RECOVERY PLAN FOR THE BLUE WHALE

(*Balaenoptera musculus*)

First Revision to the July 1998 Recovery Plan for the Blue Whale

Office of Protected Resources
National Marine Fisheries Service
National Oceanic and Atmospheric Administration

November 2020

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First Revision to the July 1998 Recovery Plan for the Blue Whale

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PREFACE

Congress passed the Endangered Species Act of 1973 (16 U.S.C. 1531 *et. seq.*) ("ESA" or "the Act") to provide a means to conserve the ecosystems upon which endangered and threatened species depend, to provide a program for the conservation of such endangered and threatened species, and to take such steps as may be appropriate to achieve the purposes of the treaties and conventions that conserve such species. The National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service share responsibility for the administration of the Act. NMFS is responsible for most marine mammals including the blue whale (*Balaenoptera musculus*). This Recovery Plan was prepared at the request of the Assistant Administrator for Fisheries to promote the conservation of blue whales.

The goals and objectives of the Plan can be achieved only if a long-term commitment is made to support the actions recommended herein. Achievement of these goals and objectives will require the continued cooperation of the governments of the United States and other nations. Within the United States, the shared resources and cooperative involvement of federal, state, and local governments, industry, academia, nongovernmental organizations, and individuals will be required throughout the recovery period.

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DISCLAIMER

Recovery plans delineate such reasonable actions as may be necessary, based upon the best scientific and commercial data available, for the conservation and survival of listed species. Plans are published by NMFS, sometimes prepared with the assistance of recovery teams, contractors, State agencies, and others. Recovery plans do not necessarily represent the views, official positions, or approval of any individuals or agencies involved in the plan formulation, other than NMFS. They represent the official position of NMFS only after they have been signed by the Assistant Administrator. Recovery plans are guidance and planning documents only; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this plan should be construed as a commitment or requirement that any Federal agency obligate or pay funds in any one fiscal year in excess of appropriations made by Congress for that fiscal year in contravention of the Anti-Deficiency Act, 31 U.S.C. 1341, or any other law or regulation. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, or the completion of recovery actions.

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LIST OF TERMS AND ACRONYMS

The following is a list of acronyms, abbreviations, and terms used throughout the Revised Recovery Plan.

BOEM	Bureau of Ocean Energy and Management
CI	confidence interval
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Convention on the Conservation of Migratory Species of Wild Animals
CV	coefficient of variance
dB	decibels
DDT	dichlorodiphenyl trichloroethane
Delisting	removal from the list of Endangered and Threatened Wildlife and Plants
DNA	deoxyribonucleic acid
Downlisting	reclassification from endangered to threatened under the ESA
EEZ	Exclusive Economic Zone
ENSO	El Niño Southern Oscillation
ESA	Endangered Species Act
ETP	Eastern tropical Pacific
FR	Federal Register
FY	fiscal year
Hz	hertz
ICRW	International Convention for the Regulation of Whaling
IUCN	International Union for Conservation of Nature
IWC	International Whaling Commission
kHz	kilohertz
LFA	low-frequency active (for sonar)
m	meters
MARU	marine acoustic recording unit
MFA	mid-frequency active (for sonar)
MMPA	Marine Mammal Protection Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
PCB	polychlorinated biphenyl
PDO	Pacific (inter) Decadal Oscillation
POP	persistent organic pollutant
PTS	permanent threshold shift
SOWER	IWC's Southern Ocean Whale Ecosystem Research program
SURTASS	Surveillance Towed Array Sensor System
TTS	temporary threshold shift
TBD	to be determined
UAS	unmanned aircraft system
U.S.	United States
USC	United States Code
USCG	United States Coast Guard

EXECUTIVE SUMMARY

Current Species Status: The blue whale (*Balaenoptera musculus*) was listed as endangered throughout its range under the precursor to the Endangered Species Act (ESA), the Endangered Species Conservation Act of 1969 (35 FR 8491; June 2, 1970), and remained on the list of threatened and endangered species after the passage of the ESA in 1973. Blue whales were subject to intensive commercial whaling, with over 380,000 blue whales taken between 1868 and 1978, mostly from Antarctic waters (Branch *et al.* 2008). The global mature population size in 1926 was around 140,000. The current global mature population size is uncertain, but estimated to be in the range of 5,000-15,000 mature individuals. This current mature population is between 3-11% of the 1926 level (Cooke *et al.* 2018). Although still depleted compared to historical abundance, blue whale populations around the world show signs of growth.

Blue whales are global in distribution. The subspecific taxonomy has not been fully resolved, but there are five currently recognized subspecies. *B. m. musculus* (Linnaeus, 1758) is the northern blue whale (North Atlantic and North Pacific Oceans); *B. m. intermedia* (Burmeister 1871) is the Antarctic blue whale; *B. m. brevicauda* (Ichihara, 1966) colloquially known as the "pygmy" blue whale (Ichihara 1966, Rice 1977); and *B. m. indica* (Blyth 1859) is the northern Indian Ocean blue whale. There is some uncertainty regarding the characteristics that distinguish *B. m. indica* from *B. m. brevicauda* and additional research is needed to clarify the separation, but *B. m. indica* is currently considered a distinct subspecies (Perrin *et al.* 2009, Anderson *et al.* 2012, Thomas *et al.* 2016). Additionally, an unnamed subspecies off Chile in the southeastern Pacific Ocean has been recognized by the Society for Marine Mammalogy's Committee on Taxonomy (Branch *et al.* 2007a, Committee on Taxonomy 2016).

There are three subspecies of blue whale that are "pygmy-type" blue whales: *B. m. brevicauda*, *B. m. indica*, and *B. m.* unnamed subspecies. All three subspecies inhabit the Indian Ocean and the Southwest Pacific (Rice, 1998). The species found in the southwestern part of the Indian Ocean south off Madagascar and in the eastern Indian Ocean west of Australia and Indonesia is commonly referred to in the biological literature as *Balaenoptera musculus brevicauda* (Ichihara, 1966). Pygmy blue whales have also been observed in the Southern Ocean from the Great Australian Bight to Bass Strait (Gill *et al.*, 2011). They are believed to belong most likely to the same population as pygmy blue whales in the eastern Indian Ocean (Branch *et al.*, 2007). This is proven to a certain extent by the same song structure of whales observed in the Indian and Southern Oceans in this study. The whales from the southwestern Pacific population found mainly off North Island, New Zealand and around the Southwest Pacific Islands differ from the pygmy blue whales of the eastern Indian Ocean population in their size and in the sounds they produce (McDonald, 2006). A separate population of pygmy blue whales was identified in the Northern Indian Ocean. The animals from this population appear to stay year-round within a limited area between Somalia and Sri Lanka and make calls distinct from those of the other pygmy blue whales in the Indian Ocean (Alling *et al.*, 1991). This population has been suggested to comprise of a separate subspecies referred to as *B. m. indica.*

Habitat Requirements and Limiting Factors: Although blue whales are listed as endangered under the ESA, it is not known whether and to what extent current threats are putting the globally listed species at risk of extinction. Nonetheless, we are able to identify numerous *potential* threats. A potential threat, as used in this recovery plan, means a stressor that a) had contributed to the species' extinction risk, such as commercial whaling, and has the potential to do so again unless certain measures are taken or remain in place; or b) is known to be affecting one or more subspecies or populations, but more research is needed to understand the extent to which the stressor occurs or affects the globally listed entity. These include directed hunting, ship strikes, entanglement in marine debris and fishing gear, anthropogenic noise, and loss of prey base due to climate and ecosystem change. Other stressors were identified, but there is currently no evidence that the effects of these other stressors (which may even include the loss of individual blue whales) are having population-level consequences or are significant enough to contribute to the species' extinction risk.

Recovery Strategy: Commercial whaling was the main cause of blue whales' historical decline, and is not a current operative threat because an international moratorium on commercial whaling implemented by 89 countries remains in place. Of those countries that engage in non-subsistence whaling, none are known to be taking blue whales. Therefore, a primary strategy of this Revised Recovery Plan is to maintain the international ban on commercial hunting that was instituted in 1986. Additionally, this Plan provides a strategy to improve our understanding regarding how potential threats may be limiting blue whale recovery. Finally, this Plan provides a research strategy to obtain data necessary to determine blue whale taxonomy, population structure, distribution, and habitat, which can then inform estimation of population abundance and trends. After the populations and their threats are more fully understood, this Plan will be modified to include actions to minimize any threats that are determined to be limiting recovery. Because blue whales move freely across international borders, it would be ineffective to confine recovery efforts to U.S. waters, and this Plan stresses the importance of a multinational approach to management.

Management Units[1]: For purposes of this Revised Recovery Plan, we define nine blue whale management units:

1. Northern subspecies (*B. m. musculus)* - North Atlantic population
2. Northern subspecies (*B. m. musculus)* - Eastern North Pacific population
3. Northern subspecies (*B. m. musculus)* - Western/Central North Pacific population
4. Northern Indian Ocean subspecies (*B. m. indica*)
5. Pygmy subspecies (*B. m. brevicauda*) - Madagascar population
6. Pygmy subspecies (*B. m. brevicauda*) - Western Australia/Indonesia population
7. Pygmy subspecies (*B. m. brevicauda*) - Eastern Australia/New Zealand population
8. Chilean subspecies (*B. m.* unnamed subsp.)
9. Antarctic subspecies (*B. m. intermedia)*

Blue whale subspecific taxonomy and population structure has not been fully resolved and is an area of active research. We identify at least one management unit for each of the five subspecies

[1] "Management Units" are defined and described in the joint NMFS-USFWS *Interim Endangered and Threatened Species Recovery Planning Guidance* (NMFS-USFWS 2018). These are units that might require different management (perhaps because of different threats in different geographic areas) that might be managed by different entities, or that might encompass different populations. However, each management unit is not necessarily essential to the conservation of the species, as is the case for each recovery unit.

currently recognized by the Society for Marine Mammalogy. We also identify management units within two subspecies. In the Northern subspecies, *B. m. musculus*, we identify one North Atlantic and two North Pacific management units. In general, individuals from different ocean basins are unlikely to interbreed when mature, and if a basin population were extirpated, the area would likely not be recolonized in a time period that is meaningful for management purposes (Angliss *et al.* 2002). It is unclear whether blue whales in the eastern and western portions of the North Atlantic Ocean belong to the same population, but until separation is more strongly supported, for this Revised Recovery Plan we consider blue whales in the North Atlantic to comprise one management unit, based on the International Whaling Commission (IWC) blue whale stock definition and the current understanding that there is only one blue whale song type in the North Atlantic. The IWC also considers blue whales in the North Pacific to be one stock, but we define two management units there based on multiple lines of evidence (song types, length-frequency data, and movement data from satellite tags and photo-identification) indicating there are at least eastern and western/central populations. In the pygmy blue whale subspecies, *B. m. brevicauda*, the three management units correspond with "acoustic populations," following recommendations of the IWC (IWC 2016b).

Despite the uncertainties, the delineation of these nine units reflects our current understanding of blue whale taxonomy and population structure and we consider them to be the appropriate unitsfor recovery. We consider recovery of all nine units to be important for achieving geographic and ecological representation of blue whales in the world's oceans, and to ensure conservation of the breadth of blue whales' genetic variability. If, based on additional research, blue whale subspecific taxonomy is revised, our understanding of population structure changes, or we learn more about whether recovery of all units is necessary for the long-term viability of the species, these management units and their associated species-level recovery criteria should be changed in a future revision of the plan.

Recovery Goals and Criteria: The goal of this Revised Recovery Plan is to promote the recovery of blue whales to the point at which they can be removed from the List of Endangered and Threatened Wildlife and Plants under the provisions of the ESA. The intermediate goal is to reach a sufficient recovery status to reclassify the species from endangered to threatened.

The two main objectives for blue whales are to 1) increase blue whale resiliency and ensure geographic and ecological representation by achieving sufficient and viable populations in all ocean basins and in each recognized subspecies, and 2) increase blue whale resiliency by managing or eliminating significant anthropogenic threats. The recovery criteria take two forms: 1) those that reflect the biological status of the species and 2) those that indicate effective management or elimination of threats. These criteria apply to the species throughout its range, but the criteria also include specific targets for each of the nine management units to support the objectives of species' viability (e.g., resiliency, redundancy, and representation).

Population viability analyses (PVAs) or other quantitative assessments for predicting a species' or population's future status can be useful in evaluating extinction risk. PVAs have been used in some recent marine mammal status reviews (e.g., Krahn *et al.* 2004, Oleson *et al.* 2010), but not in others (e.g., Boveng *et al.* 2009, Boveng *et al.* 2013, Bettridge *et al.* 2015), and are a component of several other large whale recovery plans (e.g., NMFS 2010a, NMFS 2010b, NMFS 2011, NMFS 2013). Although not required to meet the criteria below, should sufficient data become available, a quantitative PVA demonstrating a low probability of extinction over a reasonable timeframe (e.g., scaled to blue whale generation time, Taylor *et al.* 2007) could be used to further support downlisting or delisting decisions.

See Section II Recovery Strategy for further detail and explanation in support of the criteria.

<u>Downlisting Criteria</u>:

The Blue whale (listed throughout its range; 35 FR 8491 6/2/1970) may be considered for reclassifying to threatened when all of the following have been met.

Criteria: In each of the nine management units:

1. The minimum abundance is:

    a. North Atlantic: 2,000 whales
    b. Eastern North Pacific: 2,000 whales
    c. Western/Central North Pacific: 2,000 whales
    d. Northern Indian Ocean: 500 whales
    e. Madagascar: 2,000 whales
    f. Western Australia/Indonesia: 2,000 whales
    g. New Zealand: 500 whales
    h. Chilean: 2,000 whales
    i. Antarctic: 2,000 whales

2. The trend in abundance, over the most recent 30-year period assessed, for each of the nine blue whale management units is:

    a. North Atlantic: stable or increasing
    b. Eastern North Pacific: stable or increasing
    c. Western/Central North Pacific: stable or increasing
    d. Northern Indian Ocean: stable or increasing
    e. Madagascar: stable or increasing
    f. Western Australia/Indonesia: stable or increasing
    g. New Zealand: stable or increasing
    h. Chilean: stable or increasing
    i. Antarctic: increasing

3. *Criteria*: In each of the nine management units:

    Anthropogenic threats have been identified and demonstrably minimized; i.e., there is information indicating they are not contributing to the species being in danger of extinction throughout all or a significant portion of its range. Information we will assess in determining whether the criteria have been met will include published literature, technical memorandums, stranding and population monitoring results, and other credible sources. Specifically, the factors in section 4(a)(l) of the ESA as described below have been addressed:

Factor A: The present or threatened destruction, modification, or curtailment of a species' habitat or range.

- Effects of anthropogenic noise, ingestion and/or entanglement in marine debris, and reduced prey abundance due to climate change have been evaluated, and, if determined by NMFS to be impeding blue whale recovery, measures have been taken to minimize effects. Following this same evaluation and where effects to specific management units are known, management unit specific measures have been taken to minimize effects.

Factor B: Overutilization for commercial, recreational, or educational purposes.

