S in the Southern Hemisphere (Reeves et al. 1999). However, confirmed sighting records exist for Papua New Guinea and New Caledonia, with unconfirmed sightings in the Cook Islands (Programme) 2007).

There is little information on the population structure of sei whales in the Antarctic; some degree of isolation appears to exist, although sei whale movements are dynamic and individuals move between stock designation areas (Donovan 1991; IWC 1980a).

Reproduction. Reproductive activities for sei whales occur primarily in winter. Gestation is about 12.7 months, calves are weaned at 6-9 months, and the calving interval is about 2-3 years (Gambell 1985; Rice 1977). Sei whales become sexually mature at about age 10 (Rice 1977).

Feeding. Sei whales are primarily planktivorous, feeding mainly on euphausiids and copepods, although they are also known to consume fish (Waring et al. 2006). In the Northern Hemisphere, sei whales consume small schooling fish such as anchovies, sardines, and mackerel when locally abundant (Konishi et al. 2009; Mizroch et al. 1984; Rice 1977). Sei whales in the North Pacific feed on euphausiids and copepods, which make up about 95% of their diets (Calkins 1986a). The dominant food for sei whales off California during June-August is northern anchovy, while in September-October whales feed primarily on krill (Rice 1977). The balance of their diet consists of squid and schooling fish, including smelt, sand lance, Arctic cod, rockfish, pollack, capelin, and Atka mackerel (Nemoto and Kawamura 1977). In the Southern Ocean, analysis of stomach contents indicates sei whales consume *Calanus* spp. and small-sized euphasiids with prey composition showing latitudinal trends (Kawamura 1974). Sei whales in the Southern Hemisphere may reduce direct interspecific competition with blue and fin whales by consuming a wider variety of prey and by arriving later to feeding grounds (Kirkwood 1992). Rice (1977) suggested that the diverse diet of sei whales may allow them greater opportunity to take advantage of variable prey resources, but may also increase their potential for competition with commercial fisheries. In the North Pacific, sei whales appear to prefer feeding along the cold eastern currents (Perry et al. 1999). Sei whales have the flexibility to skim or engulf prey (Brodie and Vikingsson 2009).

Vocalization and hearing. Data on sei whale vocal behavior is limited, but includes records off the Antarctic Peninsula of broadband sounds in the 100-600 Hz range with 1.5 s duration and tonal and upsweep calls in the 200-600 Hz range of 1-3 s durations (McDonald et al. 2005). Differences may exist in vocalizations between ocean basins (Rankin and Barlow 2007). Vocalizations from the North Atlantic consisted of paired sequences (0.5-0.8 s, separated by 0.4-1.0 s) of 10-20 short (4 ms) FM sweeps between 1.5-3.5 kHz (Thomson and Richardson 1995).

Status and trends. The sei whale was originally listed as endangered in 1970 (35 FR 18319), and this status remained since the inception of the ESA in 1973. Table 3 provides estimates of historic and current abundance for ocean regions.

Table 3. Summary of past and present sei whale abundance.

Region	Population, stock, or study area	Pre-exploitation estimate	95% C.I.	Current estimate	95% C.I.	Source
Global	--	>105,000	--	25,000	--	(Braham 1991b)
North Atlantic	Basinwide	--	--	>4000	--	(Braham 1991b)
	NMFS - Nova Scotia stock	--	--	207	--	(NMFS 2008)
	IWC - Iceland-Denmark stock	--	--	1,290	0-2,815*	(Cattanach et al. 1993)
	IWC - Iceland-Denmark stock	--	--	1,590	343-2,837*	(Cattanach et al. 1993)
North Pacific	Basinwide	42,000	--	7,260-12,620*	--	(Tillman 1977); *circa 1974
	NMFS - eastern North Pacific stock	--	--	46	CV=0.61	(Carretta et al. 2008)
	NMFS - Hawaii stock	--	--	77	0-237*	(Carretta et al. 2008)
Southern Hemisphere	Basinwide	63,100	--	--	--	(Mizroch et al. 1984)
	Basinwide	65,000	--	--	--	(Braham 1991b)
	South of 60°S	--	--	626	553-699	(IWC 1996)
	South of 30°S	--	--	9,718	--	(IWC 1996)

*Note: Confidence Intervals (C.I.) not provided by the authors were calculated from Coefficients of Variation (C.V.) where available, using the computation from Gotelli and Ellison (2004).

North Atlantic. No information on sei whale abundance exists prior to commercial whaling (Perry et al. 1999). Between 1966 and 1972, whalers from land stations on the east coast of Nova Scotia engaged in extensive hunts of sei whales on the Nova Scotia shelf, killing about 825 individuals (Mitchell and Chapman 1977). In 1974, the North Atlantic stock was estimated to number about 2,078 individuals, including 965 whales in the Labrador Sea group and 870 whales in the Nova Scotia group (Mitchell and Chapman 1977). In the northwest Atlantic, Mitchell and Chapman (1977) estimated the Nova Scotia stock to contain 1,393-2,248 whales; an aerial survey program conducted from 1978 to 1982 on the continental shelf and edge between Cape Hatteras, North Carolina, and Nova Scotia generated an estimate of 280 sei whales (CETAP 1982). These two estimates are more than 20 years out of date and likely do not reflect the current true abundance; in addition, the CETAP estimate has a high degree of uncertainty and is considered statistically unreliable (Perry et al. 1999; Waring et al. 2004; Waring et al. 1999). The total number of sei whales in the U.S. Atlantic EEZ remains unknown (Waring et al. 2006). Rice (1977) estimated total annual mortality for adult females as 0.088 and adult males as 0.103.

North Pacific. Ohsumi and Fukuda (Ohsumi and Fukuda. 1975) estimated that sei whales in the North Pacific numbered about 49,000 whales in 1963, had been reduced to 37,000-38,000 whales by 1967, and reduced again to 20,600-23,700 whales by 1973. From 1910-1975, approximately 74,215 sei whales were caught in the entire North Pacific Ocean (Horwood 1987; Perry et al. 1999). From the early 1900s, Japanese whaling operations consisted of a large proportion of sei whales: 300-600 sei whales were killed per year from 1911-1955. The sei whale catch peaked in 1959, when 1,340 sei whales were killed. In 1971, after a decade of high sei whale catch numbers, sei whales were scarce in Japanese waters. Japanese and Soviet catches of sei whales in the North Pacific and Bering Sea increased from 260 whales in 1962 to over 4,500 in 1968-1969, after which the sei whale population declined rapidly (Mizroch et al. 1984). When commercial whaling for sei whales ended in 1974, the population in the North Pacific had been reduced to 7,260-12,620 animals (Tillman 1977). There have been no direct estimates of sei whale populations for the eastern Pacific Ocean (or the entire Pacific). Between 1991-2001, during aerial surveys, there were two confirmed sightings of sei whales along the U.S. Pacific coast. The minimum estimate of individuals along the U.S. west coast between 1996-2001 was 35 (Carretta et al. 2006).

Natural threats. Andrews (1916) suggested that killer whales attacked sei whales less frequently than fin and blue whales in the same areas. Sei whales engage in a flight response to evade killer whales, which involves high energetic output, but show little resistance if overtaken (Ford and Reeves 2008). Endoparasitic helminths (worms) are commonly found in sei whales and can result in pathogenic effects when infestations occur in the liver and kidneys (Rice 1977).

Anthropogenic threats. Human activities known to threaten sei whales include whaling, commercial fishing, and maritime vessel traffic. Historically, whaling represented the greatest threat to every population of sei whales and was ultimately responsible for listing sei whales as an endangered species. Sei whales are thought to not be widely hunted, although harvest for scientific whaling or illegal harvesting may occur in some areas.

Sei whales are occasionally killed in collisions with vessels. Of three sei whales that stranded along the U.S. Atlantic coast during 1975-1996, two showed evidence of collisions (Laist et al. 2001). Between 1999 and 2005, there were three reports of sei whales being struck by vessels along the U.S. Atlantic coast and Canada's Maritime Provinces (Cole et al. 2005; Nelson et al. 2007). Two of these ship strikes were reported as having resulted in death. New rules for seasonal (June through December) slowing of vessel traffic in the Bay of Fundy to 10 knots and changing shipping lanes by less than one nautical mile to avoid the greatest concentrations of right whales are predicted to reduce sei whale ship strike mortality by 17%.

Sei whales are known to accumulate DDT, DDE, and PCBs (Borrell 1993; Borrell and Aguilar 1987; Henry and Best 1983). Males carry larger burdens than females, as gestation and lactation transfer these toxins from mother to offspring.

Critical habitat. The NMFS has not designated critical habitat for sei whales.

Sperm whale

Description of the species. Sperm whales are distributed in all of the world's oceans, from equatorial to polar waters, and are highly migratory. Mature males range between 70° N in the North Atlantic and 70° S in the Southern Ocean (Perry et al. 1999; Reeves and Whitehead 1997), whereas mature females and immature individuals of both sexes are seldom found higher than 50° N or S (Reeves and Whitehead 1997). In winter, sperm whales migrate closer to equatorial waters (Kasuya and Miyashita 1988; Waring et al. 1993) where adult males join them to breed.

Stock designations. There is no clear understanding of the global population structure of sperm whales (Dufault et al. 1999). Recent ocean-wide genetic studies indicate low, but statistically significant, genetic diversity and no clear geographic structure, but strong differentiation between social groups (Lyrholm and Gyllensten 1998; Lyrholm et al. 1996; Lyrholm et al. 1999). The IWC currently recognizes four sperm whale stocks: North Atlantic, North Pacific, northern Indian Ocean, and Southern Hemisphere (Dufault et al. 1999; Reeves and Whitehead 1997). The NMFS recognizes six stocks under the MMPA- three in the Atlantic/Gulf of Mexico and three in the Pacific (Alaska, California-Oregon-Washington, and Hawaii; (Perry et al. 1999; Waring et al. 2004). Genetic studies indicate that movements of both sexes through expanses of ocean basins are common, and that males, but not females, often breed in different ocean basins than the ones in which they were born (Whitehead 2003). Sperm whale populations appear to be structured socially, at the level of the clan, rather than geographically (Whitehead 2003; Whitehead et al. 2008).

North Atlantic. In the western North Atlantic, sperm whales range from Greenland south into the Gulf of Mexico and the Caribbean, where they are common, especially in deep basins off of the continental shelf (Romero et al. 2001; Wardle et al. 2001). The northern distributional limit of female/immature pods is probably around Georges Bank or the Nova Scotian shelf (Whitehead et al. 1991). Seasonal aerial surveys confirm that sperm whales are present in the northern Gulf of Mexico in all seasons (Hansen et al. 1996; Mullin et al. 1994). Sperm whale distribution follows a distinct seasonal cycle, concentrating east-northeast of Cape Hatteras in winter and shifting northward in spring when whales are found throughout the Mid-Atlantic Bight. Distribution extends further northward to areas north of Georges Bank and the Northeast Channel region in summer and then south of New England in fall, back to the Mid-Atlantic Bight. In the eastern Atlantic, mature male sperm whales have been recorded as far north as Spitsbergen (Øien 1990). Recent observations of sperm whales and stranding events involving sperm whales from the eastern North Atlantic suggest that solitary and paired mature males predominantly occur in waters off Iceland, the Faroe Islands, and the Norwegian Sea (Christensen et al. 1992a; Christensen et al. 1992b; Gunnlaugsson and Sigurjónsson 1990; Øien 1990).

North Pacific. Sperm whales are found throughout the North Pacific and are distributed broadly in tropical and temperate waters to the Bering Sea as far north as Cape Navarin in summer, and occur south of 40^{o} N in winter (Gosho et al. 1984; Miyashita et al. 1995 as cited in Carretta et al. 2005; Rice 1974). Sperm whales are found year-round in Californian and Hawaiian waters (Barlow 1995; Dohl et al. 1983; Forney et al. 1995; Lee 1993; Mobley Jr . et al. 2000; Rice 1960; Shallenberger 1981), but they reach peak abundance from April through mid-June and from the end of August through mid-November (Rice 1974). They are seen in every season except winter (December-February) off Washington and Oregon (Green et al. 1992). Summer/fall surveys in the eastern tropical Pacific (Wade and Gerrodette 1993) show that although sperm whales are widely distributed in the tropics, their relative abundance tapers off markedly towards the middle of the tropical Pacific and northward towards the tip of Baja California (Carretta et al. 2006). Sperm whales occupying the California Current region are genetically distinct from those in the eastern tropical Pacific and Hawaiian waters (Mesnick et al. 2011). The discreteness of the later two areas remains uncertain (Mesnick et al. 2011).

Mediterranean. Sperm whales are found from the Alboran Sea to the Levant Basin, primarily over steep slope and deep offshore waters. Sperm whales are rarely sighted in the Sicilian Channel, and are vagrants to the northern Adriatic and Aegean seas (Notarbartolo di Sciara and Demma 1997). In Italian seas, sperm whales are more frequently associated with the continental slope off western Liguria, western Sardinia, northern and eastern Sicily, and both coasts of Calabria.

Southern Hemisphere. All sperm whales of the Southern Hemisphere are treated as a single stock with nine divisions, although this designation has little biological basis and is more in line with whaling records (Donovan 1991). Sperm whales that occur off the Galapagos Islands, mainland Ecuador, and northern Peru may be distinct from other sperm whales in the Southern Hemisphere (Dufault and Whitehead 1995; Rice 1977; Wade and Gerrodette 1993). Gaskin (1973) found females to be absent in waters south of 50º and decrease in proportion to males south of 46-47º.

Movement. Movement patterns of Pacific female and immature male groups appear to follow prey distribution and, although not random, movements are difficult to anticipate and are likely associated with feeding success, perception of the environment, and memory of optimal foraging areas (Whitehead et al. 2008). However, no sperm whale in the Pacific has been known to travel to points over 5,000 km apart and only rarely have sperm whales been known to move over 4,000 km within a time frame of several years. This means that although sperm whales do not appear to cross from eastern to western sides of the Pacific (or vice-versa), significant mixing occurs that can maintain genetic exchange. Movements of several hundred kilometers are common, (i.e. between the Galapagos Islands and the Pacific coastal Americas). Movements appear to be group or clan specific, with some groups traveling straighter courses than others over the course of several days. However, general transit speed averages about 4 km/h. Sperm whales in the Caribbean region appear to be much more restricted in their movements, with individuals repeatedly sighted within less than 160 km of previous sightings.

Habitat. Sperm whales have a strong preference for waters deeper than 1,000 m (Reeves and Whitehead 1997; Watkins 1977), although Berzin (1971) reported that they are restricted to waters deeper than 300 m. While deep water is their typical habitat, sperm whales are rarely found in waters less than 300 m in depth (Clarke 1956; Rice 1989b). Sperm whales have been observed near Long Island, New York, in water between 40-55 m deep (Scott and Sadove 1997). When they are found relatively close to shore, sperm whales are usually associated with sharp increases in topography where upwelling occurs and biological production is high, implying the presence of a good food supply (Clarke 1956). Such areas include oceanic islands and along the outer continental shelf.

Sperm whales are frequently found in locations of high productivity due to upwelling or steep underwater topography, such as continental slopes, seamounts, or canyon features (Jaquet and Whitehead 1996; Jaquet et al. 1996). Cold-core eddy features are also attractive to sperm whales in the Gulf of Mexico, likely because of the large numbers of squid that are drawn to the high concentrations of plankton associated with these features (Biggs et al. 2000; Davis et al. 2000a; Davis et al. 2000b; Davis et al. 2000c; Davis et al. 2002; Wormuth et al. 2000). Surface waters with sharp horizontal thermal gradients, such as along the Gulf Stream in the Atlantic, may also be temporary feeding areas for sperm whales (Griffin 1999; Jaquet et al. 1996; Waring et al. 1993). Sperm whales over George's Bank were associated with surface temperatures of 23.2-24.9° C (Waring et al. 2003).

Gaskin (1973) proposed a northward population shift of sperm whales off New Zealand in the austral autumn based on reduction of available food species and probable temperature tolerances of calves.

Reproduction. Female sperm whales become sexually mature at an average of 9 years or 8.25-8.8 m (Kasuya 1991). Males reach a length of 10 to 12 m at sexual maturity and take 9-20 years to become sexually mature, but require another 10 years to become large enough to successfully breed (Kasuya 1991; Würsig et al. 2000). Mean age at physical maturity is 45 years for males and 30 years for females (Waring et al. 2004). Adult females give birth after roughly 15 months of gestation and nurse their calves for 2-3 years (Waring et al. 2004). The calving interval is estimated to be every 4-6 years between the ages of 12 and 40 (Kasuya 1991; Whitehead et al. 2008). In the North Pacific, female sperm whales and their calves are usually found in tropical and temperate waters year round, while it is generally understood that males move north in the summer to feed in the Gulf of Alaska, Bering Sea, and waters off of the Aleutian Islands (Kasuya and Miyashita 1988). It has been suggested that some mature males may not migrate to breeding grounds annually during winter, and instead may remain in higher latitude feeding grounds for more than 1 year at a time (Whitehead and Arnbom 1987).

Sperm whale age distribution is unknown, but sperm whales are believed to live at least 60 years (Rice 1978). Estimated annual mortality rates of sperm whales are thought to vary by age, but previous estimates of mortality rate for juveniles and adults are now considered unreliable (IWC 1980b). In addition to anthropogenic threats, there is evidence that sperm whale age classes are subject to predation by killer whales (Arnbom et al. 1987; Pitman et al. 2001).

Stable, long-term associations among females form the core of sperm whale societies (Christal et al. 1998). Up to about a dozen females usually live in such groups, accompanied by their female and young male offspring. Young individuals are subject to alloparental care by members of either sex and may be suckled by non-maternal individuals (Gero et al. 2009). Group sizes may be smaller overall in the Caribbean Sea (6-12 individuals) versus the Pacific (25-30 individuals) (Jaquet and Gendron 2009). Mean group size in the Galapagos Islands, the nearest location to the action area, was found to be 24.8 individuals (Jaquet and Gendron 2009). Groups may be stable for long periods, such as for 80 days in the Gulf of California (Jaquet and Gendron 2009). Males start leaving these family groups at about 6 years of age, after which they live in "bachelor schools," but this may occur more than a decade later (Pinela et al. 2009). The cohesion among males within a bachelor school declines with age. During their breeding prime and old age, male sperm whales are essentially solitary (Christal and Whitehead 1997).

Diving. Sperm whales are probably the deepest and longest diving mammalian species, with dives to 3 km down and durations in excess of 2 hours (Clarke 1976; Watkins et al. 1993; Watkins et al. 1985). However, dives are generally shorter (25- 45 min) and shallower (400-1,000 m). Dives are separated by 8-11 min rests at the surface (Gordon 1987; Jochens et al. 2006; Papastavrou et al. 1989; Watwood et al. 2006; Würsig et al. 2000). Sperm whales typically travel ~3 km horizontally and 0.5 km vertically during a foraging dive (Whitehead 2003). Differences in night and day diving patterns are not known for this species, but, like most diving air-breathers for which there are data (rorquals, fur seals, and chinstrap penguins), sperm whales probably make relatively shallow dives at night when prey are closer to the surface.

Feeding. Sperm whales appear to feed regularly throughout the year (NMFS 2006). It is estimated they consume about 3-3.5% of their body weight daily (Lockyer 1981). They seem to forage mainly on or near the bottom, often ingesting stones, sand, sponges, and other non-food items (Rice 1989b). A large proportion of a sperm whale's diet consists of low-fat, ammoniacal, or luminescent squids (Clarke 1996; Clarke 1980b; Martin and Clarke 1986). While sperm whales feed primarily on large and medium-sized squids, the list of documented food items is fairly long and diverse. Prey items include other cephalopods, such as octopi, and medium- and large-sized demersal fishes, such as rays, sharks, and many teleosts (Angliss and Lodge 2004; Berzin 1972; Clarke 1977; Clarke 1980a; Rice 1989b). The diet of large males in some areas, especially in high northern latitudes, is dominated by fish (Rice 1989b). In some areas of the North Atlantic, however, males prey heavily on the oil-rich squid *Gonatus fabricii*, a species also frequently eaten by northern bottlenose whales (Clarke 1997).

Vocalization and hearing. Sound production and reception by sperm whales are better understood than in most cetaceans. Sperm whales produce broad-band clicks in the frequency range of 100 Hz to 20 kHz that can be extremely loud for a biological source (200-236 dB re 1μPa), although lower source level energy has been suggested at around 171 dB re 1 μPa (Goold and Jones 1995; Møhl et al. 2003; Weilgart and Whitehead 1993; Weilgart and Whitehead 1997). Most of the energy in sperm whale clicks is concentrated at around 2-4 kHz and 10-16 kHz (Goold and Jones 1995; NMFS 2006d; Weilgart and Whitehead 1993). The highly asymmetric head anatomy of sperm whales is likely an adaptation to produce the unique clicks recorded from these animals (Cranford 1992; Norris and Harvey 1972; Norris and Harvey. 1972). Long, repeated clicks are associated with feeding and echolocation (Goold and Jones 1995; Weilgart and Whitehead 1993; Weilgart and Whitehead 1997). However, clicks are also used in short patterns (codas) during social behavior and intragroup interactions (Weilgart and Whitehead 1993). They may also aid in intra-specific communication. Another class of sound, “squeals”, are produced with frequencies of 100 Hz to 20 kHz (e.g., Weir et al. 2007).

Our understanding of sperm whale hearing stems largely from the sounds they produce. The only direct measurement of hearing was from a young stranded individual from which auditory evoked potentials were recorded (Carder and Ridgway 1990). From this whale, responses support a hearing range of 2.5-60 kHz. However, behavioral responses of adult, free-ranging individuals also provide insight into hearing range; sperm whales have been observed to frequently stop echolocating in the presence of underwater pulses made by echosounders and submarine sonar (Watkins et al. 1985; Watkins and Schevill 1975). They also stop vocalizing for brief periods when codas are being produced by other individuals, perhaps because they can hear better when not vocalizing themselves (Goold and Jones 1995). Because they spend large amounts of time at depth and use low-frequency sound, sperm whales are likely to be susceptible to low frequency sound in the ocean (Croll et al. 1999).

Status and trends. Sperm whales were originally listed as endangered in 1970 (35 FR 18319), and this status remained with the inception of the ESA in 1973. Although population structure of sperm whales is unknown, several studies and estimates of abundance are available. Table 4 contains historic and current estimates of sperm whales by region. Sperm whale populations probably are undergoing the dynamics of small population sizes, which is a threat in and of itself. In particular, the loss of sperm whales to directed Soviet whaling likely inhibits recovery due to the loss of adult females and their calves, leaving sizeable gaps in demographic and age structuring (Whitehead 2003).

Table 4. Summary of past and present sperm whale abundance.

Region	Population, stock, or study area	Pre-exploitation estimate	95% C.I.	Current estimate	95% C.I.	Source
Global	--	--	--	900,000	--	(Würsig et al. 2000)
	--	1,110,000	672,000-1,512,000	360,000	105,984-614,016*	(Whitehead 2002)
North Atlantic	Basinwide	224,800	--	22,000	--	(Gosho et al. 1984; Würsig et al. 2000)
	Northeast Atlantic, Faroes-Iceland, and U.S. East Coast (combined)	--	--	13,190	--	(Whitehead 2002)
	NMFS - North Atlantic stock (Western North Atlantic)	--	--	4,804	1,226-8,382*	(NMFS 2008)
	Eastern North Atlantic - Iceland	--	--	1,234	823-1,645*	(Gunnlaugsson and Sigurjónsson 1990)
	Eastern North Atlantic - Faroe Islands	--	--	308	79-537*	(Gunnlaugsson and Sigurjónsson 1990)
	Eastern North Atlantic - Norwegian Sea	--	--	5,231	2,053-8,409*	(Christensen et al. 1992b)
	Eastern North Atlantic - Northern Norway to Spitsbergen	--	--	2,548	1,200-3,896*	(Øien 1990)
Gulf of Mexico	NMFS - Gulf of Mexico stock	--	--	1,665	CV=0.2	(NMFS 2008)
	Northern Gulf of Mexico - off the Mississippi River Delta between 86 ^{o} and 91 ^{o}W	--	--	398	253-607	(Jochens et al. 2006)
	North-central and Northwestern Gulf of Mexico	--	--	87	52-146	(Mullin et al. 2004)
North Pacific	Basinwide	620,400	--	472,100	--	(Gosho et al. 1984)
				930,000	--	(Rice 1989b)
	Eastern Tropical Pacific	--	--	26,053	13,797-38,309*	(Whitehead 2003)
	Off Costa Rica	--	--	1,360	823-2,248*	(Gerrodette and Palacios 1996)
	Off Central America north of Costa Rica	--	--	333	125-890*	(Gerrodette and Palacios 1996)
	Eastern Temperate North Pacific	--	--	26,300	0-68,054*	(Barlow and Taylor 2005)
				32,100	9,450-54,750*	(Barlow and Taylor 2005)
	NMFS - North Pacific stock	--	--	--	--	(Angliss and Allen 2007)
	NMFS - California/Oregon/ Washington stock	--	--	2,853	CV=0.25*	(Carretta et al. 2008)
	NMFS - Hawaii stock	--	--	7,082	2,918-11,246*	(Carretta et al. 2008)
Southern Hemisphere	Basinwide	547,600	--	299,400	--	(Gosho et al. 1984; IWC 1988; Perry et al. 1999)
	South of 60 ^{o}S	--	--	14,000	8,786-19,214*	(Butterworth et al. 1995) as cited in (Perry et al. 1999)
	South of 30 ^{o}S	--	--	128,000	17,613-238,387*	(Butterworth et al. 1995) as cited in (Perry et al. 1999)

*Note: Confidence Intervals (C.I.) not provided by the authors were calculated from Coefficients of Variation (C.V.) where available, using the computation from Gotelli and Ellison (2004).

North Atlantic. 190,000 sperm whales were estimated to have been in the entire North Atlantic, but CPUE data from which this estimate is derived are unreliable according to the IWC (Perry et al. 1999). The total number of sperm whales in the western North Atlantic is unknown (Waring et al. 2008). The best available current abundance estimate for western North Atlantic sperm whales is 4,804 based on 2004 data. The best available estimate for Northern Gulf of Mexico sperm whales is 1,665, based on 2003-2004 data, which are insufficient data to determine population trends (Waring et al. 2008). Sperm whale were widely harvested from the northeastern Caribbean (Romero et al. 2001) and the Gulf of Mexico where sperm whale fisheries operated during the late 1700s to the early 1900s (NMFS 2006; Townsend 1935).