- The international ban on commercial hunting has been maintained.
- Any subsistence or scientific hunting that has the potential to overutilize the species is restricted to levels that are sustainable, precautionary, and in accordance with the advice of the IWC's Scientific Committee.

Factor C: Disease or Predation.

- There is no information at this time indicating disease or predation is a threat to blue whale recovery.

Factor D: The inadequacy of existing regulatory mechanisms.

- Hunting is addressed under Factor B; climate change is addressed under Factor A.

Factor E: Other natural or manmade factors affecting its continued existence.

- Ship strikes have been evaluated, and, if determined by NMFS to be impeding blue whale recovery, measures have been taken to minimize effects. Following this evaluation and where effects to specific management units are known, management unit specific measures have been taken to minimize effects.
- Entanglement with fishing gear has been evaluated, and, if determined by NMFS to be impeding blue whale recovery, measures have been taken to minimize effects. Following this evaluation and where effects to specific management units are known, management unit specific measures have been taken to minimize effects.

<u>Delisting Criteria</u>:

Blue whales (listed throughout its range; 35 FR 8491 6/2/1970) will be considered for delisting when all of the following criteria are met.

Criteria: In each of the nine management units:

1. The minimum abundance is:
   a. North Atlantic: 2,500 whales
   b. Eastern North Pacific: 2,500 whales
   c. Western/Central North Pacific: 2,500 whales
   d. Northern Indian Ocean: 1,000 whales
   e. Madagascar: 2,500 whales
   f. Western Australia/Indonesia: 2,500 whales
   g. New Zealand: 1,000 whales
   h. Chilean: 2,500 whales
   i. Antarctic: 2,500 whales

2. The trend in abundance, over the most recent 30-year period assessed, for each of the nine blue whale management units is:

   a. North Atlantic: increasing
   b. Eastern North Pacific: stable or increasing
   c. Western/Central North Pacific: stable or increasing
   d. Northern Indian Ocean: stable or increasing
   e. Madagascar: stable or increasing
   f. Western Australia/Indonesia: stable or increasing
   g. New Zealand: stable or increasing
   h. Chilean: stable or increasing
   i. Antarctic: increasing

3. *Criteria*: In each of the nine management units:

Anthropogenic threats have been identified and demonstrably minimized or eliminated; i.e.,there is information indicating they are not contributing to the species being in danger of extinction within the foreseeable future throughout all or a significant portion of its range. Information we will assess in determining whether the criteria have been met will include published literature, technical memorandums, stranding and population monitoring results, and other credible sources. Specifically, the factors in section 4(a)(l) of the ESA as described below have been addressed:

Factor A: The present or threatened destruction, modification, or curtailment of a species' habitat or range.

- Effects of anthropogenic noise, ingestion and/or entanglement in marine debris, and reduced prey abundance due to climate change have been evaluated, and, if determined by NMFS to be impeding blue whale recovery, measures have been taken to minimize effects. Following this same evaluation and where effects to specific management units are known, management unit specific measures have been taken to minimize effects.

Factor B: Overutilization for commercial, recreational, or educational purposes.

- The international ban on commercial hunting has been maintained.
- Any subsistence or scientific hunting that has the potential to overutilize the species is restricted to levels that are sustainable, precautionary, and in accordance with the advice of the IWC's Scientific Committee.

Factor C: Disease or Predation.

- There is no information indicating disease or predation is a threat to blue whale recovery.

Factor D: The inadequacy of existing regulatory mechanisms.

- Hunting is addressed under Factor B; climate change is addressed under Factor A.

Factor E: Other natural or manmade factors affecting its continued existence.

- Ship strikes have been evaluated, and, if determined by NMFS to be impeding blue whale recovery, measures have been taken to minimize effects. Following this evaluation and where effects to specific management units are known, management unit specific measures have been taken to minimize effects.

- Entanglement with fishing gear has been evaluated, and, if determined by NMFS to be impeding blue whale recovery, measures have been taken to minimize effects. Following this evaluation and where effects to specific management units are known, management unit specific measures have been taken to minimize effects.

Estimated Cost of Recovery Actions for the First Five Fiscal Years (FY) (estimates are in thousands of dollars):

Action	FY1	FY2	FY3	FY4	FY5	Total[2]
Coordinate Federal and international measures to maintain international regulation of whaling for blue whales	[a]	[a]	[a]	[a]	[a]	[a]
Determine blue whale taxonomy, population structure, occurrence, distribution, and range	400	400	400	400	400	**2,000**
Estimate population size and monitor trends in abundance	780	780	780	780	780	**3,900**
Identify, characterize, protect, and monitor habitat important to blue whale populations	400	400	400	400	400	**2,000**
Investigate human-caused potential threats and, should they be determined to be limiting blue whale recovery, take steps to minimize their occurrence and severity	580[b]	580[b]	550[b]	250[b]	250[b]	**2,210[b]**
Maximize efforts to acquire scientific information from dead, stranded, and entangled or entrapped blue whales	30	30	30	30	30	**150[b]**
Total	**2,190** [b]	**2,190** [b]	**2,160** [b]	**1,860** [b]	**1,860** [b]	**10,260**[b]

[a] No cost associated, NMFS staff time only.
[b] Given uncertainty in potential threats and actions required to address them, there are additional costs that cannot be determined.

Estimated Cost of Recovery Actions (First 5 Fiscal Years): $10.26 million plus additional costs that cannot be determined. A total estimate to recovery beyond the first five fiscal years is not practicable given the uncertainty in the potential threats, any actions that might be required to address the potential threats, and the length of time beyond the first five fiscal years that will be

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[2] The totals in this table differ slightly from those in Table 2 in Section V Implementation Schedule. This table provides the estimated cost of recovery actions for the first five fiscal years, while Table 2 additionally includes minimum estimates of the cost for discrete or ongoing recovery actions that are likely to extend into FY6 and beyond. See the footnotes to Table 2 for more information.

necessary to conduct research to fill critical information gaps and evaluate effectiveness of threat reduction.

Anticipated Date of Recovery: It is not possible to predict the time and cost to recovery with the current information because of the uncertainty of potential threats. Thus, an estimate of the time required and the cost to carry out those actions needed to achieve the plan's goal and to achieve intermediate steps beyond the first 5 years is not practicable. Conducting research necessary to support conclusions regarding the impact of the potential threats to blue whale populations, and developing, implementing, and evaluating the effectiveness of recovery actions to reduce threats or potential threats (*i.e.*, to meet delisting recovery criterion 3) may take decades. The minimum data needed to satisfy recovery criteria 1 and 2 for either downlisting or delisting are population structure studies and abundance surveys, which will also take decades given the species' global distribution and the need to evaluate the abundance trend across a minimum of 30 years. If the necessary research is undertaken and demonstrates that the abundance and trend criteria have been met, and potential threats are evaluated and, as necessary, minimized or eliminated, it might be feasible to downlist or delist blue whales in approximately 30 years. In the future, as more information is obtained, it may be possible to develop estimates for the full time to recovery and its expense. However, the time to recovery is likely greater, given the available information on abundance and trends of some populations relative to the downlisting and delisting abundance criteria.

I. BACKGROUND

A. Brief Overview

The blue whale, *Balaenoptera musculus* (Linnaeus 1758), was listed as endangered throughout its range under the precursor to the Endangered Species Act (ESA), the Endangered Species Conservation Act of 1969, and remained on the list of threatened and endangered species after the passage of the ESA in 1973 (35 FR 8491; June 2, 1970). Blue whales are the largest living animal on earth. The species experienced intensive whaling throughout the 20th century, with over 380,000 blue whales taken in 1868-1978, mostly from Antarctic waters (Branch *et al.* 2008). While the current global mature population size is uncertain, it is estimated to be 10,000-25,000 total or 5,000-15,000 mature individuals compared with a 1926 global population of at least 140,000 mature individuals (Cooke *et al.* 2018). This current mature population would therefore be between 3-11% of the 1926 level (Cooke *et al.* 2018).

Although the species is globally listed, five blue whale subspecies are currently recognized (Committee on Taxonomy 2016). Blue whales generally make seasonal migrations between feeding and breeding locations, with occurrence often linked to prey aggregations. Underwater recordings of blue whale vocalizations have been used to show changing distribution and trends in local abundance at feeding locations around the world. Little is known about interspecific competition and sources of natural mortality. Though still depleted compared to historical abundance, blue whale populations around the world show signs of growth.

Below is a general description of the listed species with information on vocalizations, taxonomy, and population structure for blue whales worldwide. In addition there is general information on several natural history elements which applies to all blue whales. Where there is specific information on natural history for blue whales by subspecies or in particular regions, it is included in the more detailed sections below. Sections I.D-I.G include detailed regional information including distribution, abundance, and trends where available for blue whales in the North Atlantic, North Pacific, and Antarctic, as well as for the pygmy-type blue whales.

B. Species Description, Vocalizations, Taxonomy, Population Structure, and Natural History

B.1 Species Description

The blue whale is a cosmopolitan species of baleen whale (Gambell 1979, Yochem & Leatherwood 1985, Mead & Brownell 1993) found in all oceans except the Arctic (although they are regularly sighted near the ice edge in the North Atlantic), but largely absent from some regional areas such as the Mediterranean, Okhotsk, and Bering Seas north into the Arctic Ocean (few sightings have been observed in the Bering Sea/Sea of Okhotsk). The species is the largest animal ever to have lived: adults can reach 32.6 meters (m) in length and weigh more than 150,000 kg. Blue whales in the Northern Hemisphere are generally smaller than those in the Southern Ocean, with maximum body length in the North Atlantic and North Pacific Oceans being approximately 27 m (True 1904, Reeves *et al.* 1985). Pygmy blue whales, a subspecies of blue whales, may only reach 24.2 m in length when mature (Omura 1984). As is true of other baleen whales, female blue whales are slightly larger than males (Ralls 1976). At birth, blue whales can be 8 m long and weigh 3 tons. For the Antarctic, the average length at birth is 7 m (Mackintosh and Wheeler 1929).

Blue whales are long-bodied and slender, with proportionally smaller dorsal fins compared to other baleen whales. Their gray-blue skin color appears light blue when viewed through the water and has a unique mottling pattern that has been used to identify individuals. Viewed from above, the blue whale has a broad, flat rostrum, with a single ridge that runs from the splashguard of the blowholes to the tip of the rostrum. The blue whale may have as many as 400 relatively short (0.5 m) plates of typically black baleen on each side of the upper jaw. When a blue whale is feeding, its pleated throat expands to accommodate the enormous intake of up to 200 metric tons of seawater and food (Figure 5 in Fossette *et al.* 2017). As the water is expelled and the filtered prey is swallowed, the body returns to its characteristically slender shape.

Blue whale diet is composed almost exclusively of krill (euphausiids) (Yochem & Leatherwood 1985, Reilly *et al.* 2008). They feed both at the surface and at depths of more than 100 m, following their prey's diel vertical migration through the water column (Sears & Perrin 2009).

B.2 Hearing and Vocalizations

Marine mammal hearing has been reviewed by several authors, notably Popper (1980a, 1980b), Schusterman (1981), Ridgeway (1983), Watkins and Wartzok (1985), Moore and Schusterman (1987), Au (1993), Richardson (1995), and Wartzok and Ketten (1999). Marine mammal hearing has been studied through behavioral or electrophysiological tests and predictions based on inner ear morphology. No direct measurements of the hearing sensitivity of baleen whales (mysticetes) are available. Thus, hearing predictions for mysticetes are based on other methods including anatomical studies and modeling (Houser *et al.* 2001, Parks 2007, Ketten & Mountain 2012, Ketten & Mountain 2014, Cranford & Krysl 2015); vocalizations (Richardson *et al.* 1995, Wartzok & Ketten 1999, Au & Hastings 2008); and behavioral responses to sound (Dahlheim & Ljungblad 1990, Reichmuch 2007). Mysticetes hear at low frequencies and differ from other cetaceans and pinnipeds that hear higher frequency sounds (Southall *et al.* 2007). While little information exists specific to blue whales, recent studies of hearing in other baleen whales may be applicable.

Baleen whales' sensitivity to low-frequency sound has been inferred from observed vocalization frequencies, observed reactions to playback of sounds, and anatomical analyses of the auditory system. The anatomy of the baleen whale inner ear appears well adapted for detecting a wide range of low-frequency sounds (Ketten 1992b, Ketten 1992a, Ketten 1994, Yamato *et al.* 2008). Baleen whale calls are predominantly at low frequencies and their hearing is presumably best at detecting frequency ranges analogous to those in which they vocalize (Richardson *et al.* 1995). Based on these data, Southall *et al.* (2007) estimated the low-frequency hearing range of mysticetes to extend from approximately 7 Hz to 22 kHz. Watkins (1986) reported a variety of mysticete species responding to sounds up to 28 kHz; Au *et al.* (2006) reported humpback whales songs having harmonics that extend beyond 24 kHz; and Frankel (2005) and Lucifredi and Stein (2007) reported gray whales potentially responding to sounds above 22 kHz. Thus, the auditory system of baleen whales almost certainly lacks the acuity in high frequency ranges that are attributed to the smaller toothed whales. However, auditory sensitivity in at least some large whale species presumably extends into frequencies higher than the upper frequency ranges of their calls.

Blue whale calls are among the loudest and lowest frequency sounds made by any animal and consist of long-duration, low-frequency pulses (known as type A) and tonal calls (type B), upswept tones that precede type B calls (type C), moderate-duration downswept tones (type D), and variable amplitude-modulated and frequency-modulated sounds (Thompson *et al.* 1996, Aroyan *et al.* 2000, Thode *et al.* 2000, McDonald *et al.* 2001). Stafford *et al.* (1998) reported that the fundamental frequency for blue whale vocalizations ranged from 8 to 25 Hz. Blue whale vocalizations might vary by region, season, behavior, and time of day. Similar to other baleen whales, blue whales can produce long patterned sets of sounds referred to as songs. Ten song types have been described for blue whales around the world that have remained largely stable in the number of units and phrasing for decades, and might be used to distinguish populations in the absence of definitive genetic data (McDonald *et al.* 2006b, McDonald *et al.* 2009).

In studying the eastern North Pacific blue whales off southern California, researchers found that only males produced type AB calls, with songs (stereotypic, repeated AB call sequences) produced by lone males and singular AB calls generally produced by whales in pairs, which suggests their importance in reproductive activities (Oleson *et al.* 2007a, Calambokidis *et al.* 2010). Type D calls were produced by both males and females during shallow, daytime dives, and have been associated with social interactions between deeper foraging dives (Oleson *et al.* 2007a, Oleson *et al.* 2007b).