North Pacific. There are approximately 76,803 sperm whales in the eastern tropical Pacific, eastern North Pacific, Hawaii, and western North Pacific (Whitehead 2002). Minimum estimates in the eastern North Pacific are 1,719 individuals and 5,531 in the Hawaiian Islands (Carretta et al. 2007). The tropical Pacific is home to approximately 26,053 sperm whales and the western North Pacific has approximately 29,674 (Whitehead 2002). There was a dramatic decline in the number of females around the Galapagos Islands during 1985-1999 versus 1978-1992 levels, likely due to migration to nearshore waters of South and Central America (Whitehead 2003).

Sperm whales are sighted off Oregon in every season except winter (Green et al. 1992). However, sperm whales are found off California year-round (Barlow 1995; Dohl et al. 1983; Forney et al. 1995), with peak abundance from April to mid-June and from August to mid-November (Rice 1974).

Hill and DeMaster (1999) concluded that about 258,000 sperm whales were harvested in the North Pacific between 1947-1987. Although the IWC protected sperm whales from commercial harvest in 1981, Japanese whalers continued to hunt sperm whales in the North Pacific until 1988 (Reeves and Whitehead 1997). In 2000, the Japanese Whaling Association announced plans to kill 10 sperm whales in the Pacific Ocean for research. Although consequences of these deaths are unclear, the paucity of population data, uncertainty regarding recovery from whaling, and re-establishment of active programs for whale harvesting pose risks for the recovery and survival of this species. Sperm whales are also hunted for subsistence purposes by whalers from Lamalera, Indonesia, where a traditional whaling industry has been reported to kill up to 56 sperm whales per year.

Southern Hemisphere. Whaling in the Southern Hemisphere averaged roughly 20,000 whales between 1956-1976 (Perry et al. 1999). Population size appears to be stable (Whitehead 2003). Whitehead (2002b) estimated 12,069 sperm whales south of 60° S.

Natural threats. Sperm whales are known to be occasionally predated upon by killer whales (Jefferson and Baird 1991; Pitman et al. 2001) and large sharks (Best et al. 1984) and harassed by pilot whales (Arnbom et al. 1987; Palacios and Mate 1996; Rice 1989a; Weller et al. 1996; Whitehead 1995). Strandings are also relatively common events, with one to dozens of individuals generally beaching themselves and dying during any single event. Although several hypotheses, such as navigation errors, illness, and anthropogenic stressors, have been proposed (Goold et al. 2002; Wright 2005), direct widespread causes of strandings remain unclear. Calcivirus and papillomavirus are known pathogens of this species (Lambertsen et al. 1987; Smith and Latham 1978).

Anthropogenic threats. Sperm whales historically faced severe depletion from commercial whaling operations. From 1800 to 1900, the IWC estimated that nearly 250,000 sperm whales were killed by whalers, with another 700,000 from 1910 to 1982 (IWC Statistics 1959-1983). However, other estimates have included 436,000 individuals killed between 1800-1987 (Carretta et al. 2005). However, all of these estimates are likely underestimates due to illegal and inaccurate killings by Soviet whaling fleets between 1947-1973. In the Southern Hemisphere, these whalers killed an estimated 100,000 whales that they did not report to the IWC (Yablokov et al. 1998), with smaller harvests in the Northern Hemisphere, primarily the North Pacific, that extirpated sperm whales from large areas (Yablokov and Zemsky 2000). Additionally, Soviet whalers disproportionately killed adult females in any reproductive condition (pregnant or lactating) as well as immature sperm whales of either gender.

Although the IWC protected sperm whales from commercial harvest in 1981, Japanese whalers continued to hunt sperm whales in the North Pacific until 1988 (Reeves and Whitehead 1997). In 2000, the Japanese Whaling Association announced plans to kill 10 sperm whales in the Pacific Ocean for research. Although consequences of these deaths are unclear, the paucity of population data, uncertainly regarding recovery from whaling, and re-establishment of active programs for whale harvesting pose risks for the recovery and survival of this species. Sperm whales are also hunted for subsistence purposes by whalers from Lamalera, Indonesia, where a traditional whaling industry has been reported to take up to 56 sperm whales per year. Japan also kills up to 101 sei whales annually (IWC 2008).

Following a moratorium on whaling by the IWC, significant whaling pressures on sperm whales were eliminated. However, sperm whales are known to have become entangled in commercial fishing gear and 17 individuals are known to have been struck by vessels (Jensen and Silber 2004). Whale-watching vessels are known to influence sperm whale behavior (Richter et al. 2006).

Sperm whales are known to have been incidentally taken in drift gillnet operations, which killed or seriously injured an average of nine sperm whales annually from 1991-1995 (Barlow et al. 1997). Sperm whales have been bycaught in pelagic drift gillnets along the U.S. east coast and in artisanal gillnets targeting sharks and large pelagic fishes off the Pacific coasts of northwestern South America, Central America, and Mexico (Palacios and Gerrodette 1996; Waring et al. 1997). Interactions between longline fisheries and sperm whales have been common over the past decade (Rice 1989; Hill and DeMaster 1999). One sperm whale was observed entangled within the Hawaiian Islands EEZ in the Hawaii-based longline fishery and was able to free itself without injury (Forney 2004). An individual was caught and released from gillnetting, although injured, on Georges Bank during 1990. A second individual was freed, but injured, from gillnetting on George's Bank in 1995. In 1994, a sperm whale was disentangled from gillnet along the coast of Maine. In August 1993, a dead sperm whale, with longline gear wound tightly around the jaw, was found floating ~32 km off Maine.

There have not been any recent documented ship strikes involving sperm whales in the North Pacific, although there are a few records of ship strikes in the 1990s. Two whales described as "possibly sperm whales" are known to have died in U.S. Pacific waters in 1990 after being struck by vessels (Barlow et al. 1997). There is an anecdotal record from 1997 of a fishing vessel that struck a sperm whale in southern Prince William Sound in Alaska, although the whale did not appear to be injured (Laist et al. 2001). More recently in the Pacific, two sperm whales were struck by a ship, but it is not known if these ship strikes resulted in injury or mortality (NMFS

2009). Worldwide, sperm whales are known to have been struck 17 times out of a total record of 292 strikes of all large whales, 13 of which resulted in mortality (Jensen and Silber 2003; Laist et al. 2001). Given the current number of reported cases of injury and mortality, it does not appear that ship strikes are a significant threat to sperm whales (Whitehead 2003).

Naval activity, notably sonar use during training exercises, has gained notoriety for its coincidence with marine mammal strandings. However, other activities (also during training exercises in designated naval operating areas and training ranges) also have the potential to adversely impact marine mammals. Listed individuals travel widely in the North Pacific and could be exposed to naval activities in several ranges, including the Marianas Island Range Complex, Okinawa and Japan Range Complexes, Northwest Training Range Complex, Gulf of Alaska Operating Area, and Hawaiian Islands Operating Area.

Contaminants have been identified in sperm whales, but vary widely in concentration based upon life history and geographic location, with northern hemisphere individuals generally carrying higher burdens (Evans et al. 2004). Contaminants include dieldrin, chlordane, DDT, DDE, PCBs, HCB and HCHs in a variety of body tissues (Aguilar 1983; Evans et al. 2004), as well as several heavy metals (Law et al. 1996). However, unlike other marine mammals, females appear to bioaccumulate toxins at greater levels than males, which may be related to possible dietary differences between females who remain at relatively low latitudes compared to more migratory males (Aguilar 1983; Wise et al. 2009). Chromium levels from sperm whales skin samples worldwide have varied from undetectable to 122.6 μg Cr/g tissue, with the mean (8.8 μg Cr/g tissue) resembling levels found in human lung tissue with chromium-induced cancer (Wise et al. 2009). Older or larger individuals do not appear to accumulate chromium at higher levels.

Critical habitat. The NMFS has not designated critical habitat for sperm whales.

Environmental baseline

By regulation, environmental baselines for Opinions include the past and present impacts of all state, federal, or private actions and other human activities in the action area, the anticipated impacts of all proposed federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions that are contemporaneous with the consultation in process (50 CFR §402.02). The *Environmental baseline* for this Opinion includes the effects of several activities affecting the survival and recovery of ESA-listed species in the action area.

Physical and oceanographic features

The presence of key habitat features, such as shelter or foraging opportunities, are the primary reasons why individuals occur where they do. In the marine environment, this is fundamentally built upon local physical and oceanographic features that influence the marine environment. The proposed seismic survey will be conducted in oceanic western tropical North Pacific waters influenced by different physical and oceanographic processes.

Although ocean circulation around Wake Island is poorly understood, it is a part of the North Pacific Subtropical Gyre (NPSG), which is the largest ecosystem on Earth and the planet's largest circulation (Eldredge 1983; Karl 1999). Waters are warm (24-31˚C, mean of 27-28˚C), with low nutrients, chlorophyll, and subsequently low densities of organisms (Karl 1999; Miller 2007; NOAA 2004). Local surface waters in the region are well mixed. Below this relatively stable thermocline, waters chill rapidly. Circulation is wind-driven and anti-cyclonic, with low interchange of water from surrounding currents (Karl 1999). This relatively stable, homogenous water body can be perturbated, though, with tropical cyclones or eddies bringing nutrient-rich waters up to the surface to fuel localized primary productivity (Karl 1999; Venrick 1990).

As a whole, the west central North Pacific is considered oligotrophic, lacking significant nutrient availability in surface waters for widespread primary productivity (Rodier and Borgne 1997). Phytoplankton biomass is low, reflected by low chlorophyll α concentrations >0.1 mg/m^3 and primary productivity rates of 170-182 $mgCm^{-2}d^{-1}$ (NASA 1998; Radenac and Rodier 1996; Sea Around Us 2009). Areas with such low primary productivity tend to be dominated by nano- and picoplakton (Higgins and Mackey 2000; Le Bouteiller et al. 1992). El Niño events appear to have little effect on local productivity (Higgins and Mackey 2000; Mackey et al. 1997). As such, zooplankton productivity is also very low in general (Vinogradov and Parin 1973). However, seamounts can locally enhance productivity and, consequently, increase secondary productivity that supports pelagic and demersal fish (Boehlert and Genin 1987; Darnitsky 1980; Fedorov and Chistikov 1985; Greze and Kovalev 1985; Parin et al. 1985; Rogers 1994; Zaika and Kovalev 1984).

Climate change

We primarily discuss climate change as a threat common to all species addressed in this Opinion, rather than in each of the species-specific narratives. As we better understand responses to climate change, we will address these effects in relevant species-specific sections.

In general, based on forecasts made by the Intergovernmental Panel on Climate Change (IPCC), climate change is projected to have substantial direct and indirect effects on individuals, populations, species, and the structure and function of marine, coastal, and terrestrial ecosystems in the near future (IPCC 2000; IPCC 2001a; IPCC 2001b; IPCC 2002). From 1906-2006, global surface temperatures have risen 0.74º C and continues at an accelerating pace; 11 of the 12 warmest years on record since 1850 have occurred since 1995 (Poloczanska et al. 2009). Furthermore, the Northern Hemisphere (where a greater proportion of ESA-listed species occur) is warming faster than the Southern Hemisphere, although land temperatures are rising more rapidly than over the oceans (Poloczanska et al. 2009). The direct effects of climate change are resulting in increases in atmospheric temperatures, changes in sea surface temperatures, patterns of precipitation, and sea level. Oceanographic models project a weakening of the thermohaline circulation resulting in a reduction of heat transport into high latitudes of Europe, an increase in the mass of the Antarctic ice sheet, and a decrease in the Greenland ice sheet, although the magnitude of these changes remain unknown. Species that are shorter-lived, of larger body size, or generalist in nature are liable to be better able to adapt to climate change over the long term versus those that are longer-lived, smaller-sized, or rely upon specialized habitats (Brashares 2003; Cardillo 2003; Cardillo et al. 2005; Issac 2009; Purvis et al. 2000). Climate change is most likely to have its most pronounced affects on species whose populations are already in tenuous positions (Isaac 2008). As such, we expect the risk of extinction to listed species to rise with the degree of climate shift associated with global warming.

Some indirect effects of climate change would result from changes in the distribution of temperatures suitable for whale calving and rearing, the distribution and abundance of prey and abundance of competitors or predators. For species that undergo long migrations, individual movements are usually associated with prey availability or habitat suitability. If either is disrupted, the timing of migration can change or negatively impact population sustainability

(Simmonds and Eliott. 2009). Climate change can influence reproductive success by altering prey availability, as evidenced by high-success of northern elephant seals during El Niño periods, when cooler, more productive waters are associated with higher first year pup survival (McMahon and Burton. 2005). Reduced prey availability resulting from increased sea surface temperatures has also been suggested to explain reductions in Antarctic fur seal pup and harbor porpoise survival (Forcada et al. 2005; Macleod et al. 2007). Polygamous marine mammal mating systems can also be perturbated by rainfall levels, with the most competitive grey seal males being more successful in wetter years than in drier ones (Twiss et al. 2007). For marine mammals considered in this Opinion, available data suggest sperm whale females have lower rates of conception following periods of unusually warm sea surface temperature (Whitehead 1997). Marine mammals with restricted distributions linked to water temperature may be particularly exposed to range restriction (Issac 2009; Learmonth et al. 2006). MacLeod (2009) estimated that, based upon expected shifts in water temperature, 88% of cetaceans would be affected by climate change, 47% would be negatively affected, and 21% would be put at risk of extinction. Of greatest concern are cetaceans with ranges limited to non-tropical waters and preferences for shelf habitats (Macleod 2009). Variations in the recruitment of krill and the reproductive success of krill predators correlate to variations in sea-surface temperatures and the extent of sea-ice coverage during winter months. Although the IPCC (2001b) did not detect significant changes in the extent of Antarctic sea-ice using satellite measurements, Curran et al. (2003) analyzed ice-core samples from 1841-1995 and concluded Antarctic sea ice cover had declined by about 20% since the 1950s.

Roughly 50% of the Earth’s marine mammal biomass occurs in the Southern Ocean, with all baleen whales feeding largely on a single krill species, *Euphausia superba*, around Antarctica and feeding virtually nowhere else (Boyd 2002). Atkinson et al. (2004) linked sea ice loss to severe decreases in krill populations over the past several decades in some areas of the Antarctic. Reid and Croxall (2001) analyzed a 23-year time series of the reproductive performance of predators (Antarctic fur seals, gentoo penguins, macaroni penguins, and black-browed albatrosses) that depend on krill for prey and concluded that these populations experienced increases in the 1980s followed by significant declines in the 1990s; overall an increase in the frequency of years with reduced reproductive success occurred. These declines resulted, at least in part, from changes in the structure of the krill population, particularly reduced recruitment into older krill age classes, which lowered the number of predators krill could sustain. The authors concluded that the biomass of krill within the largest size class was sufficient to support predator demand in the 1980s but not in the 1990s. By 2055, severe reductions in fisheries catch due to climate change have been suggested to occur in the Indo-Pacific, Red Sea, Mediterranean Sea, Antarctic, and tropical areas worldwide while increased catches are expected in the Arctic, North Pacific, North Atlantic, and northern portions of the Southern Ocean (Cheung et al. 2010).

Similarly, Sims et al. (2001) found the timing of squid peak abundance in the English Channel advanced by 120-150 days in the warmest years compared with the coldest. Bottom water temperatures correlated with the extent of squid movement, and temperature increases over the 5 months before and during the month of peak squid movement did not differ between early and late years. These authors concluded that the temporal variation in peak abundance of squid seen off Plymouth represents temperature-dependent movement, which are influenced by climatic changes associated with the North Atlantic Oscillation. Cephalopods dominate the diet of sperm whales, who would likely re-distribute following changes in the distribution and abundance of their prey. If, however, cephalopod populations collapse or decline dramatically, sperm whales would likely decline as well.

Climate change has been linked to changing ocean currents. Rising carbon dioxide levels have been identified as a reason for a poleward shift in the Eastern Australian Current, shifting warm waters into the Tasman Sea and altering biotic features of the area (Poloczanska et al. 2009). Similarly, the Kuroshio Current in the western North Pacific (an important foraging area for juvenile sea turtles) has shifted southward as a result of altered long-term wind patterns over the Pacific Ocean (Poloczanska et al. 2009).

Climate-mediated changes in the distribution and abundance of keystone prey species like krill and climate-mediated changes in the distribution of cephalopod populations worldwide is likely to affect marine mammal populations as they re-distribute throughout the world's oceans in search of prey. If sea ice extent decreases, then larval krill may not be able to survive without access to underice algae to feed on. This may be a cause of decreased krill abundance in the northwestern Antarctic Peninsula during the last decade (Fraser and Hofmann 2003). Meltwaters have also reduced surface water salinities, shifting primary production along the Antarctic Peninsula (Moline et al. 2004). Blue whales, as predators that specialize in eating krill, are likely to change their distribution in response to changes in the distribution of krill (Clapham et al. 1999; Payne et al. 1986; Payne et al. 1990b). If they did not change their distribution or could not find the krill biomass necessary to sustain their population numbers, blue whale populations would likely experience declines similar to those observed in other krill predators, including dramatic declines in population size and increased year-to year variation in population size and demographics. These outcomes would dramatically increase the extinction probability of baleen whales. Edwards et al. (2007) found a 70% decrease in one zooplankton species in the North Sea and an overall reduction in plankton biomass as warm-water species invade formerly cold-water areas. Productivity may increase in other areas, though, providing more resources for local species (Brown et al. 2009). In addition, reductions in sea ice may alleviate "choke points" that allow some marine mammals to exploit additional habitats (Higdon and Ferguson 2009).

Foraging is not the only potential aspect that climate change could influence. Acevedo-Whitehouse and Duffus (2009) proposed that the rapidity of environmental changes, such as those resulting from global warming, can harm immunocompetence and reproductive parameters in wildlife to the detriment of population viability and persistence. Altered ranges can also result in the spread of novel diseases to new areas via shifts in host ranges (Simmonds and Eliott. 2009). It has also been suggested that increases in harmful algal blooms could be a result of increases in sea surface temperature (Simmonds and Eliott. 2009).

Climatic anomalies influencing the region include El Niño/Southern Oscillation (ENSO) and La Niña events (Giese and Carton 1999; Mantua and Hare 2002a; NOAA 2005a; NOAA 2005b; Sugimoto et al. 2001; Trenberth 1997). Although Guam and the Southern Marianas Islands do not appear to experience altered rainfall patterns during El Niño events, the Northern Marianas tend to experience drier dry seasons and wetter wet seasons (Pacific ENSO Applications Center 1995). Sea surface temperature in the regions also increases due to a weakening of a high pressure system over the western Pacific, potentially influencing the distribution of fish (Kubota 1987; Lehodey et al. 1997). Typhoons tend to be more frequent during El Niño events (Elsner and Liu 2003; Saunders et al. 2000).

Unlike El Niño and La Niña events, Pacific Decadal Oscillation events can persist for 20-30 years, but are more prominent outside the tropics, and mechanisms controlling them are relatively unknown (Hare and Mantua 2000; Mantua and Hare 2002b; Minobe 1997; Minobe 1999). PDO events should not strongly influence the action area.

Habitat degradation

A number of factors may be affecting listed species in the action area by degrading habitat. These include ocean noise and fisheries impacts.

Natural sources of ambient noise include: wind, waves, surf noise, precipitation, thunder, and biological noise from marine mammals, fishes, and crustaceans. Anthropogenic sources of ambient noise include: transportation and shipping traffic, dredging, construction activities, geophysical surveys, and sonars. In general, it has been asserted that ocean background noise levels have doubled every decade for the last six decades in some areas, primarily due to shipping traffic (IWC 2004). The acoustic noise that commercial traffic contributes to the marine environment is a concern for listed species because it may impair communication between individuals (Hatch et al. 2008). North Atlantic right whales increase the amplitude of their calls in response to increased background noise (Parks et al. 2010a; Parks et al. 2010b).

Seamounts are sensitive to fishery impacts due to the high level of endemism characteristic of this habitat. Species that inhabit seamounts tend to be long-lived and do not move widely between seamounts, meaning that their recovery can be very slow (Johnston and Santillo 2004; Richer de Forges 2000). Listed species may associate with seamounts, apparently due to prey availability here, and the deterioration of the habitat can have significant effects on listed species.

Vessel traffic

Vessel noise could affect marine animals in the proposed action area. Shipping and seismic noise generally dominates ambient noise at frequencies from 20 to 300 Hz (Andrew et al. 2002; Hildebrand 2009; Richardson et al. 1995c). Background noise has increased significantly in the past 50 years as a result of increasing vessel traffic, and particularly shipping, with increases of as much as 12 dB in low frequency ranges; background noise may be 20 dB higher now versus preindustrial periods (Hildebrand 2009; Jasny et al. 2005; McDonald et al. 2006; NRC 1994; NRC 2003; NRC 2005; Richardson et al. 1995a). Over the past 50 years, the number of commercial vessels has tripled, carrying an estimated six times as much cargo (requiring larger, more powerful vessels)(Hildebrand 2009).

The busiest port in Micronesia is located on Guam, where commercial waterways link the island to Hawaii and the western U.S. to the east and Asian ports such as Okinawa to the west (Matson Navigation Company 2004).

Baleen whales may be more sensitive to sound at low frequencies than are toothed whales. Dunlop et al. (2010) found that humpback whales shifted from using vocal communication (which carries relatively large amounts of information) to surface-active communication (splashes; carry relatively little information) when low-frequency background noise increased due to increased sea state. Sonars and small vessels also contribute significantly to mid-frequency ranges (Hildebrand 2009).

Naval activities

Naval activity, notably sonar use during training exercises, has gained notoriety for its coincidence with marine mammal strandings. However, other activities (also during training exercises in designated naval operating areas and training ranges) also have the potential to adversely impact marine mammals. Listed individuals travel widely in the North Pacific and could be exposed to naval activities in several ranges.

- Marianas Island Range Complex, where sei whales may breed and give birth,
- The Okinawa and Japan Range Complexes, where listed whales may occur,
- The Gulf of Alaska Operating Area, where several listed whale species are known to forage, and
- The Hawaiian Islands Operating Area, where listed whales may occur.

Naval activities to which individuals could be exposed include, among others, vessel and aircraft transects, munition detonations, and sonar use. Responses by marine mammals could include no response, short-term and long-term behavioral responses (altered vocal activity, changes in swimming speed and direction, respiration rates, dive times, and social interactions), temporary or permanent hearing loss, debris ingestion, ship-strike injury, and death. Death or injury is not expected to occur as a result of exposure to naval activities. Several unusual incidents of stranding or milling have occurred in association with naval activities on the Hawaii Range complex.

Although naval vessels represent a small fraction of the total sound level in the region and are designed to operate quietly, these ships are large and equipped with high-output sonar equipment such as ANISQS-53C tactical sonar, which produces signals at source levels of 235 dB re 1 μPa_{rms} at 1 m. The signals emitted from these devices have the potential to affect marine mammals in the action area; however, empirical data are limited.

Scientific and research activities

Scientific research permits issued by the NMFS currently authorize studies of listed species in the North Pacific Ocean, some of which extend into portions of the action area. Authorized research on ESA-listed whales includes close vessel and aerial approaches, biopsy sampling, tagging, ultrasound, and exposure to acoustic activities. Research activities involve non-lethal "takes" of these whales by harassment, with none resulting in mortality.

Tables 5-6 describe the cumulative number of takes for each listed species in the action area authorized in scientific research permits.

Table 5. Sei whale takes in the North Pacific.

Year	Approach	Biopsy	Suction cup tagging	Implantable tagging
2009	4,170*	435	75	25
2010	6,386*	730	250	100
2011	4,491	638	518	85
2012	4,491	638	518	85
2013	4,271	628	498	85
Total	23,809	3,069	1,859	380

Permit numbers: 1127-1921, 540-1811, 731-1774, 782-1719, 1058-1733, 1049-1718, 774-1714, 0642-1536, 808-1735, 14097, 14585, 14122, 14245, 14296, 14451, and 14534.

Table 6. Sperm whale takes in the North Pacific.

Year	Approach	Biopsy	Suction cup tagging	Implantable tagging	Acoustic playback
2009	17,895	770	100	40	0
2010	22,001	1,425	405	170	120
2011	20,051	3,285	2,845	340	120
2012	18,426	3,285	2,825	340	120
2013	17,416	3,165	2,825	330	120
Total	95,789	11,930	9,000	1,220	480

Permit numbers: 1127-1921, 1071-1770, 473-1700, 540-1811, 731-1774, 781-1824, 782-1719, 0642-1536, 1049-1718, 774-1714, 14097, 14122, 14296, 14451, 14534, 14585, 14245, 781-1824, 540-1811, and 727-1915.

Effects of the proposed actions

Pursuant to section 7(a)(2) of the ESA, federal agencies must ensure, through consultation with the NMFS and/or USFWS, that their activities are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat. The proposed funding by the NSF of the proposed seismic survey and issuance of the IHA by the NMFS for "takes" (as defined by the MMPA) of marine mammals during the seismic studies would expose listed species to seismic airgun pulses and sound emitted from a multi-beam bathymetric echosounder and sub-bottom profiler. In this section, we describe the potential physical, chemical, or biotic stressors associated with the proposed actions, the probability of individuals of listed species being exposed to these stressors based on the best scientific and commercial evidence available, and the probable responses of those individuals (given probable exposures) based on the available evidence. As described in the *Approach to the assessment* section, for any responses that would be expected to reduce an individual's fitness (i.e., growth, survival, annual reproductive success, or lifetime reproductive success), the assessment would consider the risk posed to the viability of the population(s) those individuals comprise and to the listed species those populations represent. The purpose of this assessment and, ultimately, of the Opinion is to determine if it is reasonable to expect the proposed action to have effects on listed species that could appreciably reduce their likelihood of surviving and recovering in the wild.