Seven of the ten blue whale song types identified worldwide have shifted linearly downward in tonal frequency, though at different rates (Nieukirk *et al.* 2005, McDonald *et al.* 2009). In one of the best documented blue whale song types, from the eastern North Pacific Ocean, the frequency of the song’s tonal section is 31% lower than it was in the early 1960s (Nieukirk *et al.* 2005, McDonald *et al.* 2009). McDonald *et al.* (2009) discussed several hypotheses for the observed pattern, and suggested it might be related to increasing population density as blue whales recover from whaling, and related effects on sexual selection pressure. Specifically, females selecting mates may prefer males producing lower frequency songs because it indicates larger body size; the greater number of singing males competing for mates may increase this selection pressure. However, there is a tradeoff: a lower frequency corresponds with a lower amplitude (quieter) song, which has a shorter propagation distance. At higher population densities, though, there is less need to communicate with other blue whales over long distances, so males can afford to sing at a lower frequency despite the decreased detection distance (McDonald *et al.* 2009).

B.3 Taxonomy

The subspecific taxonomy of blue whales is an area of continued research. Studies of intraspecific variability and life history characteristics have led to the recognition of five blue whale subspecies to date. *B. m. musculus* (Linnaeus, 1758) is the northern blue whale (North Atlantic and North Pacific Oceans); *B. m. intermedia* (Burmeister, 1871) is the Antarctic blue whale, sometimes referred to as the “true” blue whale; *B. m. brevicauda* (Ichihara 1966) is the pygmy blue whale, generally occurring in the sub-Antarctic southern Indian Ocean and the southwestern Pacific Ocean (Ichihara 1966, Rice 1977); *B. m. indica* (Blyth, 1859) is the northern Indian Ocean blue whale; and there is a recently recognized, unnamed subspecies that generally occurs off Chile and annually migrates to waters off Peru, Ecuador, and up to the Galapagos Islands (e.g., Hucke-Gaete *et al.* 2018) in the southeastern Pacific Ocean (Branch *et al.* 2007a, Committee on Taxonomy 2016).

There is some uncertainty in the characteristics that distinguish *B. m. indica* from *B. m. brevicauda* and additional research is needed to clarify the separation, but *B. m. indica* is currently considered a distinct subspecies (Perrin *et al.* 2009, Anderson *et al.* 2012, Committee on Taxonomy 2016). *B. m. indica* has a breeding season that is asynchronous with Southern Hemisphere blue whales (Mikhalev 2000), a distinct call type (Alling *et al.* 1991, McDonald *et al.* 2006b), and slightly smaller total length at maturity compared to *B. m. brevicauda* (Branch & Mikhalev 2008).

The unnamed subspecies in the southeastern Pacific, recently recognized by the Society for Marine Mammalogy's Committee on Taxonomy, is considered distinct from the other subspecies in the Southern Hemisphere based on geographic separation (latitudinal from Antarctic blue whales and longitudinal from pygmy blue whales), a difference in the mean length of mature females, a unique call type, and significant genetic differentiation (Branch *et al.* 2007a). LeDuc *et al.* (2016) reported significant mitochondrial and nuclear DNA differentiation between eastern South Pacific and eastern North Pacific blue whales, but considered them to be modest and less than the differences between eastern South Pacific versus Indian Ocean or Antarctic blue whales.

B.4 Population Structure

In the United States blue whales are managed under the Marine Mammal Protection Act (MMPA), the ESA, and the International Convention for the Regulation of Whaling (ICRW), all with different objectives and different terminology for population structure. The goal of the MMPA is to protect marine mammals by maintaining marine mammal species and population "stocks" as significant functioning elements of their ecosystem. The IWC, established under the terms of the ICRW, manages whales with a goal of maintaining healthy stocks while authorizing hunts to meet aboriginal subsistence needs (and potentially commercial catches), and scientific research and related purposes. The ESA provides a framework to conserve and protect endangered and threatened species and their habitats both domestically and abroad.

In this document, we use the term "stocks" in the context of MMPA or IWC stocks, and use the more generic term "populations" when referring to species subunits. A marine mammal "population stock" or "stock" is the fundamental unit of conservation under the MMPA. The MMPA uses the term "population stock" and "stock" interchangeably and defines both terms as "a group of marine mammals of the same species or smaller taxa in a common spatial arrangement that interbreed when mature" (NMFS 2019). The IWC has adopted two definitions of stock: biological stocks (based on genetic separation) and management stocks (based on functional population units) (Donovan 1991).

The IWC recognizes three blue whale stocks corresponding to three major ocean basins (North Atlantic Ocean, North Pacific Ocean, and Southern Hemisphere), and six management areas in the Southern Hemisphere (Donovan 1991). The IWC's Southern Hemisphere baleen whale management areas, each encompassing 50° to 70° longitude from the South Pole to the equator, were officially delineated ahead of the 1974/75 season, and are still used today (Donovan 1991).

The IWC is preparing for a comprehensive assessment of Southern Hemisphere pygmy blue whales and is evaluating the feasibility of conducting an assessment of North Pacific blue whales (IWC 2019). The outcome of these assessments may inform the recognition of blue whale stocks and/or populations. For example, after reviewing relevant scientific literature, in 2016 the IWC Scientific Committee identified six "acoustic populations" in the Southern Hemisphere and Northern Indian Ocean (Antarctic, Chilean, Northern Indian Ocean, New Zealand, Indonesia/western Australia, and southwest Indian Ocean) (IWC 2016a). In the Northern Hemisphere, NMFS recognizes three stocks in United States waters: the western North Atlantic Ocean stock, the western and central North Pacific Ocean stock, and the eastern North Pacific Ocean stock (Eagle *et al.* 2008, Waring *et al.* 2010, Carretta *et al.* 2015).

The sub-specific taxonomy of blue whales (see Section I.B.3 above) is the subject of continuing work. Researchers are also working to define and distinguish regional populations or stocks by evaluating differences in genetics, acoustics, morphology, and movements. For example:

- *Genetics*. Conway (2005) conducted a global comparison of nuclear DNA and found a significant genetic separation between Antarctic and southern Indian Ocean samples and moderate substructure suggesting separation between blue whales in the western North Atlantic, eastern North Pacific, southern Indian, and Southern Oceans. LeDuc *et al.* (2007) evaluated nuclear and mitochondrial DNA of blue whale subspecies and populations in the Southern Hemisphere, and found, among other things, significant differentiation between populations of pygmy blue whales. Attard *et al.* (2016) found evidence of three sympatric populations of blue whales on Antarctic feeding grounds which likely have separate (but unknown) breeding grounds, although the IWC Scientific Committee found the evidence for these populations inconclusive (IWC 2016a). There is also evidence of hybridization between fin and blue whales (Berube & Aguilar 1998, NAMMCO 2014) and between pygmy and Antarctic blue whales (Attard *et al.* 2012).
- *Acoustics*. McDonald *et al.* (2006b) used temporally stable blue whale songs to identify regional populations around the world, and suggested that any differences not reflected in genetic analysis represent more recent patterns in movement and distribution. Stafford (2003) and Stafford *et al.* (2001) found that blue whales in the North Pacific Ocean produce two distinct, stereotypic calls that have been termed the northwestern and northeastern call types, and it has been proposed that these represent two distinct populations with some degree of geographic overlap.
- *Morphological differences.* Gilpatrick and Perryman (2008) used whaling records and aerial photographs to examine morphological differences between regional populations to inform subspecies and stock distinctions. They found that blue whales from the eastern North Pacific Ocean are on average 2 meters shorter in length at maturity than those in the central and western areas of the North Pacific Ocean (Gilpatrick & Perryman 2008).
- *Movements.* Satellite tagging and photo-identification research demonstrated that the eastern tropical Pacific Ocean is a migratory destination for blue whales that were tagged and/or photo-identified off California (Mate *et al.* 1999, Calambokidis *et al.* 2009a, Irvine *et al.* 2014).

More information about population structure is described in the region-specific sections of this document (Sections I.D.1, I.E.1, I.F.1, and I.G.1 below).

B.5 Natural History

B.5.1 Feeding and Prey Selection

Blue whales often forage in small groups at depths of approximately 100 m, although some whales forage around 250-300 m (Calambokidis *et al.* 2008b). They are considered lunge-feeders and filter large quantities of seawater (as much as 70% of their body weight with every feeding lunge) (Pivorunas 1979) to capture prey in their baleen. Sustaining swim speeds with the increased drag required by this feeding behavior is energetically expensive and may explain typical dive times (approximately 10 minutes) being much shorter than would otherwise be predicted based on body size (Croll *et al.* 2001b). In support of this hypothesis, blue whales spend more time recovering from foraging dives compared to shallower non-foraging dives (Acevedo-Gutierrez *et al.* 2002). However, Goldbogen *et al.* (2011) suggested that a large body size enables relatively high feeding efficiency because blue whales have a slow metabolism and consume large quantities of rapidly filtered prey with each feeding event. Blue whales are able to consume and assimilate as much as 90 times the amount of energy expended in obtaining their prey (Goldbogen *et al.* 2011, Knight 2011). While globally blue whale populations predominantly feed on krill, the Northern Indian Ocean subspecies is now known to feed on Sergestid shrimp (de Vos *et al.* 2018).

B.5.2 Reproduction

Most blue whale reproductive activity, including birthing and mating, takes place in winter and is marked by annual migratory cycles, but the breeding grounds for some populations are still unknown. Female blue whales typically reach sexual maturity beginning at an average length of 19.2-23.5 m depending on the subspecies (Mackintosh and Wheeler 1929, Branch & Mikhalev 2008), at about ten years of age in both males and females (Rice 1963, Ohsumi 1979, Branch 2008a, Valenzuela-Molina *et al.* 2018). Recent testosterone profiles suggest that male blue whales reach sexual maturity at approximately 10 years of age (Trumble *et al.* 2013). Little is known about the blue whale mating system, but anatomical characteristics (Brownell & Ralls 1986) and behavioral observations during the breeding season (Sears *et al.* 2013) suggest a polygynous, antagonistic male-male competition strategy. Blue whales are also known occasionally to hybridize with other large whale species, such as fin and humpback whales (Berube & Aguilar 1998, Reeves *et al.* 2002). Calf production is thought to be determined by a combination of age and food availability, with a gestation period lasting approximately 10 to 11 months (Mackintosh and Wheeler 1929). Pregnant females have been observed to consume 4% of their body weight daily (Sergeant 1969), amounting to 60% of their overall body weight throughout summer foraging periods (Lockyer 1984). Calving was documented in 1946 in the Trincomalee harbor on the east coast of Sri Lanka (Deraniyagala 1948). Weaning likely occurs six to seven months after birth en route to, or after whales arrive at, summer feeding areas (Mackintosh and Wheeler 1929)). The average calving interval for most females is two to three years and depends on the cow's ability to replenish food stores depleted during the lactation period (Lockyer 1984).

B.5.3 Competition

Nearly all baleen whale species that are sympatric with the blue whale eat euphausiids to some extent and are, therefore, potential competitors (Nemoto 1973). However, there is currently little or no direct evidence for interspecific competition involving blue whales (Clapham & Brownell 1996). In some locations, researchers have found evidence of resource partitioning among sympatric baleen whales, including separation in space and/or time and selection of prey species (Doniol-Valcroze 2008, Fossette *et al.* 2017). It seems unlikely that resource competition would be an important factor in preventing blue whale recovery. In addition, blue whales are capable of traveling great distances, which should enable them to take advantage of prey concentrations over very large areas and exploit prey even as oceanographic conditions vary.

B.5.4 Natural Mortality

At maturity, blue whales have little vulnerability to natural predators; however, young or ailing blue whales are likely vulnerable to shark and killer whale predation. Calves are most vulnerable to these attacks and most encounters are likely fatal, based on observations of killer whale attacks with other baleen whale calves. In some locations, ice entrapment is another source of mortality.

C. Zoogeography

As noted above, blue whales are a cosmopolitan species inhabiting nearly all major oceans of the world (Figure 1). Although populations of blue whales were severely depleted by whaling, this exploitation has not resulted in a major change in their distribution, and some areas with consistent survey effort are showing positive growth: 5% annual growth in Iceland (Christensen *et al.* 1992) and 7% annual growth in the eastern South Atlantic Ocean (Branch *et al.* 2007b). In general, blue whale distribution is driven largely by food requirements. Blue whales avoid the oligotrophic central gyres in the Indian, Pacific, and Atlantic Oceans, but are common where phytoplankton densities are high, and where there are dynamic oceanographic processes such as upwelling and oceanic fronts (Branch *et al.* 2007b; de Vos *et al.* 2014a). Blue whales generally migrate seasonally toward the polar regions in spring to areas with abundant summer zooplankton, and toward the subtropics in the fall to avoid ice entrapment in some areas and engage in reproductive activities in warmer waters.

However, blue whales have been acoustically detected year-round in some locations, such as the Northern Indian Ocean population, which does not undertake long-range migrations between cold feeding areas and warm breeding and calving areas, but remains in warm, tropical waters year-round (Alling *et al.* 1991, de Vos *et al.* 2012). This subspecies has a restricted range within the Bay of Bengal apart from the southwestern most extent, around the east coast of Sri Lanka, suggesting resident populations or portions of populations that do not migrate each year (Alling *et al.* 1991, Stafford *et al.* 1999a, Širović *et al.* 2004, Širović *et al.* 2009, Samaran *et al.* 2010, Stafford *et al.* 2011, de Vos *et al.* 2012, Samaran *et al.* 2013).

Figure 1. Distribution of blue whales spanning all oceans except the Arctic Ocean and Mediterranean Sea (adapted from http://maps.iucnredlist.org/map.html?id=2477). The yellow area represents the species' approximate range.

D. Natural History – Northern Blue Whales (*B. m. musculus)* in the North Atlantic Ocean (North Atlantic population management unit)

D.1 Population Structure

Blue whales in the North Atlantic Ocean may exist as eastern and western populations, with regional feeding subgroups (Christensen 1955, Jonsgard 1955, Sigurjónsson & Gunnlaugsson 1990). Blue whales in the western North Atlantic Ocean generally extend from the Arctic to at least mid-latitude waters, but are most frequently sighted in the waters off eastern Canada, with the majority of recent records in the Gulf of St. Lawrence (Waring *et al.* 2010). Photo identification research has shown that whales inhabiting the Gulf of St. Lawrence and waters off eastern Canada, New England, and Greenland belong to one population, with no known matches to the eastern population. Blue whales identified off West Greenland, the Scotian Shelf, and the Gulf of Maine were observed in subsequent years in the Gulf of St. Lawrence (Wenzel *et al.* 1988, Sears 1990). Based on whaling records, Jonsgard (1955) argued that the blue whales hunted along the coasts of Newfoundland and Labrador belonged to the same population as those hunted in Davis Strait as far north as Disko Island, Greenland. Blue whales in the eastern North Atlantic Ocean are centered around Iceland and have been observed passing through the Azores to northwest Africa (CETAP 1982, Wenzel *et al.* 1988, Sears & Calambokidis 2002, Sears & Larsen 2002, Sears *et al.* 2005, Visser *et al.* 2011).

Clark (1994) found that blue whale songs do not vary significantly in different regions of the North Atlantic Ocean, suggesting that these blue whales may range over the entire ocean basin and comprise a single panmictic population. Other researchers noted subtle differences in the cadence and composition of song phrases between blue whales in the Gulf of St. Lawrence and the rest of the North Atlantic Ocean (Berchok *et al.* 2006).