For this consultation, we are particularly concerned about behavioral disruptions that may result in animals that fail to feed or breed successfully or fail to complete their life history because these responses are likely to have population-level consequences. The proposed action would authorize non-lethal "takes" by harassment of listed species during seismic survey activities. The ESA does not define harassment nor has the NMFS defined the term pursuant to the ESA through regulation. The Marine Mammal Protection Act of 1972, as amended, defines harassment as any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal population in the wild (level A) or has the potential to disturb a marine mammal or marine mammal population in the wild (level B) by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering [16 U.S.C. 1362(18)(A)]. The latter portion of this definition (that is, "...causing disruption of behavioral patterns including...migration, breathing, nursing, breeding, feeding, or sheltering") is almost identical to the U.S. Fish and Wildlife Service's regulatory definition of "harass"[1] pursuant to the ESA. For this Opinion, we define harassment similarly: an intentional or unintentional human act or omission that creates the probability of injury to an individual animal by disrupting one or more behavioral patterns that are essential to the animal's life history or its contribution to the population the animal represents.

Our analysis considers that behavioral harassment or disturbance is not limited to the "take" definition and may in fact occur in many ways. Fundamentally, if our analysis leads us to conclude that an individual changes its behavioral state (for example, from resting to traveling away from the approaching vessel or from traveling to evading), we consider the individual to have been harassed or disturbed. In addition, individuals may respond in a variety of ways, some of which have more significant fitness consequences than others. For example, evasion of an approaching vessel would be more significant than slow travel away from the same stressor due to increased metabolic demands, stress responses, and potential for habitat abandonment that this response could or would entail. As described in the *Approach to the assessment*, the universe of likely responses is considered in evaluating the fitness consequences to the individual and (if appropriate), the affected population and species as a whole to determine the likelihood of jeopardy.

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[1] An intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering (50 CFR 17.3)

Potential stressors

The assessment for this consultation identified several possible stressors associated with the proposed seismic activities, including

1. pollution by oil or fuel leakage
2. ship-strikes
4. sound fields produced by engine noise and machinery
5. entanglement in towed hydrophone streamers
6. sound fields produced by airguns, sub-bottom profiler, and multibeam echosounder

Based on a review of available information, this Opinion determined which of these possible stressors would be likely to occur and which would be discountable or insignificant. The potential for fuel or oil leakages and ship strikes are extremely unlikely. The former would likely pose a significant risk to the vessel and its crew and actions to correct a leak should occur immediately to the extent possible. In the event that a leak should occur, the amount of fuel and oil onboard the *Thompson* is unlikely to cause widespread, high-dose contamination (excluding the remote possibility of severe damage to the vessel) that would impact listed species directly or pose hazards to their food sources. We are not aware of a ship strike by a seismic survey vessel, although 1,000s of hours of vessel travel occur annually. We do not expect a significant probability of ship strike due to low whale density and general expected movement away or parallel to the *Thompson* (Hauser and Holst 2009; Holst 2009; Holst 2010; Holst and Smultea 2008a) as well as the lack of strikes in the past. Thus, we feel the potential for a ship strike is discountable.

We expect that the *Thompson* will add to the local noise environment in its operating area due to the propulsion and other noise characteristics of the vessel's machinery. This contribution is likely small in the overall regional sound field. The *Thompson*'s passage past a whale would be brief and not likely to be significant in impacting any individual's ability to feed, reproduce, or avoid predators. Brief interruptions in communication via masking are possible, but unlikely given the habits of whales to move away from vessels, either as a result of engine noise, the physical presence of the vessel, or both (Lusseau 2006). In addition, the *Thompson* will be traveling at slow speeds, reducing the amount of noise produced by the propulsion system and the probability of a ship-strike (Kite-Powell et al. 2007; Vanderlaan and Taggart 2007). Thus, we feel the potential for acoustic interference from propulsion and mechanical noise is discountable.

The towed hydrophone streamers could come in direct contact with a listed species and sea turtle entanglements have occurred in towed seismic gear. Marine mammal entanglement is highly unlikely due to the streamer design and extensive use of this equipment without entanglement of marine mammals. Entanglement of marine mammals is therefore considered discountable.

Accordingly, this consultation focused on the following stressors likely to occur from the proposed seismic activities and may adversely affect ESA-listed species: 1. acoustic energy introduced into the marine environment by the airgun array and 2. acoustic energy introduced by both the multibeam echosounder and sub-bottom profiler sonars.

Exposure analysis

Exposure analyses identify the ESA-listed species that are likely to co-occur with the actions' effects on the environment in space and time, and identify the nature of that co-occurrence. The *Exposure analysis* identifies, as possible, the number, age or life stage, and gender of the individuals likely to be exposed to the actions' effects and the population(s) or subpopulation(s) those individuals represent.

The NMFS applies certain acoustic thresholds to help determine at what point during exposure to seismic airguns (and other acoustic sources) marine mammals are "harassed," under the MMPA (65 FR 16374). These thresholds help to develop exclusion radii around a source and the necessary shut-down criteria. Airguns contribute a massive amount of anthropogenic energy to the world's oceans ($3.9\text{x}10^{13}$ joules), second only to nuclear explosions (Moore and Angliss 2006). Although most energy is in the low-frequency range, airguns emit a substantial amount of energy up to 150 kHz (Goold and Coates 2006). Seismic airgun noise can propagate long distances at low frequencies (e.g., Nieukirk et al. 2004).

The *Exposure analysis* for this Opinion is concerned with the number of sei and sperm whales likely to be exposed to received levels greater than 160 dB re 1 $\mu\text{Pa}_{\text{rms}}$. The NSF and Permits Division estimated the expected number of ESA-listed whales exposed to received levels ≥160 dB re 1 $\mu\text{Pa}_{\text{rms}}$. The data and methodology used were adopted in this Opinion because the Endangered Species Division believed they represent the best available information and methods to evaluate exposure to listed whales.

The SIO and the Permits Division provided density estimates for listed whales in the action area. The NSF and Permits Division used data from regional marine mammal surveys to calculate expected marine mammal densities in the action area. The presence/absence and densities of sei and sperm whales stem from surveys of the Marianas Islands as well as the outer EEZ of Hawaii (Barlow 2006; SRS-Parsons et al. 2007).

Review of the local survey data and surveys in the wider North Pacific as well as knowledge of listed species life history and local oceanographic conditions supports these estimates as the best available information. Sei whales were frequently observed or detected during the 2007 U.S. Navy ship surveys conducted from roughly January-April through waters surrounding the Marianas Islands (SRS-Parsons et al. 2007). Baleen whale life histories provide support for the area potentially being a breeding and calving area. The 2007 Navy survey may have spotted a sei whale cow/calf pair near the Marianas Islands, supporting calving of this species in the area (SRS-Parsons et al. 2007). This survey was the first to document sei whales below 20º N (action area is 16.5-19 º N) anywhere in the Pacific. Thus, the single year Navy sightings may represent an unusual distribution pattern during that year, or represent a general pattern, as very few low-latitude marine mammal surveys have been conducted in the western Pacific Ocean. The region is considered oligotrophic and not likely to support significant feeding by baleen whales (NASA 1998; Radenac and Rodier 1996; Rodier and Borgne 1997), although a Bryde's whale was observed lunge feeding during 2007 Navy surveys (SRS-Parsons et al. 2007). Localized transient features should not attract individuals for feeding or other activities. However, available data do support the distinct possibility that sei whales could occur in the action area. The likelihood of encountering a sei whale should be low, but reasonably possible. As the area may serve as a calving area, it is also reasonable that a newborn or very young calf may accompany adults.

Sperm whale occurrence is expected to follow trends seen during the 2007 Navy survey around the Marianas Islands, with the area being used as a feeding, breeding, and calving area (Fulling and Vega 2009; SRS-Parsons et al. 2007). Although adult males are known to forage in more northerly latitudes, males should be present for breeding (Kasuya and Miyashita 1988). Females and younger males should be engaged in foraging in these latitudes (Miller et al. 2004; SRS-Parsons et al. 2007; Weilgart and Whitehead 1988). Sperm whale distribution may be somewhat localized to seamounts and areas of sharp bathymetric relief for possible foraging opportunities in these areas (Clarke 1956; Jaquet and Whitehead 1996; Jaquet et al. 1996; Whitehead 2003). However, sperm whale sighting data from the 2007 Navy cruise do not clearly support this and general occurrence in deep oceanic waters seems routine (SRS-Parsons et al. 2007).

The SIO estimated the exposure radii around the proposed *Thompson* operations. The distances to which sound levels (rms) might propagate are provided in Table 1 on page 6. The maximum distance from airguns where received levels might reach 160 dB re 1 μPa_{rms} is 670 m with a 3 m tow depth. A thorough review of available literature (see *Response analysis*) supports this level as a general point at which whales tend to show some avoidance response to received seismic sound. The NSF's assumption that individuals will move away if they experience sound levels high enough to cause significant stress or functional impairment is also reasonable (see *Response analysis*), although lacking in scientific testing. Isopleth modeling tends to overestimate the distance to which various isopleths will propagate in intermediate and deep depths because most exposure will likely occur at depths shallower than 2,000 m, where received sound levels should be reduced; only one listed species in the action area is believed capable of diving to 1,000 m or greater (sperm whales). As we are unable to know where individuals will be in the water column at the time of exposure, we accept the NSF's assumption.

A major mitigation factor proposed by the NSF is visual monitoring for marine mammals, which should reduce exposure. However, visual monitoring has several limitations. Although regions ensonified by 160 dB re 1 μPa_{rms} and 180 dB re 1 μPa_{rms} are both within the visual range of the *Thompson* and its observers, it is unlikely that all listed species would be easily visible (or in the case of nighttime operations or in weather with reduced visibility, visible at all). Shut-down procedures are unlikely to be completely effective at eliminating the co-occurrence of listed individuals within the sound field ≥180 dB re 1 μPa_{rms}.

Marine mammals

Exposure of listed mammals to airguns. The exposure estimates stem from the best available information on whale densities and a planned ensonified area of approximately 2,680 km^2 along survey track lines.

The NSF's exposure estimates (Table 7) were calculated by using whale density per 1,000 km^2 multiplied by the total survey track area (2,680 km^2) to obtain the total number of exposures. Resulting values were increased to account for the possible exposure of mother-calf pairs (sei whales) or the mean group size of gregarious species (sperm whales). Some degree of re-exposure may occur. The NSF assumes that individuals would not move within their environment; an assumption that is highly unlikely. We expect listed individuals to move in their environment to feed on available prey, continue migration, or complete other life functions. There is no known factor by which we can account for the probability of movement, and we do not know of a mechanism by which we can accurately calculate the number of exposures per individual in this situation. Therefore, we accept NSF's approach pending better information.

Table 7. Estimated exposure of ESA-listed whales to sound levels $\geq$160 dB re 1 µPa$_{rms}$ during the proposed seismic activities.

Whale density per 1,000 km^2	# of individuals exposed to proposed activities	Population size	% of population exposed	Population/ location
Sei-0.13	2[1]	16,625	0.01	North Pacific[3]
Sperm-2.22	25[2]	29,674	0.08	western North Pacific[4]
Total	**27**	**--**	**--**	**--**

[1] Exposures increased from 1 to 2 to account for the possible exposure of a mother-calf pair.

[2] Exposures increased from 6 to 25 to account for best available estimate of group size (Jaquet and Gendron 2009).

[3] Braham (1991a) and Ohsumi and Wada (Braham 1991b; 1974a; 1974b)

[4] Whitehead (2002)

Whales of any age classes may be exposed. Sperm whales are expected to be engaged in foraging and/or breeding, while sei whales may be nursing, migrating, or breeding. It is assumed that sex distribution is even for whales and sexes are exposed at a relatively equal level.

Exposure of listed marine mammals to multibeam echosounder and sub-bottom profiler. Two additional acoustic systems will operate during the proposed *Thompson* cruise: the multibeam echosounder and the sub-bottom profiler. Both of these systems have the potential to expose listed species to sound above the 160 dB re 1 µPa$_{rms}$ threshold. Both systems operate at generally higher frequencies than airguns (30 kHz for the multibeam echosounder and 3-6 kHz for the sub-bottom profiler) and this mitigates effects; their frequencies will attenuate more rapidly than those from airgun sources. Listed individuals would experience higher levels of airgun noise before either multibeam echosounder or sub-bottom profiler noise of equal amplitude would reach them. Thus, operational airguns mitigate multibeam echosounder and sub-bottom profiler noise exposure. While airguns are not operational, marine mammal observers will remain on duty to collect sighting data. If listed marine mammals were to closely approach the vessel, the *Thompson* would take evasive actions to mitigate a ship strike, simultaneously mitigating exposure to very high source levels. As ship strike has already been ruled out as a discountable effect, so can high-level ensonification (multibeam echosounder source level = 237 dB re 1 µPa$_{rms}$; sub-bottom profiler source level = 221 dB re 1 µPa) of listed marine mammals. Boebel et al. (2006) concluded that multibeam echosounders and sub-bottom profilers similar to those to be used during the proposed activities presented a low risk for auditory damage or any other injury, and that an individual would require exposure to 250–1,000 pulses from a sub-bottom profiler to be at risk for a temporary threshold shift (TTS). To be susceptible to TTS, a marine mammal would have to pass at very close range and match the vessel's speed; we expect a very small probability of this during the proposed study. An individual would have to be within 10 m of the vessel to experience a single multibeam echosounder pulse that could result in TTS (LGL Ltd. 2010). The same result could only occur at even closer ranges for sub-bottom profiler signals, because the signals are weaker. Furthermore, we expect both multibeam echosounder and sub-bottom profiler systems to operate continuously with duty cycles of 3-8 s. It is possible, however, that some small number of listed marine mammals (fewer than those exposed to airguns) could experience low-level multibeam echosounder and/or sub-bottom profiler sound exposure. We are unable to quantify the number or level of exposure.

Response analysis

As discussed in the *Approach to the assessment* section of this Opinion, response analyses determine how listed resources are likely to respond after exposure to an action's effects on the environment or directly on listed species themselves. For the purposes of consultation, our assessments try to detect potential lethal, sub-lethal (physiological), or behavioral responses that might result in reducing the fitness of listed individuals. Ideally, response analyses would consider and weigh evidence of adverse consequences as well as evidence suggesting the absence of such consequences.

Response of marine mammals to airguns. A pulse of seismic airgun sound displaces water around the airgun and creates a wave of pressure, resulting in physical effects on the marine environment that can then affect marine organisms, such as listed marine mammals considered in this Opinion. Possible responses considered in this analysis consist of

- threshold shifts
- auditory interference (masking)
- behavioral responses
- non-auditory physical or physiological effects

The *Response analysis* also considers information on the potential for stranding and the potential effects on the prey of ESA-listed marine mammals in the action area.

Marine mammals and threshold shifts. Exposure of marine mammals to very strong sound pulses can result in physical effects, such as changes to sensory hairs in the auditory system, which may temporarily or permanently impair hearing. Temporary threshold shifts can last minutes to days. Full recovery is expected and this condition is not considered a physical injury. However, a recent mouse study has shown that although full hearing can be regained from TTS (i.e., the sensory cells actually receiving sound are normal), damage can still occur to nerves of the cochlear nerve leading to delayed but permanent hearing damage (Kujawa and Liberman 2009). At higher received levels, or in frequency ranges where animals are more sensitive, permanent threshold shifts (PTSs) can occur in which auditory sensitivity is unrecoverable. Either of these conditions can result from a single pulse or from the accumulated effects of multiple pulses, in which case each pulse need not be as loud as a single pulse to have the same accumulated effect. A TTS or PTS are specific only to the frequencies over which exposure occurs.

Few data are available to precisely define each listed species' hearing range, let alone its sensitivity and levels necessary to induce TTS or PTS. Based upon captive studies of odontocetes, our understanding of terrestrial mammal hearing, and extensive modeling, the best available information supports sound levels at a given frequency would need to be ~186 dB SEL or ~196-201 dB re 1 μPa_{rms} in order to produce a low-level TTS from a single pulse (Southall et al. 2007). If an individual experienced exposure to several airgun pulses of ~190 dB re 1 μPa_{rms}, PTS could occur. A marine mammal would have to be within 20 m of the *Thompson's* airgun array to be within the 190 dB re 1 μPa_{rms} isopleth and risk a PTS (repetitive exposure to >170 dB re 1 μPa_{rms} could cumulatively result in a TTS). A PTS is expected at levels ~6 dB greater than TTS levels on a peak-pressure basis, or 15 dB greater on an SEL basis (Southall et al. 2007). Estimates that are conservative for species protection are 230 dB re 1 μPa (peak) for a single pulse, or multiple exposures to ~198 dB re 1 $\mu Pa^2 \cdot s$. In terms of exposure to the *Thompson's* airgun array, an individual would need to be within a few meters of the largest airgun to experience a single pulse >230 dB re 1 μPa peak (Caldwell and Dragoset 2000).

Overall, we do not expect TTS or PTS to occur to any listed marine mammal as a result of airgun exposure for several reasons. We expect that individuals will move away from the airgun array as it approaches. We further believe that as sound intensity increases, individuals will experience conditions (stress, loss of prey, discomfort, etc.) that prompt them to move away from the sound source and thus avoid exposures that would induce TTS. Ramp-ups would also reduce the probability of TTS exposure at the start of seismic surveys. Furthermore, mitigation measures would be in place to initiate a shut-down if individuals are seen to enter or are about to enter the 180 dB isopleth, which is below the levels believed to be necessary for potential TTS.

Marine mammals and auditory interference (masking). Interference, or masking, generally occurs when the interfering noise is of a similar frequency and similar to or louder than the auditory signal received by an animal processing echolocation signals or listening for acoustic information from other individuals. Masking can interfere with an individual's ability to gather acoustic information about its environment, such as predators, prey, conspecifics, and other environment cues. Generally, noise will only mask a signal if it is sufficiently close to the signal in frequency. Low frequency sounds are broad and tend to have relatively constant bandwidth, whereas higher frequency bandwidths are narrower (NMFS 2006h).

There is frequency overlap between airgun noise and vocalizations of listed whales, particularly baleen whales. Any masking that might occur would likely be temporary because seismic sources are discontinuous and the seismic vessel would continue to transit. Some reduction in communication due to masking may still occur between seismic pulses, as airgun pulses tend to reverberate, increasing the background noise level in the marine environment (Guerra et al. 2009). The proposed seismic surveys could mask whale calls at some of the lower frequencies, in particular for baleen whales but also for sperm whales. This could affect communication between individuals, affect their ability to receive information from their environment, or affect sperm whale echolocation (Evans 1998; NMFS 2006h). Most of the energy of sperm whales clicks is concentrated at 2 to 4 kHz and 10 to 16 kHz, and though the findings by Madsen et al. (2006) suggest frequencies of seismic pulses can overlap this range, the strongest spectrum levels of airguns are below 200 Hz (<188 Hz for the *Thompson's* airguns). Given the disparity between sperm whale echolocation and communication-related sounds with the dominant frequencies for seismic surveys, masking is not likely to be significant for sperm whales (NMFS 2006h). Overlap of the dominant low frequencies of airgun pulses with low-frequency baleen whale calls would be expected to pose a greater risk of effects due to masking. However, masking should not be a concern in the proposed action. This is primarily because masking tends to result from continuous sounds rather than short pulses, such as seismic airguns (Richardson et al. 1995b).

The *Thompson's* airguns will emit a 0.1 s pulse when fired every 5-10 s. Therefore, pulses will not "cover up" the vocalizations of listed whales to a significant extent and reverberation should be small enough so as not to increase background noise levels for significant periods of time between pulses (Madsen et al. 2002). We address the response of listed whales stopping vocalizations as a result of airgun sound in behavioral responses.

Marine mammals and behavioral responses. We expect the greatest response to airgun sounds by number and overall impact to be from behavioral responses. Listed individuals may briefly respond to underwater sound by slightly changing their behavior or relocating a short distance, in which case the effects are unlikely to be individually significant. Displacement from important feeding or breeding areas over a prolonged period would likely be significant. This has been suggested for humpback whales along the Brazilian coast as a result of increased seismic survey activity (Parente et al. 2007). Marine mammal responses to anthropogenic sound vary by species, state of maturity, prior exposure, current activity, reproductive state, time of day, and other factors. Although some studies are available which address responses of listed marine mammals considered in this Opinion directly, additional studies of other related marine mammals (such as bowhead and gray whales) are relevant in determining the responses expected by species under consideration. Therefore, studies from non-listed species or species outside the action area are also considered here.

Several studies have aided in assessing the various levels at which whales may modify or stop their calls in response to airgun sound. Whales continue calling while seismic surveys are occurring locally (Greene Jr et al. 1999; Jochens et al. 2006; Madsen et al. 2002; McDonald et al. 1993; McDonald et al. 1995; Nieukirk et al. 2004; Richardson et al. 1986; Smultea et al. 2004; Tyack et al. 2003). Some blue and sperm whales stopped calling for short and long periods apparently in response to airguns (Bowles et al. 1994; Clark and Gagnon 2006; McDonald et al. 1995). A blue whale discontinued calls in response to received airgun sound of 143 dB re 1 μPa for one hour before resuming (McDonald et al. 1995). Blue whales may attempt to compensate for elevated ambient sound by calling more frequently during seismic surveys (Iorio and Clark 2009). Sperm whales, at least under some conditions, may be particularly sensitive to airgun sounds, as they have been documented to cease calling in association with airguns being fired hundreds of kilometers away (Bowles et al. 1994). Other studies have found no response by sperm whales to received airgun sound levels up to 146 dB re 1 $\mu\mathrm{Pa}_{\mathrm{p\text{-}p}}$ (Madsen et al. 2002; McCall Howard 1999). Some exposed individuals may cease calling in response to the *Thompson's* airguns. If individuals ceased calling in response to the *Thompson's* airguns during the course of the proposed survey, the effect would likely be temporary.

There are numerous studies of the responses of some baleen whale to airguns. Most studies seem to support a threshold of ~160 dB re 1 $\mu\mathrm{Pa}_{\mathrm{rms}}$ as the received sound level to cause behavioral responses other than vocalization changes (Richardson et al. 1995c), although responses to lower-amplitude sounds are known. Individual activity seems to influence response, as feeding individuals seem to respond less than mother/calf pairs and migrating individuals (Harris et al. 2007; Malme and Miles 1985; Malme et al. 1984; Miller et al. 1999; Miller et al. 2005; Richardson et al. 1995c; Richardson et al. 1999). Migrating bowhead whales show strong avoidance reactions to received 120–130 dB re 1 $\mu\mathrm{Pa}_{\mathrm{rms}}$ exposures at distances of 20-30 km, but only changed dive and respiratory patterns while feeding and showed avoidance at higher received sound levels (152–178 dB re 1 $\mu\mathrm{Pa}_{\mathrm{rms}}$; (Harris et al. 2007; Ljungblad et al. 1988; Miller et al. 1999; Miller et al. 2005; Richardson et al. 1995c; Richardson et al. 1999; Richardson et al. 1986). Responses such as stress may occur and the threshold for displacement may simply be higher while feeding. Bowhead calling rate was found to decrease during migration in the Beaufort Sea as well as temporary displacement from seismic sources (Nations et al. 2009). Despite the above information and exposure to repeated seismic surveys, bowheads continue to return to summer feeding areas and when displaced, appear to reoccupy areas within a day (Richardson et al. 1986). Bowheads feeding during late summer and autumn did not show overt large-scale distribution shifts when exposed to seismic operations (Christie et al. 2009; Koski et al. 2009). We do not know whether the individuals exposed in these ensonified areas are the same individuals returning or whether individuals that tolerate repeat exposures may still experience a stress response.

Gray whales respond similarly as bowheads to seismic survey exposure. Gray whales discontinued feeding and/or moved away at received sound levels of 163 dB re 1 μPa_{rms} (Bain and Williams 2006; Gailey et al. 2007; Johnson et al. 2007a; Malme and Miles 1985; Malme et al. 1984; Malme et al. 1986; Malme et al. 1988; Würsig et al. 1999; Yazvenko et al. 2007a; Yazvenko et al. 2007b). Migrating gray whales began to show changes in swimming patterns at ~160 dB re 1 μPa and slight behavioral changes at 140-160 dB re 1 μPa_{rms} (Malme and Miles 1985; Malme et al. 1984). As with bowheads, habitat continues to be used despite frequent seismic survey activity, but long-term effects have not been identified, if they are present at all (Malme et al. 1984). Johnson et al. (2007b) reported that gray whales exposed to seismic airguns off Sakhalin Island, Russia, did not experience any biologically significant or population level effects, based on subsequent research in the area from 2002–2005.

Humpback whales continue a pattern of lower threshold of response when not occupied with feeding. Migrating humpbacks altered their travel path (at least locally) along Western Australia at received levels as low as 140 dB re 1 μPa_{rms} when females with calves were present, or 8-12 km from the seismic source (McCauley et al. 2000a; McCauley et al. 1998). A startle response occurred as low as 112 dB re 1 μPa_{rms}. Closest approaches were generally limited to 3-4 km, although some individuals (mainly males) approached to within 100 m on occasion where sound levels were 179 dB re 1 μPa_{rms}. Changes in course and speed generally occurred at estimated received levels of 157–164 dB re 1 μPa_{rms}. Feeding humpbacks appear to be somewhat more tolerant. Humpback whales along Alaska startled at 150–169 dB re 1 μPa and no clear evidence of avoidance was apparent at received levels up to 172 re 1 μPa_{rms} (Malme et al. 1984; Malme et al. 1985). Potter et al. (2007) found that humpbacks on feeding grounds in the Atlantic did exhibit localized avoidance to airguns. Among humpback whales on Angolan breeding grounds, no clear difference was observed in encounter rate or point of closest approach during seismic versus non-seismic periods (Weir 2008).

Available data support a general avoidance response by baleen whales. Some fin and sei whale sighting data indicate similar sighting rates during seismic versus non-seismic periods, but sightings tended to be further away and individuals remained underwater longer (Stone 2003; Stone and Tasker 2006). Other studies have found at least small differences in sighting rates (lower during seismic activities) as well as whales being more distant during seismic operations (Moulton et al. 2006a; Moulton et al. 2006b; Moulton and Miller 2005). When spotted at the average sighting distance, individuals would have likely been exposed to ~169 dB re 1 μPa_{rms} (Moulton and Miller 2005). Castellote et al. (2009) found that migrating fin whales in the Mediterranean Sea likely vacated a wintering area during ten days of seismic airgun activity as well as ten days following the end of survey activity. Fin whales in the Mediterranean Sea shortened their pulse durations, decreased the bandwidth, center, and peak frequencies of their calls during\g the seismic survey (Castellote et al. 2010).