In some sections below, we discuss information specific to blue whales in the western and eastern North Atlantic Ocean, but recognize that there is uncertainty in whether they represent two separate units. Genetic analyses are needed to further elucidate population structure in the North Atlantic Ocean.

D.2 Distribution and Habitat Use

Blue whale distribution in the North Atlantic Ocean extends from largely temperate areas north to Baffin Bay and the Greenland Sea (Jonsgard 1955, Yochem & Leatherwood 1985, Sears & Larsen 2002), with whales primarily sighted in the northwestern portion of the Gulf of St. Lawrence (Lesage *et al.* 2007, Comtois *et al.* 2010). A stranding at Ocean City, Maryland, in 1891 (True 1904) is the southernmost confirmed record along the U.S. east coast. There are only two records from the Gulf of Mexico, a 1924 stranding near Sabine Pass, Louisiana and a 1940 stranding between Freeport and San Luis Pass, Texas. However, the species identification for both strandings is considered to be questionable, so blue whale occurrence in the Gulf of Mexico remains unconfirmed (Davis & Schmidly 1994 (rev)).

In general, blue whales migrate seasonally between feeding and calving areas. The seasonal and interannual distribution of blue whales is strongly associated with both the static and dynamic oceanographic features that result in krill aggregations (Gendron 1990, Reilly & Thayer 1990, Del-Angel-Rodriguez 1997, Croll *et al.* 1998, Fiedler *et al.* 1998, Benson *et al.* 2002, Hamazaki 2002, Croll *et al.* 2005, Matteson *et al.* 2010). Blue whales depend on a critical density of prey to feed efficiently, and thus seek out highly productive areas near upwelling zones and thermal fronts where krill abundance is greatest (Doniol-Valcroze *et al.* 2007). Since krill, the primary prey for blue whales, has relatively limited capacity for horizontal displacement, its distribution is strongly linked to areas of phytoplankton blooms and enhanced biomass retention.

Much of the recent research on blue whale distribution has focused on correlating seasonal survey observations with whaling data and whale vocalizations to elucidate potential feeding and breeding areas. This work often corroborates modeling predictions based on oceanographic features such as those noted above. For example, Clark and Gagnon (2004) found that blue whale singers strongly prefer shelf breaks, seamounts, and other highly productive areas throughout the year.

Western North Atlantic

In the 1960s, whalers regularly observed blue whales on the Scotian Shelf throughout summer and fall (Sutcliffe & Brodie 1977), with summer catches made off the northern Newfoundland and southern Labrador coasts, including the Strait of Belle Isle (Sergeant 1953, Jonsgard 1955, Sergeant 1966). In the Gulf of St. Lawrence, blue whales have been described as nomadic with varying degrees of site fidelity (Sears 1990, Comtois *et al.* 2010). Four individuals were documented to have traveled more than 400 km in two weeks (Sears 1990), while others remain in the same area for a month or more (Ramp & Sears 2013). The largest concentrations of blue whales are found in the lower St. Lawrence Estuary, around the eastern tip of the Gaspé Peninsula, along the north shore of the Jacques-Cartier Passage, and in the waters adjacent to

Sept-Îles. However, the low numbers of re-sightings within years suggest that blue whales in the Gulf of St. Lawrence are highly mobile. Compared to other baleen whales in the region, blue whales have exhibited the most specific habitat preferences, using areas with high salinity and slow currents (Doniol-Valcroze 2008). Although blue whales come mainly to the Gulf of St. Lawrence to feed in summer, they can occur year-round. The number of sightings tends to increase throughout summer, peaking in late August and early September; however, regional differences are apparent. The first peak in sightings occurs in June/July when blue whales are observed off the Gaspé Peninsula, while sightings in the lower St. Lawrence Estuary tend to drive the main peak in August/September. Seasonally, most blue whales leave the Gulf of St. Lawrence by early winter when ice cover becomes a factor. Blue whales were observed an average of only two days per season (occurrence), with an average occupancy of 22 days (Ramp & Sears 2013).

Outside the Gulf of St. Lawrence in Canadian waters, a few sightings have occurred on the Scotian Shelf and two blue whales were sighted in the lower Bay of Fundy in the summer of 1995 (Sutcliffe & Brodie 1977, CETAP 1982). Farther south, blue whales are occasionally seen in eastern U.S. shelf waters, with a few sightings off Cape Cod, MA, in summer and fall (Wenzel *et al.* 1988). This region may represent the current southern limit of the blue whales' feeding range. However, acoustic detections and tracking using the U.S. Navy's Sound Surveillance System indicate blue whales can travel long distances throughout the western North Atlantic, including to waters north of the West Indies and deep waters east of the U.S. Exclusive Economic Zone (Clark 1995). A vertebrae specimen from the British Museum of Natural History was reported to have come from a blue whale that entered the Panama Canal at Cristobal, Panama in January 1922 (Harmer 1923). During periods of peak whaling, blue whales were known to frequent subtropical waters in the North Atlantic Ocean throughout the fall and winter (Reeves *et al.* 2004).

Eastern North Atlantic

Blue whales were regularly hunted from land stations in West Greenland, Iceland, Norway, Ireland, the Shetland Islands, the Hebrides, and the Faroes Islands (True 1904, Thompson 1928, Sergeant 1953, Jonsgard 1955, Sergeant 1966, Jonsgard 1977, Kapel 1979, Sigurjónsson & Gunnlaugsson 1990). The paucity of sightings during recent surveys along the coasts of Finnmark and on the banks west of Bear Island and Svalbard, where blue whales were common in the late 1800s and early 1900s, may indicate that either the historic distribution and migratory pattern have changed or that the population was depleted by whaling (Christensen *et al.* 1992). More recently, however, sighting of blue whales in Svalbard have increased noticeably and there were "many sightings" during the 2014 North Atlantic Sightings Surveys in the Norwegian Sea and part of the area around Jan Mayen (NAMMCO 2014).

Migration patterns for blue whales in the eastern North Atlantic Ocean are poorly understood. However, blue whales have been documented in winter months off Mauritania in northwest Africa (Baines & Reichelt 2014); in the Azores, where their arrival is linked to secondary production generated by the North Atlantic spring phytoplankton bloom (Visser *et al.* 2011); and traveling through deep-water areas near the shelf break west of the British Isles (Charif & Clark 2009). Blue whale calls have been detected in winter on hydrophones along the mid-Atlantic ridge south of the Azores (Nieukirk *et al.* 2004). Sears *et al.* (2005) reported a photo-identification match between a blue whale sighted in Mauritania and Iceland, representing an estimated 5,200 km migration.

D.3 Feeding and Prey Selection

Stomach content analysis provides information on blue whale diet, but it cannot determine whether this reflects preferred prey, or the relative abundance of prey species. Blue whales in the North Atlantic feed on relatively large euphausiid crustaceans or krill species (Jonsgard 1955, Sergeant 1966, Christensen *et al.* 1992). The species *Thysanoëssa raschii* and *Meganyctiphanes norvegica* represent important food sources of blue whales in the Gulf of St. Lawrence, based on observations of feeding whales and water sampling (Sears 1987).

Although little is known about their winter distribution and migratory routes (Reeves *et al.* 2004), North Atlantic blue whales are found in the summer on a range of high latitude feeding grounds from eastern Canada to Greenland (Sears & Calambokidis 2002). Doniol-Valcroze *et al.* (2012) identified sites of intense feeding activity in the northwestern Atlantic Ocean. The dominant topographic feature of this area is the Laurentian Channel that extends from the Scotian Shelf, outside the Gulf of St. Lawrence, to Tadoussac in the St. Lawrence Estuary (Doniol-Valcroze *et al.* 2012). The 200-300 m deep channel is characterized by steep slopes on both sides, and comes within 100 m of the north shore in some places. Tidal mixing and interaction with bathymetric features result in rich krill aggregations (Simard *et al.* 1986). Sears (1987) suggested that the whales' preference for the 100 m depth during daylight hours along the north shore of the Gulf of St. Lawrence is linked to krill concentrations that occur regularly at depths of 90–120 m (Doniol-Valcroze *et al.* 2012). In general, blue whales do not typically frequent foraging areas if prey concentration does not reach a minimum threshold (Goldbogen *et al.* 2011) as is evident in the Gulf of St. Lawrence and in other blue whale foraging areas.

Less is known about blue whale diet composition in the eastern North Atlantic Ocean, but *Thysanoëssa inermis* and *Meganyctiphanes norvegica* are likely important prey in this region (Hjort & Ruud 1929, Christensen *et al.* 1992).

D.4 Competition

Blue whales may have little competition with other baleen whales in the North Atlantic Ocean due to resource partitioning. Doniol-Valcroze (2008) found that all baleen whales in the Gulf of St. Lawrence exhibit specialized niche preferences such that they use habitats and feed on prey that differs from sympatric species. Isotope ratios in whale tissue indicate blue, fin, minke, and humpback whales in the Gulf of St. Lawrence consume different proportions of shared prey species and have different trophic niches (Gavrilchuk *et al.* 2014). In the western North Atlantic Ocean, Clark and Gagnon (2004) found that blue and fin whales overlap in high latitude summer feeding areas while humpback whales were not detected in large numbers in the area. Similarly, in the eastern North Atlantic Ocean, Charif and Clark (2009) found that detection levels of fin, humpback, and blue whales peaked at different times throughout the year, suggesting little competition for food or space.

Blue whale distribution patterns are strongly correlated with the location of dense euphausiid patches (Reilly & Thayer 1990, Croll *et al.* 1998, Fiedler *et al.* 1998, Croll *et al.* 2005).

Therefore, any downward trend in the abundance of blue whales in important feeding areas could be an indication of significant biological changes occurring within the ecosystem. For example, Comtois *et al.* (2010) attributed a decline in numbers of blue whales in the Gulf of St. Lawrence beginning in 1994 to ecosystem changes or diminished prey availability following the groundfish stocks collapse (Hanson & Chouinard 2002, Savenkoff *et al.* 2007, Harvey & Devine 2008, Comtois *et al.* 2009). The collapse of the groundfish stocks and resulting increase in the small-bodied forage species, such as northern sand lance, capelin, and Atlantic herring that largely feed on krill, may impact blue whales because of the whales' relatively narrow trophic niche, compared to other baleen whales with generalist foraging strategies.

D.5 Reproduction

Only 13 blue whale calves were observed from 1979 – 2002 along the north shore of the Gulf of St. Lawrence (Ramp *et al.* 2006), suggesting that lactating females reside in unsurveyed areas, that weaning occurs before reaching the nearshore estuaries, or that few calves were born during that time (Reeves *et al.* 1998). While it has been suggested that reproductive parameters of Antarctic blue whales, such as interbirth interval, have been changing over time due to recovery from whaling pressure (Gambell 1973, Lockyer 1979), it is unknown whether these changes are occurring in the North Atlantic Ocean populations.

D.6 Natural Mortality

Long-term sightings and photo identification data have enabled researchers to understand certain aspects of natural mortality rates among western North Atlantic Ocean blue whales. Ice entrapment is known to injure and kill some blue whales, particularly along the southwest coast of Newfoundland during late winter and early spring (Beamish 1979, Sergeant 1982). Scarring on the dorsal surface of some whales in the Gulf of St. Lawrence is thought to be from contact with ice and or killer whales, but no direct evidence of predation has been reported (Sears 1987, Sears 1990). Based on sightings records from 1979 to 2002, Ramp *et al.* (2006) provided an estimated annual adult survival rate of 0.975 (95% confidence interval (CI) 0.960-0.985) for whales occurring in the Gulf of St. Lawrence region. Though little is known about survival rates in the eastern North Atlantic Ocean, a similar estimate may apply.

D.7 Abundance and Trends

Few abundance estimates exist for blue whales occurring in the North Atlantic Ocean due to the wide distribution and highly migratory nature of these animals. Historically, as many as 15,000 blue whales may have inhabited the North Atlantic before whaling began (Sergeant 1966, Allen 1970, Rørvik & Jonsgård 1981). Although uncertainties and caveats surround these historical estimates, researchers agree that populations were largely depleted by modern whaling throughout the 20th century and only now may be showing signs of modest recovery. The IWC annual catch database indicates over 10,000 blue whales were killed in the North Atlantic Ocean between 1868 and 1978, although only about 1,600 blue whales were taken after 1914 (Branch *et al.* 2008). Based on compiled survey and photo identification data, it is likely that the number of blue whales throughout the entire North Atlantic Ocean now ranges from 600 to 1,500 animals (Sears & Calambokidis 2002). There are insufficient data to determine population trends for

North Atlantic blue whales. Data gaps highlight the importance of long-term monitoring to understand the trends in abundance.

Western North Atlantic

Based on cumulative catches from 1898 to 1915, researchers estimate that between 1,100 and 1,500 blue whales frequented the western North Atlantic before modern whaling began (Sergeant 1966, Allen 1970), and researchers agree that blue whales were severely depleted by 1955 when IWC prohibitions against killing blue whales in the North Atlantic Ocean came into force (Jonsgard 1955, Best 1993).

Almost all recent information about the abundance of blue whales in the western North Atlantic comes from the Gulf of St. Lawrence, Canada. Within the Gulf of St. Lawrence, a long-term monitoring project provided a rare opportunity to observe changes in baleen whale distribution and ecosystem processes (Ramp & Sears 2013). From 1979 to 2009, about 440 blue whales were identified within and around the estuary area, with between 20 and 105 blue whales identified each year, with varying degrees of site fidelity among and between years (Ramp & Sears 2013; see Section I.D.2). Because the Gulf of St. Lawrence is a small portion of the population's range and it is difficult to determine the percentage of whales within the population that use the area in any given year or at any given time, the known number of individuals in those discrete areas cannot be extrapolated for an overall abundance estimate.

Ramp and Sears (2013) provided a summary of sightings from opportunistic observations from the published literature and other records of individual blue whales outside of the Gulf of St. Lawrence area. While the information was not a complete overview of historic sightings of blue whales outside of the Gulf of St. Lawrence area, it provides insight on the importance of these additional areas and further exhibits the challenge in determining an overall abundance.

Given the small number of blue whales encountered and photographed and the limited survey data, an estimate of abundance of blue whales in the Northwest Atlantic Ocean is not possible with a minimum degree of certainty (Hammond *et al.* 1990, Sears *et al.* 1990, Sears & Calambokidis 2002, Beauchamp *et al.* 2009, Waring *et al.* 2010). Some researchers speculate that there may be between 400 and 600 blue whales there (Mitchell 1974, Waring *et al.* 2010).

Without accurate current abundance estimates, no trend information is available.

Eastern North Atlantic

Estimates of pre-exploitation abundance are likely unreliable. Prior to commercial whaling, there were estimated to be a "few thousand" to 10,000 blue whales in the Denmark Strait (Rørvik & Jonsgård 1981) and 2,500 from northern Norway (Rørvik & Jonsgård 1981).

Based on the results of a summer shipboard survey in 1987, Sigurjónsson and Gunnlaugsson (1990) estimated a maximum of 442 blue whales in Icelandic waters. Sighting data from whaling vessels operating off the west coast of Iceland have demonstrated an increasing trend of approximately 5% per year since the late 1960s (Sigurjónsson & Gunnlaugsson 1990). This observed trend is considered to apply only to the population in these waters and has been corroborated by Pike *et al.* (2009). An estimate of approximately 1,000 individuals in Icelandic waters would suggest that this population is the largest in the North Atlantic (Pike *et al.* 2009).

Based on the North Atlantic Sightings Surveys in 1995 and 2001, Pike *et al.* (2004) estimate there are between 1,000 and 2,000 blue whales in the surveyed areas off the east coast of Greenland, Denmark Strait, Iceland, Jan Mayen, Faroe Islands, west coast of Ireland, and north of the United Kingdom. While these figures are uncertain, historical abundance estimates indicate that this population is diminished compared with pre-exploitation estimates.

E. Natural History – Northern Blue Whales (*B. m. musculus)* in the North Pacific Ocean (Eastern North Pacific and Western/Central North Pacific population management units)

E.1 Population Structure

The population structure of blue whales in the North Pacific Ocean has been evaluated through the analysis of whaling data, length frequencies, vocal repertoire, and movement data from tagging studies. There may be as many as five populations with an unknown degree of mixing among them: (a) southern Japan; (b) northern Japan/Kuril Islands/Kamchatka; (c) Aleutian Islands (which may winter in deep water north of Hawaii); (d) eastern Gulf of Alaska; and (e) the eastern North Pacific (Reeves *et al.* 1998). Blue whales were heavily exploited in waters off southern Japan (Kasahara 1950), and are no longer sighted in the area, leading researchers to believe that the population may have been extirpated. Blue whales have also been observed ranging from northern Japan in winter to the Kamchatka Peninsula in summer (Nishiwaki 1966, Ohsumi & Wada 1974, Fujise *et al.* 1995). Forney and Brownell (1996) concluded that these whales were a separate group from those exploited around the Aleutian Islands based on whaling catch locations and body size.

More recent data, described below, suggest that blue whales in the North Pacific Ocean consist of at least two existing populations, the eastern and western/central populations (Stafford *et al.* 2001, Stafford 2003, McDonald *et al.* 2006b, Monnahan *et al.* 2014, Calambokidis *et al.* 2015). NMFS recognizes Eastern and Central North Pacific stocks under the MMPA.

Blue whales in the North Pacific produce two distinct, stereotypic calls that have been termed the northwestern and northeastern North Pacific Ocean call types, and it has been proposed that these are indicative of two distinct populations with some degree of geographic overlap (Stafford *et al.* 2001, Stafford 2003, Monnahan *et al.* 2014). The calls used to identify the distinct populations are known as 'AB' call type, which are produced exclusively by lone, traveling males. There are other call types such as the 'D' call, which is produced by both sexes when foraging (Monnahan *et al.* 2014). The northeastern Pacific Ocean call predominates in the Gulf of Alaska, the U.S. West Coast, and the eastern tropical Pacific Ocean, while the northwestern Pacific Ocean call is heard among calling blue whales from along the Aleutian Islands to the Kamchatka Peninsula off Russia, though both call types have been recorded concurrently in the Gulf of Alaska (Stafford *et al.* 2001, Stafford 2003). Both call types were recorded in lower latitudes in the central North Pacific Ocean, although with much lower occurrence (Stafford *et al.* 2001).

Length frequency data analysis by Gilpatrick and Perryman (2008) supports separation of North Pacific Ocean blue whales into eastern and western/central populations. They found that blue whales from waters off California to Central America (the eastern North Pacific stock) are on average, two meters shorter than blue whales measured from historic whaling records in the central and western North Pacific Ocean. Monnahan *et al.* (2014) found that mature female eastern north Pacific blue whales are shorter by 0.91 m on average than the western/central North Pacific population. Additionally, satellite tagging data and photo-identification studies have shown that whales from the eastern population move between the Gulf of Alaska and the Costa Rica Dome off central America (Mate *et al.* 1999, Calambokidis *et al.* 2009a, Bailey *et al.* 2010).

E.2 Distribution and Habitat Use

In general, blue whales migrate seasonally between feeding and calving areas (Sears & Calambokidis 2002, Burtenshaw *et al.* 2004). Blue whales range throughout much of the North Pacific Ocean, from Kamchatka to southern Japan in the west, and from the Gulf of Alaska and waters off California to areas off Central America. Small numbers have been observed in Hawaiian waters and as far north as the Chukchi Sea (Berzin & Rovnin 1966, Northrop *et al.* 1970, Thompson & Friedl 1982, Yochem & Leatherwood 1985, Barlow 1997). Whales in the eastern and central North Pacific Ocean stocks range along the U.S. west and eastern Russian coasts, respectively.

As in the North Atlantic Ocean, blue whales inhabit both coastal and pelagic environments and are frequently found on the continental shelf (Calambokidis *et al.* 1990, Fiedler *et al.* 1998) and also far offshore in deep water (Wade & Friedrichsen 1978). Seasonal and interannual distribution of blue whales is strongly associated with both the static and dynamic oceanographic features that result in krill aggregations (Gendron 1990, Reilly & Thayer 1990, Del-Angel-Rodriguez 1997, Croll *et al.* 1998, Fiedler *et al.* 1998, Benson *et al.* 2002, Hamazaki 2002, Croll *et al.* 2005). Blue whales depend on a critical density of prey to feed efficiently, and thus seek out productive areas near upwelling zones and underwater thermal fronts where krill abundance is highest (Doniol-Valcroze *et al.* 2007). In the North Pacific Ocean, Munger *et al.* (2009) found that distribution was most strongly linked to cool sea surface temperatures, particularly in summer. Irvine *et al.* (2014) found that blue whale “home ranges” and “core areas” are typically near highly productive, strong upwelling centers. Additionally, Stafford *et al.* (2009) found that vocalization occurrence and rates could be predicted by sea surface temperatures, with peaks in calling occurring one to two months after cold spells.

Eastern North Pacific

Blue whales inhabit a broad area throughout the eastern North Pacific coincident with shifting feeding areas (Calambokidis *et al.* 2009a, Calambokidis *et al.* 2015). Since the 1970s, large concentrations of blue whales have been documented feeding off California each summer and fall (Calambokidis *et al.* 1990), and increasingly have been found feeding to the north and south of these summer/fall feeding areas (Calambokidis & Barlow 2004, Barlow & Forney 2007, Calambokidis *et al.* 2009a). Nine “biologically important areas” for blue whale feeding were identified off the California coast by Calambokidis *et al.* (2015), including six in southern California and three in central California. In fall, blue whales migrate northward along the North American coast to secondary feeding areas off Oregon and Washington (Burtenshaw *et al.* 2004), the Alaska Gyre, and Aleutian Islands (Stafford *et al.* 2001, Stafford *et al.* 2007). This migration was first documented in 1997 and may represent the return to a historical migratory route that was prevalent before whaling activities exploited the population (Calambokidis *et al.* 2009a). These whales also range north into the Gulf of Alaska where they seasonally overlap with the western/central North Pacific stock (Stafford *et al.* 2001, Stafford 2003). It is possible that this northward migration constitutes only a small portion of the California feeding population, though the sex and age composition of this group remains unknown. Bailey *et al.* (2010) monitored migratory routes of tagged whales from 1993 to 1997 and noted interannual variability in the occurrence of the whales undergoing this northward movement, which they attribute to environmental changes affecting the whales' prey.

In winter and spring, Eastern North Pacific blue whales move to feed and breed in low latitudes, especially in the Gulf of California and the Costa Rica Dome (Reilly & Thayer 1990, Mate *et al.* 1999). Many whales have been documented off the coast of Baja California, Mexico and the relatively deep waters of the southern Gulf of California (Gendron & Hernandez 1995, Mate *et al.* 1999, Calambokidis *et al.* 2009a), but blue whale abundance in this area is relatively low (approximately 5% of the California feeding population) and peaks in March-April (Tershy *et al.* 1990). The Baja California Frontal System, a dynamic region at the convergence of the California and Davidson Currents (Etnoyer *et al.* 2004), appears to be used as a migratory stopover for whales wintering off Central America and those returning north to California waters for the summer (Rice 1974). Whales may also be feeding in this transitory area (Etnoyer *et al.* 2006). Matteson *et al.* (2010) found that blue whale distribution around the Costa Rica Dome during winter was most significantly associated with chlorophyll concentration and subsurface temperature, indicating that feeding is linked to zooplankton aggregations. Blue whales have been observed feeding year-round near the Costa Rica Dome, though Southern Hemisphere blue whales may also frequent the area (Reilly & Thayer 1990).

Blue whale occurrence and distribution may change with prey abundance and oceanographic conditions. The California Current is a dynamic ecosystem governed by large-scale oceanographic patterns, most notably the El Niño Southern Oscillation (ENSO) characterized by unusually warm temperatures. La Niña conditions can feature unusually cool temperatures in the equatorial Pacific. The Pacific (inter) Decadal Oscillation (PDO) is an El Niño-like oscillatory pattern of climate variability centered over the Pacific Ocean and North America. The PDO has considerable influence on climate sensitive living marine resources in the Pacific and over North America, including major marine ecosystems from coastal California to the Gulf of Alaska and Bering Sea (Mantua 2002). Pardo *et al.* (2015) found that inter-annual variation in blue whale distribution during El Niño anomalies suggests that the local and regional densities of the species decreases in the Equatorial Cold Tongue and the Costa Rica Dome, and occurrence retracts to areas that remain productive (*i.e.,* the California Current, northern Gulf of California, the North Equatorial Countercurrent thermocline ridge, and the southern portion of the Humboldt Current System). During the 1997/1998 ENSO event, blue whale distribution off the U.S. West Coast was significantly different from other years as the whales shifted northward to areas that remained productive (Burtenshaw *et al.* 2004).

Western/Central North Pacific

Little is known about the distribution, migration, and habitat use of blue whales in the central and western North Pacific Ocean. Blue whales appear to feed in summer southwest of Kamchatka, south of the Aleutian Islands, the Gulf of Alaska (Gambell 1973, Watkins *et al.* 2000, Stafford 2003), and waters off Vancouver Island, Canada (Omura & Ohsumi 1964, Ivashin & Rovnin 1967, Ohsumi & Masaki 1975). Based on acoustic records (Monahan *et al.* 2014), satellite tags and photo-identification recaptures (Calambokidis *et al.* 2009a), these blue whales are most likely eastern North Pacific blue whales. Whaling records indicate whales were commonly taken off the southern portion of the main Japanese islands in winter, off Hokkaido in spring, and off Kamchatka, the Kurils, and the western Aleutians in summer (Kasahara 1950), suggesting a seasonal northward migration.

In winter, blue whales migrate to low latitudes in the western and central Pacific, including Hawaiian waters (Berzin & Rovnin 1966, Northrop *et al.* 1970, Thompson & Friedl 1982, Stafford *et al.* 2001, Bradford *et al.* 2017). It is possible that some individuals from this stock undertake a seasonal migration while others do not. One study, based on vocalizations, documented individual blue whales remaining off the coast of Kamchatka year-round, with peak calling in fall (Watkins *et al.* 2000). Additionally, Stafford (2003) recorded the northwestern Pacific blue whale call type (identified from recordings in Hawaii, Midway Island, the Aleutian Islands, and the northwest Pacific) (Northrop *et al.* 1970, Thompson & Friedl 1982, Stafford *et al.* 2001) in the Gulf of Alaska during fall and early winter, which may indicate some individuals do not undertake a winter migration south.

E.3 Feeding and Prey Selection

North Pacific Ocean blue whales feed primarily on *Euphausia pacifica* and *Thysanoëssa spinifera* (Rice 1986, Schoenherr 1991, Kieckhefer *et al.* 1995, Fiedler *et al.* 1998). In the Gulf of California, Mexico, blue whales feed primarily on *Nyctiphanes simplex* (Gendron 1990, Gendron 1992, Del-Angel-Rodriguez 1997), which often aggregates in dense swarms near the surface except during periods of increased surface water temperatures related to the El Niño Southern Oscillation (Gendron 1990, Sears 1990, Gendron 1992, Gendron & Sears 1993). Other known prey species include *T. inermis, T. longipes, T. raschii,* and *Nematoscelis megalops* (Kawamura 1980, Yochem & Leatherwood 1985).

One exception to their near-total dependence on euphausiid prey is that blue whales have been observed feeding on pelagic red crabs off Baja California (Rice 1974, Rice 1986), although these observations have not been confirmed by subsequent observations or other analyses (*e.g.,* fecal samples). The discovery of copepods and amphipods in the stomach contents of some whales taken during whaling activities or reports of foraging on schooling fish (Mizue 1951, Sleptsov 1955) are thought to be the result of opportunistic or accidental consumption rather than evidence of a mixed diet (Nemoto 1957, Nemoto & Kawamura 1977).

E.4 Competition

In the California Current Ecosystem, other baleen whales are present throughout the year, but the most overlap with blue whales occurs during periods of high primary productivity. It would seem unlikely that resource competition would occur with abundant prey present. In summer, blue and fin whales off the coast of central California in summer target ephemeral krill patches. Despite the overall similarities in blue and fin whales' dive profiles, Friedlaender *et al.* (2015) found differences in feeding performance that may represent unique predatory strategies that minimize competition yet maximize energy gain. Blue whale competition with another sympatric baleen whale species in the California Current Ecosystem, the humpback whale, may be minimized by the whales' partitioning of prey resources in space, time, and trophic level (Fossette *et al.* 2017).

E.5 Reproduction

No differences in the reproductive biology between blue whales in the North Pacific and North Atlantic Oceans are known or suspected. In the eastern North Pacific stock, blue whales accompanied by young calves have been observed often in the Gulf of California, Mexico from December through March, suggesting that this area is likely an important calving and nursing area (Sears 1990). However, only a portion of females observed off the U.S. West Coast were observed in the Gulf of California, indicating that there is likely another, unknown calving or nursing ground for this population (Sears *et al.* 2013). Observations of females re-sighted in alternating years with calves supports the estimated two-year calving interval noted by Lockyer (1984); Sears *et al.* (2013) estimate a mean calving interval of 2.57 years and an age of first parturition of more than 10 years; Rice (1963) estimated age at first parturition of 9-11 years and calving intervals, based on ovulation rates, of every 2.0-2.4 years. In coastal waters off California, observations of females with young whales in late summer support the idea that weaning occurs at approximately six months of age (Reeves *et al.* 1998). No information on reproductive parameters exists specific to blue whales in the western/central North Pacific stock.

Oleson *et al.* (2007a) assessed eastern North Pacific Ocean blue whale vocalizations and found patterns in behavior, sex, and group size for certain call types. Only males produced song, indicating song is likely involved in reproductive activities, despite being produced year-round and on both feeding and presumed breeding grounds (Stafford *et al.* 2001, Oleson *et al.* 2007a). The purpose of producing song during the feeding season is not known, but suggests that mate selection can occur outside of the breeding season (Oleson *et al.* 2007a).