Sperm whale response to airguns has thus far included mild behavioral disturbance (disrupted foraging, avoidance, cessation of vocal behavior) or no reaction. Several studies have found Atlantic sperm whales to show little or no response (Davis et al. 2000b; Madsen et al. 2006; Miller et al. 2009b; Moulton et al. 2006a; Moulton and Miller 2005; Stone 2003; Stone and Tasker 2006; Weir 2008). Detailed study of Gulf of Mexico sperm whales suggests some alteration in foraging from 111-147 dB re 1 μPa$_{rms}$, although other behavioral reactions were not noted by several authors (Gordon et al. 2004; Jochens et al. 2006; Madsen et al. 2006; Winsor and Mate 2006), including changes in vocalization rate associated with prey capture (Miller et al. 2009a; Tyack 2009). This has been contradicted by other studies, which found avoidance reactions by sperm whales in the Gulf of Mexico in response to seismic ensonification (Jochens and Biggs 2004; Mate et al. 1994). Johnson and Miller (2002) noted possible avoidance at received sound levels of 137 dB re 1 μPa. Other anthropogenic sounds, such as pingers and sonars, disrupt behavior and vocal patterns (Goold 1999; Watkins et al. 1985; Watkins and Schevill 1975). Miller et al. (2009b) found sperm whales to be generally unresponsive to airgun exposure in the Gulf of Mexico, with possible but inconsistent responses that included delayed foraging and altered vocal behavior. Displacement from the area was not observed. The lack of response by this species may in part be due to its higher range of hearing sensitivity and the low-frequency (generally <188 Hz) pulses produced by seismic airguns (Richardson et al. 1995c). Sperm whales are exposed to considerable energy above 500 Hz (Goold and Fish 1998). Breitzke et al. (2008) found that source levels were ~30 dB re 1 μPa lower at 1 kHz and 60 dB re 1 μPa lower at 80 kHz compared to dominant frequencies during a seismic source calibration. Reactions to impulse noise likely vary depending on the activity at time of exposure – e.g., in the presence of abundant food or during sexual encounters, toothed whales sometimes are extremely tolerant of noise pulses (NMFS 2006b).

For whales exposed to seismic airguns during the proposed activities, behavioral changes stemming from airgun exposure may result in loss of feeding opportunities. We expect listed whales exposed to seismic airgun sound will exhibit an avoidance reaction, displacing individuals from the area. We also expect secondary foraging areas to be available where sperm whales could continue feeding. In addition, we expect exposure of a given area to be brief and reoccupation can occur soon after the *Thompson* transects through.

Marine mammals and physical or physiological effects. Individual whales exposed to airguns (as well as other sound sources) could experience effects not readily observable, such as stress, that can significantly affect life history.

There is mounting evidence that wild animals respond to human disturbance in the same way that they respond to predators (Beale and Monaghan 2004; Frid 2003; Frid and Dill 2002; Gill et al. 2001; Harrington and Veitch 1992; Lima 1998; Romero 2004). These responses manifest themselves as stress responses (in which an animal perceives human activity as a potential threat and undergoes physiological changes to prepare for a flight or fight response or more serious physiological changes with chronic exposure to stressors), interruptions of essential behavioral or physiological events, alteration of an animal's time budget, or some combination of these responses (Frid and Dill 2002; Romero 2004; Sapolsky et al. 2000; Walker et al. 2005). These responses have been associated with abandonment of sites (Sutherland and Crockford 1993), reduced reproductive success (Giese 1996; Mullner et al. 2004), and the death of individual animals (Bearzi 2000; Daan 1996; Feare 1976). Stress is an adaptive response and does not normally place an animal at risk. However, distress involves a stress response resulting in a biological consequence to the individual. The mammalian stress response involves the hypothalamic-pituitary-adrenal (HPA) axis being stimulated by a stressor, causing a cascade of physiological responses, such as the release of the stress hormones adrenaline (epinephrine), glucocorticosteroids, and others (Busch and Hayward 2009)(Gulland et al. 1999; Morton et al. 1995; St. Aubin and Geraci 1988; St. Aubin et al. 1996; Thomson and Geraci 1986). These hormones subsequently can cause short-term weight loss, the liberation of glucose into the blood stream, impairment of the immune and nervous systems, elevated heart rate, body temperature, blood pressure, and alertness, and other responses (Busch and Hayward 2009; NMFS 2006g)(Cattet et al. 2003; Delehanty and Boonstra 2009; Elftman et al. 2007; Fonfara et al. 2007; Kaufman and Kaufman 1994; Mancia et al. 2008; Moe and Bakken 1997; Noda et al. 2007; Thomson and Geraci 1986)(Dierauf and Gulland 2001; Omsjoe et al. 2009). In some species, stress can also increase an individual's susceptibility to gastrointestinal parasitism (Greer et al. 2008). In highly-stressful circumstances, or in species prone to strong "fight-or-flight" responses, more extreme consequences can result, including muscle damage and death (Cowan and Curry 1998; Cowan and Curry 2002; Cowan and Curry 2008; Herraez et al. 2007). The most widely-recognized indicator of vertebrate stress, cortisol, normally takes hours to days to return to baseline levels following a significantly stressful event, but other hormones of the HPA axis may persist for weeks (Dierauf and Gulland 2001). Mammalian stress levels can vary by age, sex, season, and health status (Gardiner and Hall 1997; Hunt et al. 2006; Keay et al. 2006; Kenagy and Place 2000; Nunes et al. 2006; Romero et al. 2008; St. Aubin et al. 1996). Smaller mammals tend to react more strongly to stress than larger mammals (Peters 1983); a trend reflected in data from Gauthier and Sears (1999) where smaller whale species tended to react more frequently to biopsy than larger whales. Stress is lower in immature right whales than adults and mammals with poor diets or undergoing dietary change tend to have higher fecal cortisol levels (Hunt et al. 2006; Keay et al. 2006; Kitaysky and Springer 2004).

Romano et al. (2004) found beluga whales and bottlenose dolphins exposed to a seismic water gun (up to 228 dB re 1 μPa · m_{p-p}) and single pure tones (up to 201 dB re 1 μPa) had increases in stress chemicals, including catecholamines, which could affect an individual's ability to fight off disease. These levels returned to baseline after 24 hours. A whale's hearing is a primary way to gather information about its environment and for communication; we assume that limiting these abilities would be stressful. Stress responses may also occur at levels lower than those required for TTS (NMFS 2006g). Therefore, exposure to levels sufficient to trigger onset of PTS or TTS are expected to be accompanied by physiological stress responses (NMFS 2006g; NRC 2003). As we do not expect individuals to experience TTS or PTS, (see *Marine mammals and threshold shifts*) or be exposed to other similarly stressful stimuli, we also do not expect any listed individual to experience a stress response at high levels. We assume that a stress response could be associated with displacement or, if individuals remain in a stressful environment, the stressor (sounds associated with the airgun, multibeam echosounder, or sub-bottom profiler) will dissipate in a short period as the vessel (and stressors) transects away without significant or long-term harm to the individual via the stress response.

Marine mammals and strandings. There is some concern regarding the coincidence of marine mammal strandings and proximal seismic surveys. No conclusive evidence exists to causally link stranding events to seismic surveys.

Suggestions that there was a link between seismic surveys and strandings of humpback whales in Brazil (Engel et al., 2004) were not well founded (IAGC, 2004; IWC, 2007). In September 2002, two Cuvier's beaked whales stranded in the Gulf of California, Mexico. The *R/V Ewing* had been operating a 20-airgun, 8,490-in^3 airgun array 22 km offshore the general area at the time that strandings occurred. The link between the stranding and the seismic surveys was inconclusive and not based on any physical evidence (Hogarth, 2002; Yoder, 2002) as some vacationing marine mammal researchers who happened upon the stranding were ill-equipped to perform an adequate necropsy. Furthermore, the small numbers of animals involved and the lack of knowledge regarding the spatial and temporal correlation between the beaked whales and the sound source underlies the uncertainty regarding the linkage between seismic sound sources and beaked whale strandings (Cox et al., 2006).

Responses of marine mammal prey. Seismic surveys may also have indirect, adverse effects on prey availability through lethal or sub-lethal damage, stress responses, or alterations in their behavior or distribution. Studies described herein provide extensive support for this, which is the basis for later discussion on implications for listed whales. Unfortunately, species-specific information on the prey of listed whales is not generally available. Until more specific information is available, we expect that teleost, cephalopod, and krill prey of listed whales to react in manners similar to those described herein.

Some support has been found for fish or invertebrate mortality resulting from airgun exposure, and this is limited to close-range exposure to high-amplitude sound (Bjarti 2002; Falk and Lawrence 1973; Hassel et al. 2003; Holliday et al. 1987; Kostyuchenko 1973; La Bella et al. 1996; McCauley et al. 2000a; McCauley et al. 2000b; McCauley et al. 2003; Popper et al. 2005; Santulli et al. 1999). Lethal effects, if any, would be limited to within a few meters of the airgun array (Buchanan et al. 2004). We expect fish to be capable of moving away from the airgun array if it causes them discomfort.

More evidence exists for sub-lethal effects. Several species at various life stages have been exposed to high-intensity sound sources (220-242 dB re 1 μPa) at close distances, with some cases of injury (Booman et al. 1996; McCauley et al. 2003). TTS was not found in whitefish at received levels of ~175 dB re 1 $\mu Pa^2 \cdot s$, but pike did show 10-15 dB of hearing loss with recovery within 1 day (Popper et al. 2005). Caged pink snapper have experienced PTS when exposed over 600 times to received seismic sound levels of 165-209 dB re 1 $\mu Pa_{p\text{-}p}$. Capelin and monkfish larvae exposed to 199 to 205 dB re 1 $\mu Pa_{p\text{-}p}$ did not show increased mortality, even when exposed multiple times (Payne et al. 2009).

By far the most common response by fishes is a startle or distributional response, where fish react momentarily by changing orientation or swimming speed, or change their vertical distribution in the water column. Startle responses were observed in rockfish at received airgun levels of 200 dB re 1 $\mu Pa_{0\text{-}p}$ and alarm responses at >177 dB re 1 $\mu Pa_{0\text{-}p}$ (Pearson et al. 1992). Fish also tightened schools and shifted their distribution downward. Normal position and behavior resumed 20-60 minutes after seismic firing ceased. A downward shift was also noted by Skalski et al. (1992) at received seismic sounds of 186–191 re 1 $\mu Pa_{0\text{-}p}$. Caged European sea bass showed elevated stress levels when exposed to airguns, but levels returned to normal after 3 days (Skalski et al. 1992). These fish also showed a startle response when the survey vessel was as much as 2.5 km away; this response increased in severity as the vessel approached and sound levels increased, but returned to normal after ~2 hours following cessation of airgun activity. Whiting exhibited a downward distributional shift upon exposure to 178 dB re 1 $\mu Pa_{0\text{-}p}$ airgun sound, but habituated to the sound after 1 hour and returned to normal depth (sound environments of 185-192 dB re 1 μPa) despite airgun activity (Chapman and Hawkins 1969). Whiting may also flee from airgun sound (Dalen and Knutsen 1986). Hake may redistribute downward (La Bella et al. 1996). Lesser sandeels exhibited initial startle responses and upward vertical movements before fleeing from the survey area upon approach of an active seismic vessel (Hassel et al. 2003; Hassel et al. 2004). McCauley et al. (2000; 2000a) found smaller fish show startle responses at lower levels than larger fish in a variety of fish species and generally observed responses at received sound levels of 156–161 dB re 1 μPa_{rms}, but responses tended to decrease over time suggesting habituation. As with previous studies, caged fish showed increases in swimming speeds and downward vertical shifts. Pollock did not respond to airgun sounds received at 195–218 dB re 1 μPa_{0-p}, but did exhibit continual startle responses and fled from the seismic source when visible (Wardle et al. 2001). Blue whiting and mesopelagic fishes were found to redistribute 20–50 m deeper in response to airgun ensonification and a shift away from the survey area was also found (Slotte et al. 2004). Salmonid swim bladders were reportedly damaged by received sound levels of ~230 dB re 1 μPa (Falk and Lawrence 1973). Startle responses were infrequently observed from salmonids receiving 142–186 dB re 1 μPa_{p-p} sound levels from an airgun (Thomsen 2002). Cod and haddock likely vacate seismic survey areas in response to airgun activity and estimated catchability decreased starting at received sound levels of 160–180 dB re 1 μPa_{0-p} (Dalen and Knutsen 1986; Engås et al. 1996; Engås et al. 1993; Løkkeborg 1991; Løkkeborg and Soldal 1993; Turnpenny et al. 1994). Bass did not appear to vacate during a shallow-water seismic survey with received sound levels of 163–191 dB re 1 μPa_{0-p} (Turnpenny and Nedwell 1994). Similarly, European sea bass apparently did not leave their inshore habitat during a 4-5 month seismic survey (Pickett et al. 1994).

Squid responses to airguns have also been studied, although to a lesser extent than fishes. Auditory brainstem responses of the squid *Sepioteuthis lessoniana* and the octopus *Octopus vulgaris* showed hearing ranges of 400-1,500 Hz and 400-1,000 Hz, respectively (Hu et al. 2009). In response to airgun exposure, squid exhibited both startle and avoidance responses at received sound levels of 174 dB re 1 μPa_{rms} by first ejecting ink and then moving rapidly away from the area (McCauley et al. 2000a; McCauley et al. 2000b). The authors also noted some movement upward. During ramp-up, squid did not discharge ink but alarm responses occurred when received sound levels reached 156–161 dB re 1 μPa_{rms}. Andre et al. (Kirkman 2010) found all squid exposed in aquaria to 50-400 Hz sinusoidal wave with a 100% duty cycle at 152-162 dB re 1 μPa (peak 175 dB) for two hours had lesions on the auditory apparatus (hair cells) versus control individuals. The implications of this for free-ranging individuals exposed to airguns is unclear, but supports the possibility that squid hearing may be permanently impacts by low frequency sound at levels below that which has previously been of concern. Additional study, particularly in free-swimming, natural environments using airguns should help to better address what, if any concern is reasonable for cephalopods.

The overall response of fishes and squids is to exhibit startle responses and undergo vertical and horizontal movements away from the sound field. We do not expect krill (the primary prey of most listed baleen whales) to experience effects from airgun sound. We do not expect any adverse effects from lack of prey availability to baleen whales. Sperm whales regularly feed on squid and some fishes and we expect individuals to feed while in the action area during the proposed survey. Based upon the best available information, fishes and squids ensonified by the ~160 dB isopleths could vacate the area and/or dive to greater depths, and be more alert for predators. We do not expect indirect effects from airgun activities through reduced feeding opportunities sufficient to reach a significant level. Effects are likely to be temporary and, if displaced, both sperm whales and their prey would re-distribute back into the area once survey activities have passed.

Marine mammal response to multibeam echosounder and sub-bottom profiler. We expect listed marine mammals to experience ensonification from not only airguns, but also seafloor mapping systems. Multibeam echosounder and sub-bottom profiler frequencies are much higher than frequencies used by all listed whales except humpback and sperm whales. Although Todd et al. (1992) found that mysticetes reacted to sonar sounds at 3.5 kHz within the 80-90 dB re 1 μPa range, it is difficult to determine the significance of this because the source was a signal designed to be alarming and the sound level was well below typical ambient noise. Hearing is poorly understood for listed marine mammals, but it is assumed that they are most sensitive to frequencies over which they vocalize, which are much lower than frequencies emitted by the multibeam echosounder and sub-bottom profiler systems (Ketten 1997; Richardson et al. 1995c). Thus, if sei whales are exposed, they are unlikely to hear these frequencies well (if at all) and a response is not expected.

Assumptions for sperm whale hearing are much different than for other listed whales. Sperm whales vocalize between 3.5-12.6 kHz and an audiogram of a juvenile sperm whale provides direct support for hearing over this entire range (Au 2000; Au et al. 2006; Carder and Ridgway 1990; Erbe 2002; Frazer and Mercado 2000; Goold and Jones 1995; Levenson 1974; Payne and Payne 1985; Payne 1970; Richardson et al. 1995c; Silber 1986; Thompson et al. 1986; Tyack 1983; Tyack and Whitehead 1983; Weilgart and Whitehead 1993; Weilgart and Whitehead 1997; Weir et al. 2007; Winn et al. 1970). Kremser et al. (2005) concluded the probability of a cetacean swimming through the area of exposure when such sources emit a pulse is small, as the animal would have to pass at close range and be swimming at speeds similar to the vessel. Sperm whales have stopped vocalizing in response to 6-13 kHz pingers, but did not respond to 12 kHz echo-sounders (Backus and Schevill 1966; Watkins 1977; Watkins and Schevill 1975).

We do not expect masking of sperm whale communications to appreciably occur due to multibeam echosounder or sub-bottom profiler signal directionality, low duty cycle, and the brief period when an individual could be within its beam.

Recent stranding events associated with the operation of naval sonar suggest that mid-frequency sonar sounds may have the capacity to cause serious impacts to marine mammals. The sonars proposed for use by SIO differ from sonars used during naval operations, which generally have a longer pulse duration and more horizontal orientation than the more downward-directed multibeam echosounder and sub-bottom profiler. The sound energy received by any individuals exposed to the multibeam echosounder and sub-bottom profiler sources during the proposed activities is lower relative to naval sonars, as is the duration of exposure. The area of possible influence for the multibeam echosounder and sub-bottom profiler is also much smaller, consisting of a narrow zone close to and below the source vessel. Although navigational sonars are operated routinely by thousands of vessels around the world, stranding incidence has not been correlated to use of these sonars. Because of these differences, we do not expect these systems to contribute to a stranding event.

Cumulative effects

Cumulative effects include the effects of future state, tribal, local, or private actions that are reasonably certain to occur in the action area considered by this Opinion. Future federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

We expect that those aspects described in the *Environmental baseline* will continue to impact listed resources into the foreseeable future. We expect climate change, ship strikes, bycatch, entanglements, scientific research, vessel traffic, and harvests to continue into the future.

Integration and synthesis of effects

As explained in the *Approach to the assessment* section, risks to listed individuals are measured using changes to an individual's "fitness" – i.e., the individual's growth, survival, annual reproductive success, and lifetime reproductive success. When listed plants or animals exposed to an action's effects are not expected to experience reductions in fitness, we would not expect the action to have adverse consequences on the viability of the population(s) those individuals represent or the species those populations comprise (Anderson 2000; Brandon 1978; Mills and Beatty 1979; Stearns 1992). As a result, if the assessment indicates that listed plants or animals are not likely to experience reductions in their fitness, we conclude our assessment. If reductions in individuals' fitness are likely to occur, the assessment considers the risk posed to population(s) to which those individuals belong, and then to the species those population(s) represent.

The NSF proposes to fund a seismic survey by SIO that could incidentally harass sei and sperm whales by causing behavioral responses that could adversely affect important behavioral functions.

The *Status of listed resources* section identified commercial whaling as the primary reason for reduced whale populations, many of whom are a small fraction of their former abundance (Tables 3-4). Although large-scale commercial harvests no longer occur for these species, some harvests from subsistence and scientific research in regional and worldwide populations still occur. Other worldwide threats to the survival and recovery of listed marine mammals of the action area include: altered prey base and habitat quality as a result of global warming, ship-strike, entanglement in fishing gear, toxic chemical burden and biotoxins, ship noise, and killer whale predation.

Despite these pressures, available trend information indicates most local populations of listed whales are increasing. As previously mentioned, the *Cumulative effects* section identifies actions in the *Environmental baseline* we expect to generally continue for the foreseeable future.

The *Effects analysis* supports the conclusion of harassment to listed marine mammals by proposed seismic activities. We expect exposure of two sei and 25 sperm whales to airgun sounds which will elicit a behavioral response of temporarily moving out of the area. We expect a low-level, transitory stress response to accompany this behavior. The number of individuals exposed in a population represent a tiny fraction of the populations (Table 7). The other stressors we considered in the Opinion, the operation of multibeam echosounder and sub-bottom profiler systems, are not expected to be audible to sei whales and consequently are not expected to have any direct effects on this species. However, sperm whales could hear sounds produced by these systems. Responses could include cessation of vocalization by sperm whales and/or movement out of the survey area species. Exposed individuals of both species are expected to be engaged in foraging, moving to/from foraging locations, or breeding. Behavioral harassment caused by exposure to sound sources associated with the proposed seismic survey are expected to cause some individuals to cease these activities temporarily and possibly move out of the immediate area. However, we expect that individuals will either resume activities in a secondary location or reoccupy the habitat from which they were displaced within a short period of time. We do not expect these effects to have fitness consequences for any individual. The *Effects analysis* also found that, although sperm whales may experience temporarily reduced feeding opportunities, this indirect effect would be transient and not reduce individual fitness of any whale. Overall, we do not expect a fitness reduction to any individual marine mammal. As such, we do not expect fitness consequences to populations or listed marine mammal species as a whole.

Conclusion

After reviewing the current status of sei and sperm whales; the *Environmental baseline* for the action area; the anticipated effects of the proposed activities; and the *Cumulative effects*, it is the NMFS' Opinion that the actions (NSF's funding of and the Permits Division's issuance of an IHA for a seismic survey in the western tropical North Pacific) are not likely to jeopardize the continued existence of these species.

Incidental take statement

Section 9 of the ESA and federal regulation pursuant to section 4(d) of the ESA prohibit the "take" of endangered and threatened species, respectively, without special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by the NMFS as an act which actually kills or injures wildlife, which may include significant habitat modification or degradation which actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of sections 7(b)(4) and 7(o)(2), taking that is incidental and not intended as part of the agency action is not considered to be prohibited taking under the ESA provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are nondiscretionary, and must be undertaken by the NSF and the Permits Division so that they become binding conditions for SIO for the exemption in section 7(o)(2) to apply. Section 7(b)(4) of the ESA requires that when a proposed agency action is found to be consistent with section 7(a)(2) of the ESA and the proposed action may incidentally take individuals of listed species, the NMFS will issue a statement that specifies the impact of any incidental taking of endangered or threatened species. To minimize such impacts, reasonable and prudent measures and term and conditions to implement the measures, must be provided. Only incidental take resulting from the agency actions and any specified reasonable and prudent measures and terms and conditions identified in the incidental take statement are exempt from the taking prohibition of section 9(a), pursuant to section 7(o) of the ESA.

Section 7(b)(4)(C) of the ESA specifies that in order to provide an incidental take statement for an endangered or threatened species of marine mammal, the taking must be authorized under section 101(a)(5) of the MMPA. One of the federal actions considered in this Opinion is the Permits Division's proposed authorization of the incidental taking of sei and sperm whales pursuant to Section 101(a)(5)(D) of the MMPA. With this authorization, the incidental take of listed species is exempt from the taking prohibition of section 9(a), pursuant to section 7(o) of the ESA.

Amount or extent of take

The NMFS anticipates the proposed seismic survey in the western tropical North Pacific might result in the incidental take of listed species. The proposed action is expected to take by harassment two sei and 25 sperm whales by exposing individuals to received seismic sound levels greater than 160 dB re 1 µPa. These estimates are based on the best available information of whale densities in the area to be ensonified above 160 dB re 1 µPa during the proposed activities. This incidental take would result primarily from exposure to acoustic energy during seismic operations and would be in the form of harassment. Death or injury of any individuals that are exposed is not expected.

Harassment of sei and sperm whales exposed to seismic studies at levels less than 160 dB re 1 µPa is not expected. If overt adverse reactions (for example, startle responses, dive reactions, or rapid departures from the area) by listed marine mammals are observed outside of the 160 dB dB re 1 µPa isopleths while airguns are operating, incidental take may be exceeded. If such reactions by listed species are observed while airguns, multibeam echosounder, or sub-bottom profiler are in operation, this may constitute take that is not covered in this Incidental Take Statement. The NSF and the Permits Division must contact the Endangered Species Division to determine whether reinitiation of consultation is required because of such operations.

Reasonable and prudent measures

The NMFS believes the reasonable and prudent measures described below are necessary and appropriate to minimize the impact of incidental take of listed marine mammals resulting from the proposed action and are the best practical means of ensuring the total taking is within the limits allowable under the IHA. These measures are non-discretionary and must be binding conditions of the NSF funding of the proposed seismic studies and the NMFS' authorization for the exemption in section 7(o)(2) to apply. If the NSF or the NMFS fail to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse.

1. For listed marine mammal species these measures include the following: vessel-based visual monitoring by marine mammal observers as specified in the environmental assessment; speed or course alteration as practicable; implementation of a marine mammal exclusion zone within the 180 dB re 1 μPa_{rms} isopleth for shut-down procedures; and emergency shutdown procedures in the event of an injury or mortality of a listed marine mammal. The measures for marine mammals are required to be implemented through the terms of the IHA issued under section 101(a)(5)(D) and 50 CFR 216.107.
2. The implementation and effectiveness of mitigation measures incorporated as part of the Reasonable and Prudent Measure mentioned above and the associated Terms and Conditions must be monitored.

Terms and conditions

In order to be exempt from the prohibitions of section 9 of the ESA, the NSF, Permits Division, and SIO must comply with the following terms and conditions, which implement the Reasonable and Prudent Measures described above. These terms and conditions are non-discretionary.

To implement the Reasonable and Prudent Measures, the NSF and the NMFS shall ensure that

1. SIO implements the mitigation, monitoring, and reporting conditions contained in the

IHA and this Opinion.

2. The Chief of the Endangered Species Division is immediately informed of any changes or deletions to any portions of the monitoring plan or IHA.
3. SIO immediately reports all sightings and locations of injured or dead endangered and threatened species to the Permits Division and the NSF.
4. The NSF and the Permits Division provide a summary of the implementation and effectiveness of the terms of the IHA to the Chief of the Endangered Species Division. This report shall confirm the implementation of each term and summarize the effectiveness of the terms for minimizing the adverse effects of the project on listed marine mammals.

Conservation recommendations

Section 7(a)(1) of the ESA directs federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information.

We have no recommended conservation measures at this time.

In order for the Endangered Species Division to be kept informed of actions minimizing or avoiding adverse effects on, or benefiting ESA-listed species or their habitats, the Permits Division should notify the Endangered Species Division of any conservation recommendations they implement in their final action.

Reinitiation notice

This concludes formal consultation on the proposed seismic source survey to be funded by the NSF and conducted by the SIO on board the *R/V Thompson* in the western tropical North Pacific, and the issuance of an incidental harassment authorization for the proposed studies pursuant to section 101(a)(5)(D) of the Marine Mammal Protection Act (MMPA). As provided in 50 CFR §402.16, control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of authorized take is exceeded, section 7 consultation must be reinitiated immediately.

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