E.6 Natural Mortality

A high proportion of the blue whales in the Gulf of California show signs of injuries or rake-like scars that are the result of encounters with killer whales (Sears 1990), although the rate of fatal attacks by killer whales is unknown. A well-documented observation of killer whales attacking a blue whale off Baja California Sur, Mexico indicates that blue whales are at least occasionally vulnerable to these predators in this area (Tarpy 1979). Additionally, killer whales were observed feeding on a blue whale calf off the coast of Nicaragua, but the frequency of these events remains unknown (Pitman *et al.* 2007). Unlike in the western North Atlantic Ocean, injury or suffocation from ice entrapment is not known to be a factor in the natural mortality of blue whales in the North Pacific. Based on earplug aging data collected during the early 1960s, the survival rate for North Pacific blue whales was estimated to range from 0.93 – 0.95 (Ohsumi and Wada 1974), which is lower than that of blue whales in the North Atlantic and Indian Oceans (Branch 2008a,b and Ramp *et al.* 2006).

E.7 Abundance and Trends

In the North Pacific Ocean, commercial whaling operations killed 9,773 blue whales from 1905 to 1971 (Monnahan *et al.* 2014). Approximately 65% of these catches are estimated to have been from the western North Pacific population, which suggests that the pre-whaling abundance of the western population was much larger than the eastern population (Monnahan *et al.* 2014).

Omura and Ohsumi (1974) estimated an "initial stock size" of 4,900 for the entire North Pacific. However, this estimate and those by Wada (1975) were actually indices of abundance based on sightings from Japanese whaling catcher boats. The data were not collected or analyzed in the same ways as those from more recent sighting cruises, nor did the area of coverage include several well-known centers of blue whale abundance in the North Pacific (for example, Wada (1975), Figures 1-2, compared with Reilly and Thayer (1990), Figures 1, 3). It is therefore not possible to evaluate trends by comparing the Japanese "indices" from the 1960s and 1970s with the more recent abundance estimates from sighting cruises and photo-identification studies.

Eastern North Pacific

Based on a crude analysis of catch statistics and whaling effort, Rice (1974) estimated an initial (1924) population size of about 6,000 blue whales in the eastern North Pacific (Baja California to Alaska) and a decline to fewer than 2,000 by the early 1970s. In contrast, Monnahan *et al.* (2015) used a population dynamics model to estimate pre-whaling abundance of the eastern North Pacific population as 2,210 (95% Bayesian credible interval 1,823-3,721). The assessment by Monnahan *et al.* (2014) has been accepted by the IWC Scientific Committee (IWC 2016b).

The eastern North Pacific stock is one of the most well-studied population of blue whales, with directed surveys occurring almost every year off the California coast. The size of the feeding stock of blue whales off the U.S. West Coast has been estimated by both line-transect and mark-recapture methods, but because some fraction of the population is always outside the survey area, the line-transect and mark recapture estimation methods provide different measures of abundance for this stock. From ship-based line-transect survey data from 1986-1990, Wade and Gerrodette (1993) estimated 1,400 blue whales in the eastern tropical Pacific. Line-transect abundance estimates from summer/autumn 2001 to 2008 research cruises in the California Current ranged between 400 and 800 individuals (Barlow & Forney 2007, Forney 2007, Barlow 2010). These estimates are considerably lower than previous line-transect estimates of approximately 1,900 whales between 1991 and 1996 (Barlow 2010). Part of the reason for the discrepancy is likely due to the northward shift in blue whale distribution related to oceanographic conditions and prey abundance, and not a population decline (Barlow & Forney 2007, Calambokidis *et al.* 2009a). New abundance estimates based on photographic mark-recapture data for the period 2005 to 2011 range from approximately 1,000 to 2,300 whales (Calambokidis & Barlow 2013). An estimate of 1,647 (CV=0.07) whales is regarded as the best estimate of blue whale abundance for the period 2008-2011, based on Calambokidis and Barlow's (2013) Chao 4-year model (Carretta *et al.* 2015).

Mark-recapture estimates provide the best indicator of population trends for this stock, because recent northward shifts in blue whale distribution might result in a negative bias in estimates based on line transect surveys due to the locations of those surveys. Based on mark-recapture estimates from the U.S. West Coast and Baja California, Mexico coast, Calambokidis *et al.* (2009b) estimated an abundance increase of just under 3% per year, but it is not known if that corresponds to the maximum growth rate of this stock.

Calambokidis *et al.* (2015) argued that the eastern Pacific blue whale population has not shown signs of recovery from commercial whaling over the last twenty years, particularly compared to other baleen whale populations in the region. In contrast, Monnahan *et al.* (2015) used a population dynamics model to estimate that the eastern Pacific blue whale population was at

97% of carrying capacity (95% Bayesian credible interval 62%–99%) in 2013 and suggested that an observed lack of a population size increase since the early 1990s can be attributed to density dependence. The authors estimated that the minimum population size of the eastern North Pacific Ocean population was at least 460 whales during the last century, despite extensive commercial whaling exploitation. In 2015, the IWC Scientific Committee endorsed the conclusions of Monnahan *et al.* (2015) regarding the population approaching carrying capacity, but recommended refinement of the analysis to address uncertainties when additional data become available (IWC 2016b).

Western/Central North Pacific

The IWC's POWER surveys (https://iwc.int/power), and JAPAN's JARPN cruises cover almost the entirety of the western/central North Pacific population (Branch *et al.* 2018a). The JARPN and JARPNII cruises have sighted 374 blue whale schools, many close to Japan, with abundance estimates ranging from 38 to 958 during 2008-2014 (Hakamada & Matsuoka 2016). The POWER cruises sighted 20 blue whales during 2010-2017 covering 170°E to 135°W and 20°N northwards to the Bering Sea, but no abundance estimate is forthcoming yet. Additional surveys of this population are also listed in Branch *et al.* (2018a). No blue whales were observed during a summer/fall 2002 survey of the entire U.S. EEZ around the Hawaiian Islands (Barlow 2006), but some blue whales were observed in these waters during a summer/fall 2010 survey, resulting in an abundance estimate of 133 (CV = 1.09) blue whales (Bradford *et al.* 2017). This is currently the best available abundance estimate for this stock within the U.S. EEZ around the Hawaiian Islands, but the majority of blue whales would be expected to be at higher latitude feeding grounds during the time of year the survey was conducted. Developing abundance estimates for this stock is difficult due to the uncertainty surrounding their seasonal distribution and overlap with the eastern stock in the central North Pacific Ocean. Thus, the status of blue whales in Hawaiian waters is unknown and there are insufficient data to evaluate trends in abundance.

An aerial survey of the former Akutan whaling grounds around the eastern Aleutians in 1984 produced no sightings of blue whales, suggesting that the population remained severely depleted (Stewart *et al.* 1987). No blue whales were sighted during a marine mammal survey south of the Aleutian Islands in 1994 (Forney & Brownell 1996). However, as described in Sections I.E.1 and I.E.2, northwestern blue whale calls have been recorded in summer southwest of Kamchatka, south of the Aleutian Islands, in the Gulf of Alaska, and in lower latitudes of the western and central Pacific, including Hawaii, in winter (Watkins *et al.* 2000, Stafford *et al.* 2001, Stafford 2003, Carretta *et al.* 2015).

F. Natural History – Antarctic Blue Whales (*B. m. intermedia)* (Antarctic subspecies management unit)

F.1 Population Structure

Antarctic blue whale movement information from Discovery tags (i.e., uniquely numbered metal tubes that were shot into whales' muscles during scientific cruises and recovered when the animals were killed during whaling), photo-identification, individual genotype identification, and satellite tagging show both small-scale movements (e.g., within IWC Areas, both within and between seasons) and large-scale movements (e.g., up to 180° longitude) (Branch *et al.* 2007a, Branch *et al.* 2007b, Branch *et al.* 2009). Only one blue whale call type has been recorded in the

Southern Ocean (Donovan 1991, Rankin *et al.* 2005, McDonald *et al.* 2006b, Širović *et al.* 2009), suggesting a single population, or alternatively, that any discrete populations are not acoustically distinct.

Antarctic blue whales have the greatest haplotypic diversity of any of the blue whale subspecies, likely due to a large historical abundance (LeDuc *et al.* 2007). Sremba *et al.* (2012) found significant genetic differences at fixation indices between some IWC Areas. Attard *et al.* (2016) analyzed a larger set of genetic samples that was not bound by *a priori* population boundaries, and found three genetically differentiated populations that occur sympatrically off Antarctica during the austral summer feeding season. However, in 2016 the IWC Scientific Committee found the evidence for three populations to be inconclusive and recommended that alternate methods with greater power to discriminate population structure should be considered (IWC 2016a).

F.2 Distribution and Habitat Use

Blue whales in the Antarctic are almost exclusively from the Antarctic subspecies (Branch *et al.* 2007a,b and 2009). Due to the rarity of sightings, most of the information on Antarctic blue whale distribution and habitat use has been obtained from monitoring of vocalizations and historical whaling data. Acoustic recordings indicate that blue whales are distributed around Antarctica, generally remaining south of the Antarctic Convergence Zone (55° S) during summer, and likely moving into mid- and low-latitude waters in fall and winter (Stafford *et al.* 1999b, Clark & Fowler 2001, Širović *et al.* 2004, Stafford *et al.* 2004, McKay *et al.* 2005, Rankin *et al.* 2005, Stafford *et al.* 2005, McCauley *et al.* 2006, McDonald *et al.* 2006b, Ensor *et al.* 2009, Širović & Hildebrand 2011). However, as described later in this section, not all Antarctic blue whales migrate each year.

The seasonal and inter-annual distribution of Antarctic blue whales is strongly associated with both the static and dynamic oceanographic features that aggregate krill (Gendron 1990, Reilly & Thayer 1990, Del-Angel-Rodriguez 1997, Fiedler *et al.* 1998, Benson *et al.* 2002, Hamazaki 2002, Croll *et al.* 2005). Blue whales depend on a critical density of prey to feed efficiently, and thus occur in highly productive areas near upwelling zones and thermal fronts where krill are most abundant (Doniol-Valcroze *et al.* 2007). In the Antarctic, krill abundance is governed by the combination of a number of oceanographic features, but mainly by the presence of phytoplankton near ice edges and continental shelves (Murase *et al.* 2002, Atkinson *et al.* 2004, Siegel 2005). Many of the sub-Antarctic islands and coastal areas where Antarctic blue whales have been detected are highly productive in winter and sustain abundant zooplankton (Moore & Abbott 2000).

Most Antarctic blue whales are believed to make annual migrations between summer feeding and winter breeding/calving grounds. This theory is supported by detection of Antarctic call types in winter in low latitude areas, including the eastern tropical Pacific, the central Indian Ocean, and off southwestern Australia and northern New Zealand (McCauley *et al.* 2001, Stafford *et al.* 2004, McDonald 2006, Samaran *et al.* 2013). Antarctic blue whales were known to migrate into South African and Namibian waters in a period prior to the onset of intensive whaling; the region off southwest Africa could be a breeding location based on seasonality of Antarctic blue whale historical catches there (Branch *et al.* 2007a, Branch *et al.* 2007b), but since the cessation of whaling, there have been few recorded blue whale sightings there (Branch *et al.* 2007b, Figueiredo & Weir 2014).

Not all Antarctic blue whales migrate each year and some migrations may depend on age. Most Antartic whales caught in winter shore whaling stations in the southeast Atlantic were immature individuals, suggesting the possibility that migrations are age-dependent to some extent (e.g., Mackintosh and Wheeler 1929, Branch *et al.* 2018b). Year-round acoustic detections of Antarctic blue whale calls near the West Antarctic Peninsula (Širović *et al.* 2004, Širović *et al.* 2009), the Weddell Sea and along the Greenwich meridian (Thomisch *et al.* 2016), eastern Antarctica at 67° S, 70° E (McKay *et al.* 2005, Širović *et al.* 2009), and South Georgia Island (Hinton 1915, Risting 1928) suggest that only a portion of the population migrates north each year, or that at least one population is resident in Antarctica throughout the year (Attard *et al.* 2016). However, the frequency of calling in these Antarctic areas generally decreases during winter as many of the whales migrate northward (Širović *et al.* 2009). Antarctic blue whales have also been detected in mid-latitude waters year-round. Samaran *et al.* (2010) documented the year-round presence of Antarctic blue whales around the Crozet Islands in the southern Indian Ocean.

F.3 Feeding and Prey Selection

Cotte *et al.* (2006) found that historical abundance of blue whales in the Antarctic, based on whale catches, was highly correlated with the extent of the seasonal ice zone. The timing and extent of sea ice formation varies each year, but data indicate that, in contrast to patterns in the Arctic Ocean, the Southern Ocean around Antarctica has experienced a slight but statistically significant increase in sea ice extent since the 1970s, although regional trends differ (Parkinson & Cavalieri 2012). However, after decades of increase, including record high daily extents in 2015 and a record high winter maximum in 2014, the sea ice minimum extent reached a record low in March 2017 (National Snow & Ice Data Center 2017). Given the variability in these conditions and uncertainty in how Antarctic sea ice is responding to climate change, impacts on baleen whales, including blue whales, are unclear. See Section I.H.1.4 below for more information about potential impacts to blue whale prey due to climate and ecosystem changes.

F.4 Competition

In the Southern Ocean around the West Antarctic Peninsula, fin whales are found farther from shore than other baleen whales foraging near the ice edge, making them less likely to compete with blue whales for resources (Murase *et al.* 2002, Murase *et al.* 2006, Širović 2006), but there is significant spatial overlap between blue, minke, and killer whales throughout known Antarctic feeding areas (Kasamatsu *et al.* 2000). Mori and Butterworth (2004) suggested that blue whales have a competitive advantage over minke whales, which have a higher growth rate and are more afftected by low krill density compared to blue whaless.

Baleen whales from different species have been shown to preferentially feed on Antarctic krill of specific sizes, supporting the hypothesis that spatial separation and unique feeding habits result in less interspecific competition (Santora *et al.* 2010). It is not clear how climate change may influence the density, distribution, or availability of krill and whether these changes may impact interspecific competition. However, it is unlikely that interspecific competition is limiting recovery of Antarctic blue whales.

F.5 Reproduction

The reproductive biology of Antarctic blue whales is likely very similar to that of blue whales in the North Pacific and North Atlantic Oceans. Little is known about the reproductive behavior of Antarctic blue whales. Branch (2008b) reviewed available information on Antarctic blue whale life history parameters, including age at sexual maturity and inter-calf interval. Based on analysis of a very small sample of earplug layers, Antarctic blue whales are thought to reach sexual maturity between 8-12 years old, which is later than blue whales in the Northern Hemisphere (Ichihara 1966, Ohsumi & Wada 1974, Branch 2008a, Branch 2008b). However, Lockyer (1984) argues that they may reach sexual maturity as young as five years old. Antarctic blue whales are thought to give birth every 2.5 years (Ohsumi & Wada 1974, Branch 2008b).

The historically intensive exploitation pressure on this population may have affected reproductive output. A lower post-exploitation density of whales (compared with pygmy blue and other baleen whales; (Branch *et al.* 2007a) that has access to relatively plentiful prey resources may have led individuals to reach sexual maturity more quickly, give birth more often, or live longer (Branch 2008b). However, this has not been confirmed.

F.6 Natural Mortality

Little information exists concerning the natural mortality of Antarctic blue whales. It is possible that calves fall victim to killer whale predation based on similar observations in the north and central Pacific, noted above. No estimates of mortality rates among adults or calves exist for this population, though survival rates are likely comparable to other blue whale populations ranging from 0.93-0.98 (Mizroch *et al.* 1984, Ramp *et al.* 2006, Branch 2008a).

F.7 Abundance and Trends

Some 360,000 blue whales were whaled from the Southern Hemisphere last century (Clapham & Baker 2002). Branch *et al.* (2004) and Branch (2008c) estimated that catches of Antarctic blue whales (345,775 whales) reduced the population from 239,000 (95% credibility interval 202,000-311,000) in 1904 to a low of 360 (150-840) animals in the early 1970s, which is just 0.15% (0.07-0.29%) of pre-exploitation levels. Blue whale sightings remain rare in the Antarctic (0.17-0.52 groups sighted per 1,000 km surveyed) (Branch *et al.* 2007b), although sighting rates increased over three circumpolar surveys corresponding to mid-years of 1981, 1988, and 1998 (Branch 2007). The distribution of recent sightings is narrowly concentrated along the edge of the pack ice and continental shelves, compared to the more broadly distributed historical catches (Branch *et al.* 2007b).

Currently, Antarctic blue whales are estimated to number 2,280 individuals (CV = 0.36) based on the IWC International Decade of Cetacean Research and the Southern Ocean Whale Ecosystem Research (SOWER) annual summer surveys from 1991/92 through 2003/04, which covered 99.7% of the area between the pack ice and 60° S (Branch 2007). The population is estimated to be increasing at a rate of 7.3% per year (95% credibility interval 1.4-11.6%), but remains depleted at less than 1% of pre-exploitation abundance (Branch *et al.* 2004).

G. Natural History – Pygmy-type blue whales (*B. m. brevicauda, B. m. indica,* and *B. m.* unnamed subsp.) (Northern Indian Ocean subspecies, Madagascar population, Western Australia/Indonesia population, Eastern Australia/New Zealand population, and Chilean subspecies management units)

G.1 Population Structure

The population structure of pygmy-type blue whales was reviewed at the 2016 IWC Scientific Committee meeting, in preparation for population assessments. The IWC noted certain shortcomings in the currently available genetic data. Specifically, most of the pygmy blue whale samples collected in the Southern Hemisphere are from feeding areas or along migratory pathways, many of which are also used by Antarctic blue whales. The geographic stratification of samples by area may be confounded by this mixing, such that any genetic differences found between areas may not represent different breeding populations (IWC 2016a). Therefore, the IWC recommended using “acoustic populations” to delineate pygmy blue whale populations for purposes of assessment, until additional genetic samples are obtained (IWC 2016a).

As discussed in previous sections, stereotypical call types can be an indication of population structure. After reviewing relevant scientific literature, the IWC Scientific committee identified six acoustic populations in the Southern Hemisphere and Northern Indian Ocean, including Antarctic blue whales (discussed in Section I.F), Chilean blue whales, and pygmy-type blue whales from the Northern Indian Ocean, New Zealand, the Indonesia/western Australia region, and the southwest Indian Ocean (IWC 2016a). Chilean and Northern Indian Ocean blue whales are considered separate subspecies. The three remaining non-Antarctic acoustic populations belong to *B. m. brevicauda*.

An earlier study found that Australia and New Zealand blue whales are not genetically separated (Sremba *et al.* 2015). However, more recent data analyzed from surveys, sighting records, acoustic recordings, photographs, and genetic samples indicate that the New Zealand population is likely resident and isolated from other Southern Hemisphere populations (Barlow *et al.* 2018). Based on a large genomic dataset (8294 filtered single nucleotide polymorphisms (SNPs)), the populations feeding at Bonney Upwelling and Perth Canyon off Australia were found to be genetically related (Attard *et al.* 2018). Balcazar *et al.* (2015) identified the acoustic boundary between Australian and New Zealand whales as the junction of the Indian and Pacific Oceans.

G.2 Distribution and Habitat Use

G.2.1 *B. m. brevicauda*

The subspecies *B. m. brevicauda* (known as the ‘pygmy’ blue whale) undergoes seasonal migrations to breeding and feeding locations, and are generally tied to highly productive areas with dense aggregations of krill. Pygmy blue whales mainly remain north of the Antarctic Circumpolar Current (52-56° S) (Branch *et al.* 2007a, 2009, 2018b) and are most abundant in waters off Australia, Madagascar, and New Zealand (Reilly *et al.* 2008).

Australia

Australian pygmy blue whales likely spend winter in waters off Indonesia before traveling south along western Australia to feed in summer (Gill 2002, Branch *et al.* 2007b, Rennie *et al.* 2009, McCauley & Jenner 2010, Double *et al.* 2014). Acoustic data indicate that these whales are also distributed in the sub-Antarctic waters of the southern Indian Ocean in summer and fall, including near the Crozet Islands and Amsterdam Island, likely following productive waters of the Subantarctic and Subtropical Fronts (Samaran *et al.* 2010, Samaran *et al.* 2013).

Two main feeding aggregations around Australia have been identified: Perth Canyon off Western Australia (Rennie *et al.* 2009) and between the Great Australian Bight and Bass Strait in the Bonney Upwelling off South Australia and Victoria (Gill 2002, Gill *et al.* 2011). Genetic evidence suggests that the whales comprise one mating group (Attard *et al.* 2010, 2018).

A small number of Australian pygmy blue whales, as well as hybrids between Australian pygmy and Antarctic blue whales, have been identified off Antarctica, which may indicate pygmy blue whales are moving into Antarctic waters in response to less competition with the depleted population of Antarctic blue whales for food, or may be a result of environmental conditions related to climate change (Attard *et al.* 2012).

Madagascar

Ljungblad *et al.* (1998) first described the unique call types of whales feeding in sub-Antarctic waters near the Madagascar Plateau and into subtropical areas. These whales are thought to migrate in spring and summer south from the Seychelles and Amirante Islands, through the Mozambique Channel to the Crozet Islands and Prince Edward Islands to feed before returning north in fall (Zemsky & Sazhinov 1982). In summer, pygmy blue whales have a nearly continuous distribution in sub-Antarctic waters between Africa and Australia (Branch *et al.* 2007b).

The Madagascar call type has been recorded throughout this region, including Diego Garcia in May-July (Stafford *et al.* 2011); the Mozambique Channel in November-December (Cerchio *et al.* 2016); the Madagascar Basin south of La Reunion Island from March-June, peaking in April-May (Samaran *et al.* 2013); southwest of Amsterdam Island from December-May, peaking in March (Samaran *et al.* 2013); and off Crozet Island in December-June, peaking in April (Samaran *et al.* 2010). The Madagascar call type has also been recorded at approximately 61.5° S, indicating they may, at least occasionally, travel as far south as the Antarctic continental shelf (Gedamke & Robinson 2010).

Ocean currents running into the steep bathymetric features of the Madagascar Plateau likely stimulate upwelling and zooplankton production that attract whales to the area (Branch *et al.* 2007b). The sighting rates on the Madagascar Plateau (Best *et al.* 2003) are an order of magnitude greater than Antarctic sightings (Branch *et al.* 2007b).

New Zealand

Based on surveys, sightings, strandings, and acoustic detections, pygmy-type blue whales are present in New Zealand waters year-round (McDonald *et al.* 2006b, Miller *et al.* 2014, Olson *et al.* 2015, Barlow *et al.* 2018). New Zealand blue whale calls have also been detected year round

(January-December) in the South Taranaki Bight (Barlow *et al.* 2018), in winter (June-August) in the Tasman Sea and the Lau Basin near Tonga (Balcazar *et al.* 2015), and as far south as 52° S in summer (January-March) (Miller *et al.* 2014). Whales appear to be concentrated on foraging grounds in the South Taranaki Bight (Barlow *et al.* 2018), and along the east coast of Northland (North Island), which may be a migratory corridor (Torres 2013). Feeding behavior has been observed in the South Taranaki Bight (Barlow *et al.* 2018), off the east and west coasts of the South Island and the Hauraki Gulf (Torres 2013, Olson *et al.* 2015).

G.2.2 *B. m. indica*

Blue whales are considered to be resident within the northwestern Indian Ocean, given sightings and strandings year-round (Yochem & Leatherwood 1985, Branch *et al.* 2007b, Anderson *et al.* 2012, Ilangakoon & Sathasivam 2012), as well as distributional gaps to the south and east (Branch *et al.* 2007b). However, blue whales undertake migrations within the region. Based on catch, sighting, stranding, and acoustic detection data, Anderson *et al.* (2012) proposed that blue whale distribution in the Northern Indian Ocean is driven by oceanographic changes associated with the monsoons. Specifically, most blue whales feed in productive upwelling areas off Somalia and southern Arabia during the Southwest Monsoon (approximately May-October), while some feed off the southwest coast of India and the west and south coasts of Sri Lanka. The whales then disperse during the Northeast Monsoon (approximately December-March) to areas such as the east and south coasts of Sri Lanka, west of the Maldives, the Indus Canyon, and parts of the southern Indian Ocean (Anderson *et al.* 2012, de Vos *et al.* 2014a; de Vos *et al.* 2014b).

Acoustic evidence suggests that some of these whales may travel as far south as the sub-Antarctic waters around Crozet Islands in late summer and early fall, though calling was much less frequent compared with the other blue whale populations simultaneously using the area (Samaran *et al.* 2010).

G.2.3 *B. m.* unnamed subspecies

In summer and fall, Chilean blue whales feed along the west coast of South America, particularly in the Chiloense Ecoregion including the Corcovado Gulf, Pacific and northwest coasts of Chiloe Island, and inner sea of Chiloe Island (Hucke-Gaete *et al.* 2004, Cabrera *et al.* 2005, Abramson & Gibbons 2010, Galletti Vernazzani *et al.* 2012). The whales then migrate to lower latitude areas including the Galapagos Islands and the Eastern Tropical Pacific (ETP) (Hucke-Gaete *et al.* 2004, Torres-Florez *et al.* 2015, Hucke-Gaete *et al.* 2018).

The Southeast Pacific blue whale call type has been recorded in the ETP year-round, although the occurrence is an order of magnitude lower than in the Chiloense Ecoregion (Buchan *et al.* 2015). The calls generally peak in June (Buchan *et al.* 2015), and are detected less frequently from September to March (Stafford *et al.* 1999a).

Chilean blue whales may mix with whales from the northeast Pacific in the ETP. Despite extensive surveys, there is a gap between two clusters of sightings in the ETP between 0° and 7°N (Branch *et al.* 2007b, LeDuc *et al.* 2016), which likely represents the boundary between the Chilean and NE Pacific populations. Based on genetic analysis, it appears that northeast Pacific blue whales primarily use northern ETP waters (e.g., the Costa Rica Dome off Central America) and Chilean blue whales primarily use southern ETP waters (e.g., off Peru and Ecuador), but they do not do so exclusively. There may be gene flow between hemispheres, and indeed, Chilean blue whales' genetic differentiation from northeast Pacific blue whales is less than their differentiation from Antarctic or Indian Ocean blue whales (LeDuc *et al.* 2016). LeDuc *et al.* (2016) suggested that, at least seasonally, the Chilean blue whale range should perhaps include the Costa Rica Dome and mid-latitudes of the eastern North Pacific.

There is also sympatry with Antarctic blue whales in the southern ETP breeding area, and likely on migratory pathways along the western coast of South America. Antarctic blue whale calls have been acoustically detected in the ETP in May-September, peaking in July (Stafford *et al.* 2004). However, Chilean blue whales are genetically differentiated from Antarctic blue whales (LeDuc *et al.* 2016), so they are unlikely to be interbreeding.

G.3 Feeding and Prey Selection

Similar to other blue whales, pygmy-type blue whales feed on abundant and accessible euphausiids and other crustaceous zooplankton (Yochem and Leatherwood 1985). An analysis of stomach contents revealed a range of krill and other zooplankton within the pygmy whale diet, with a large proportion of *Euphausia frigida*, *Euphausia vallentini*, and *Myctophum punctatum* (Pervushin 1968). The Australian population feeds primarily on *Euphausia recurva* and *Nyctiphanes australis* that are abundant in nearshore upwelling areas off the southern coast (Gill 2002, Rennie *et al.* 2009). In New Zealand's South Taranaki Bight, pygmy blue whales feed predominantly on *Nyctiphanes australis* (Torres *et al.* 2014). However, a recent study of Northern Indian blue whales found that this population predominantly feeds on Dendrobranchiata, specifically Sergestid shrimp, which demonstrates that blue whales can locate and feed on other types of prey when they occur (de Vos *et al.* 2018).

The Chiloense Ecoregion feeding ground is a complex system that receives inputs of both oceanic subantarctic and continental freshwater (Palma and Silva 2004) leading to an array of frontal features that influence primary production. *Euphausia vallentini* dominates the mesoplankton in this Ecoregion (Buchan and Quiñones 2016). It doubles in abundance between winter and spring (González *et al.* 2010) and likely peaks in late summer (Croll *et al.* 2005), which coincides with the seasonal peak in acoustic detections made by Buchan *et al.* (2015).

G.4 Competition

Little or nothing is known about possible competition between pygmy-type blue whales and sympatric species. The high mobility of these whales enables them to take advantage of transitory concentrations of prey over a very large area and adapt to local prey availability with variable oceanographic conditions.

G.5 Reproduction

The reproductive biology of pygmy-type blue whales is likely very similar to that of blue whales in the North Pacific and North Atlantic Oceans. In addition, considerable data on the size and age of pygmy blue whales at sexual maturity has been derived from translated and reanalyzed Japanese and Soviet whaling catch data from the Indian Ocean. Earplug layers, size descriptions, and ovarian corpora reveal that female pygmy-type blue whales in the Indian Ocean are approximately 18.4-19.9 m and 9.9 years old when sexually mature (Branch 2008a, Branch & Mikhalev 2008) Similar to other blue whales, pygmy-type blue whales are thought to give birth every 2.6 years (95% CI 2.2 – 3.0) (Branch 2008b), with an average 43% of females pregnant among the population in a given year (Mizroch *et al.* 1984, Mikhalev 2000, Branch *et al.* 2004).

G.6 Natural Mortality

Predation and other sources of natural mortality have not been documented for pygmy-type blue whales. Soviet and Japanese whaling records have been analyzed to reveal the number of pygmy blue whales in various age classes. From this information, researchers estimated that the mortality rate among this subspecies is approximately 0.06 (95% CI 0.05 – 0.07) (Branch 2008b). Calf mortality rates have not been calculated for blue whales, but it is likely higher than adult mortality, as it is in other baleen whales (Branch *et al.* 2004).

In the Northern Indian Ocean, shark bite scars were observed less frequently in blue whales caught by Soviet whaling fleets in the Arabian Sea compared with pygmy blue whales in the southern Indian Ocean (Mikhalev 2000).

G.7 Abundance and Trends

G.7.1 *B. m. brevicauda*

The status and abundance of pygmy blue whales is less well known compared to the Antarctic subspecies due to their large range and uncertain population structure. Similar to the Antarctic subspecies, pygmy blue whale populations were exploited throughout the 20th century, though they likely had a lower pre-exploitation abundance (Branch *et al.* 2008, Reilly *et al.* 2008, Stafford *et al.* 2011). Some abundance estimates exist, although little work has been done to determine overall pygmy blue whale abundance. Best *et al.* (2003) suggest a minimum abundance of 424 (CV = 0.42) pygmy blue whales on the Madagascar Plateau, or 472 (CV = 0.48) when an unidentified "like blue" whale sighting was included in the analysis. Kato *et al.* (2007) estimated 671 (279–1613) pygmy blue whales from a line-transect survey of a small area off the southern coast of Australia. Acoustic monitoring of Australian pygmy whales during feeding migrations in the southeastern Indian Ocean has yielded an estimate that this population likely ranges between 660-1,750 whales (Jenner *et al.* 2008, McCauley and Jenner 2010, Gill *et al.* 2011). A conservative abundance estimate for pygmy blue whales in New Zealand based on photo-identification mark-recapture is 718 (95% CI 279-1926) (Barlow *et al.* 2018). Combining the Australian, Madagascar, and New Zealand populations would yield a minimum of about 2,500 pygmy blue whales in the southern Indian Ocean.

While little population trend information is available for pygmy blue whales, researchers have estimated pre-exploitation abundance for some of the feeding populations. Zemsky and Sazhinov (1982) estimate a pre-exploitation (1959/1960) abundance of 7,598 pygmy blue whales in the sub-Antarctic region north of 54° S between 0° and 80° E, corresponding with the Madagascar population, and 2,900 pygmy blue whales in the Australian region. Catch records from the northern and southern Indian Ocean through to New Zealand, 97% coming from Japanese and illegal Soviet whaling in the 1960s and early 1970s, indicate that 12,184 (Branch *et al.* 2018) or 13,022 (Branch *et al.* 2008) pygmy-type blue whales were caught in this region. There is some uncertainty in assigning these catches to individual populations, but preliminary estimates suggest that median catches of 1,228 came from the northern Indian Ocean, plus pygmy-type catches of 6,889 from the south-west Indian Ocean (Madagascar), 3,646 from the south-east Indian Ocean (Australia/Indonesia), and 421 from the south-west Pacific Ocean (New Zealand) (Branch *et al.* 2018). It is possible that the combined current estimate of nearly 2,500 whales represents less than 23% of the historical pre-exploitation population size (10,498 see above) or 19-20% of the combined catch total (13,022 Branch *et al.* 2008;12,184 Branch *et al.* 2018). The New Zealand population is likely to be the least depleted of these three populations.

These figures indicate that pygmy blue whales remain depleted throughout their range, though perhaps to a lesser extent than Antarctic blue whales (Branch *et al.* 2007b, Branch *et al.* 2008).

G.7.2 *B. m. indica*

Nearly 1,300 blue whales were caught illegally in the Arabian Sea by Soviet whalers from 1963-1966 (Mikhalev 2000). The only abundance estimate for northern Indian Ocean blue whales comes from repeated surveys in a 7500 km^2 area south of Sri Lanka in 2014 and 2015, which estimated there to be 270 individuals (CV=0.09, 95% CI 226-322) (Priyadarshana *et al.* 2016).

G.7.3 *B. m.* unnamed subspecies

From 1908-1971, an estimated 5,782 blue whales were caught by whalers in the Southeast Pacific, including waters offshore of Chile, Peru, and Ecuador, with an estimated 4,288 from Chile alone (Williams *et al.* 2011a). Jackson (2016) estimated the median pre-exploitation abundance to be 2,100-3,600 blue whales, while Williams *et al.* (2011a, erratum 2017) estimate approximately 1,500-5,000. An abundance estimate for the Chiloé Island feeding ground in southern Chile in 2012 is 762 animals (95% CI 638-933) based on left side pictures and 570 (95% CI 475-705) animals based on right side pictures, allowing for a mixture of resident and transient whales (Galletti Vernazzani *et al.* 2017). Since this represents only a portion of the population's feeding range, this is considered a minimum abundance for Chilean blue whales.

H. Potential Threats and Other Stressors

In this Revised Recovery Plan, we considered eleven natural and human-related stressors to determine whether they might present a threat to blue whale recovery. As used in this plan, a threat is any factor, natural or human-related, that impedes recovery or contributes to blue whale extinction risk. Our assessment of these stressors is summarized in Table 1, including the relevant ESA listing factor(s)[3], potential effect pathways for the stressor to act on individual animals, the subspecies and/or populations known to be affected (or if unknown, whether one or

[3] Section 4(a)(1) of the ESA and the listing regulations (50 CFR part 424) set forth considerations for listing species. We list a species if it is endangered or threatened because of any one or a combination of the following: (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) inadequacy of existing regulatory mechanisms; or (E) other natural or human-made factors affecting its continued existence.

more is particularly vulnerable), and the severity of the effects. More specific information is discussed in each subsection.

Although the species is listed as endangered, it is not known whether and to what extent current threats are putting the globally listed species at risk of extinction. We have, however, identified numerous *potential* threats. We use the term potential threat to mean a stressor that a) contributed to the species' extinction risk, such as commercial whaling, and has the potential to do so again unless certain measures are taken or remain in place; or b) is known to be affecting one or more subspecies or populations, but more research is needed to understand the extent to which the stressor occurs or affects the globally listed entity. We also describe other stressors for which there is sufficient information to indicate that they do not currently pose a threat to the listed global species. For these stressors, there is currently no evidence that the effects (which may even include the loss of individual blue whales) have population-level consequences or are significant enough to contribute to the species' extinction risk.

Table 1. Stressors that may be affecting blue whale recovery.

Stressor	ESA Listing Factors	Potential Effect Pathways	Subspecies/Populations Affected	Severity of Impact
Directed Hunting	• Overutilization	• Injury and/or mortality	• All	Historically severe but presently controlled. Requires continued action to ensure it does not return as an operative threat.
Ship Strikes	• Other natural or manmade factors	• Injury and/or mortality	• Northern Indian Ocean • Eastern North Pacific • Chilean • Unknown whether or to what extent other populations are affected, but those with ranges overlapping areas of high shipping traffic are vulnerable.	Unknown; likely varies by population
Marine Debris and Fishing Gear Ingestion and/or Entanglement	• Habitat • Other natural or manmade factors	• Injury and/or mortality • Impairment of swimming, feeding, breeding • Physiological response and negative health effects of long-term entanglement	• Northern Indian Ocean • Eastern North Pacific • Unknown but potentially all, particularly those with ranges that include areas of high fishing effort	Unknown but potentially low; likely varies by population. Very few entanglements have been reported but others likely go unreported or undetected.
Anthropogenic Noise	• Habitat	• Behavioral response • Physiological response • Injury (hearing damage or impairment)	• Unknown but potentially all, particularly those with ranges that include areas of high shipping traffic, oil and gas exploration and development, and military activity	May range from no effect to potentially significant effects on whales' fitness and their habitat; likely varies by population. Research needed to determine degree of impact.

Stressor	ESA Listing Factors	Potential Effect Pathways	Subspecies/Populations Affected	Severity of Impact
Loss of Prey Base Due to Climate and Ecosystem Change	• Habitat • Other natural or manmade factors • Inadequacy of existing requlatory mechanisms	• Changes in prey abundance and/or distribution	• Unknown but potentially all, particularly those that feed at high latitudes or are geographically restricted (*e.g.*, Northern Indian Ocean population)	Unknown, but impacts to krill under certain future climate scenarios may be severe. Likely varies by population.
Environmental Debris, Contaminants, and Pollutants	• Habitat	• Sublethal health effects • Mortality	• Unknown but potentially all	Low; no evidence of population- or species-level effects; broad distribution and wide-ranging movements expected to lessen impact of localized events (e.g., oil spills).
Disease	• Disease or predation	• Sublethal health effects • Mortality	• Chilean • Unknown but potentially all	Low; no evidence linking toxins or disease to chronic health problems or deaths of blue whales.
Behavioral Disturbance from Vessel and UAS Interactions	• Habitat • Overutilization • Inadequacy of existing regulations	• Behavioral response • Physiological response	• Unknown but potentially all, particularly those with ranges that include nearshore areas accessible to whale watching activities	Low; no evidence linking short-term effects of disturbance to population- or species level impacts.
Research	• Other natural or manmade factors	• Behavioral response • Physiological response	• All	Low; no evidence linking short-term effects of disturbance to population- or species level impacts.
Predation and Natural Mortality	• Disease or predation	• Injury and/or mortality	• All	Low; no evidence this is a threat to recovery of any population or the species.
Competition for Resources	• Habitat • Other natural or manmade factors	• Changes in prey abundance and/or distribution	• All	Low; no evidence that competition with sympatric species is a threat; management limits impacts of krill fisheries on the whales' prey resource.

H.1 Potential Threats

H.1.1 Directed Hunting

Direct hunts were the main cause of depletion of blue whales and other large whales. Because of their size and speed, blue whales were safe from early whalers, who could not pursue them in open boats with hand harpoons. However, a Norwegian, Sven Foyn, revolutionized the whaling industry with the invention of the exploding harpoon gun and by using steam and diesel powered factory ships and catcher boats (Schmitt *et al.* 1980, Reeves & Barto 1985). Foyn also perfected the technique of inflating dead whales with air so they would not sink after being harpooned. The eventual introduction of deck-mounted harpoon cannons made it possible to kill and secure blue, fin, and sei whales on an industrial scale (Tønnessen & Johnsen 1982). (Tønnessen & Johnsen 1982). Over 380,000 blue whales were taken from 1868-1978, mostly from Antarctic waters (Branch *et al.* 2008). The directed hunt peaked in 1931 when over 29,000 blue whales were killed in one season. After that, blue whales became so scarce that the whalers turned to other species. The IWC banned all hunting of blue whales in 1966 and gave them worldwide protection, although illegal Soviet whaling continued through to 1973 (Yablokov 1994, Mikhalev 2000) and Spanish whalers caught 11 blue whales after the moratorium, the last in 1978, before becoming IWC members (Aguilar and Sanpera 1982). The IWC's moratorium on the commercial hunting of all whale species has been in effect since 1986, and it has almost certainly had a positive effect on the species' recovery, although the slow rate of recovery of some populations is likely a direct result of the extent of past hunting. There is currently no commercial, aboriginal subsistence, or scientific whaling for blue whales by IWC member nations party to the moratorium. While Iceland and Norway do not adhere to the moratorium since both countries filed objections or reservations to it,[4] there is no evidence of whaling of blue whales in recent years; although a number of blue-fin hybrids have been caught by whalers (e.g., Bérubé and Aguilar 1998), most recently in Iceland in 2018. Additionally, while Japan withdrew from the ICRW effective June 30, 2019, it is only harvesting whales within its exclusive economic zone at levels considered sustainable by the IWC Scientific Committee, and there is no evidence that Japan is targeting or taking blue whales. While directed hunting is presently controlled, it requires continued U.S. involvement and collaboration through the IWC to ensure it does not return as an operative threat.

H.1.2 Ship Strikes

Blue whales are vulnerable to ship strikes, due at least in part to the seasonally coastal distribution of some populations and the overlap with shipping routes. The IWC noted that human-induced mortality caused by vessel strikes can be an impediment to cetacean population growth (IWC 2017). Some blue whale populations are likely more vulnerable than others, based on differences in distribution relative to shipping traffic. Collisions with blue whales appear to be

[4] In 1982, the IWC adopted a moratorium on the commercial whaling of all whale species, effective from 1986. Norway objected to the moratorium, but nevertheless introduced a temporary ban on minke whaling pending more reliable information on the state of the stocks. The Norwegian government unilaterally decided to resume whaling in 1993. Norway's legal right to hunt minke whales is not disputed, as Norway objected to the moratorium when it was adopted by the IWC. Iceland conducts commercial whaling under a reservation to the moratorium (NMFS 2011).

less common than for other large whale species (Laist *et al.* 2001, Jensen & Silber 2004), but many ship strikes go unreported or undetected, and estimates of mortality and serious injury should be considered minimums. For example, carcass detection and recovery was estimated to be <= 17% for blue whales off Southern California (Redfern *et al.* 2013) and only 2% (range: 0–6.2%) of cetacean (including sperm whales and smaller cetaceans) deaths in the northern Gulf of Mexico (Williams *et al.* 2011b). Redfern *et al.* (2013) also estimated 10.6 blue whales were struck by ships each year off the Southern California coast. Ship strikes of blue whales have been documented for almost two decades along the California coast, but this issue drew particular attention when NOAA received reports in September 2007 of five blue whales killed by ship strikes between Santa Cruz Island and San Diego; NMFS designated these mortalities as an "Unusual Mortality Event" (UME) (Berman-Kowalewski *et al.* 2010; Abramson *et al.* 2011).). The magnitude of this potential threat for blue whales along the U.S. West Coast could be considerably larger than indicated based on reported incidents due to the unknown number of vessel strikes that go undocumented (NMFS 2011). From 1998-2019 the total estimated number of observed or assumed mortality and serious injury attributed to vessel strikes off the U.S. west coast is approximately 17 blue whales (WCR stranding database).

The size of a ship and its speed affect the likelihood and severity of the collision. Reviews of stranding and collision records indicate that larger ships (262.5 ft [80 m] or larger) and ships traveling at or above 14 knots (26 km/hour) have a much higher instance of fatal collisions with whales (Laist *et al.* 2001). Vanderlaan and Taggart (2007) demonstrated the relationship between ship speed and likelihood of fatal strikes; and Conn and Silber (2013) found that vessel speed restrictions diminished the risk of a fatal strike by 80-90%. Vessel speed restrictions have proved successful in reducing fatal whale strikes in some locations (Laist *et al.* 2014; Freedman *et al.* 2017); however, reducing the co-occurrence of whales and vessels is likely the only sure means of reducing ship strikes, but it is not possible in many locations. Maritime industries, resource managers, and government agencies have proposed seeking ways to reduce the magnitude of the threat through technological solutions. However, there are no easy technological "fixes" and no technology exists, or is expected to be developed in the near future, that will completely ameliorate, or reduce to zero the chances of, ship strikes of large whales; and no single technology will fit all situations (Silber *et al.* 2009).

Increased ship traffic may increase the risk of blue whale ship strikes. The number of trips taken by ships globally has steadily increased in recent decades. Further, changes in the extent of polar sea ice could influence the number of vessels transiting blue whale habitat. For example, the opening of the Northwest Passage and Northern Sea Route may bring an increase in the volume of vessel traffic through polar waters and corresponding lower latitude waters including the North Pacific, and North Atlantic Ocean blue whale habitat. If this occurs, the potential for negative impacts on blue whales and other cetaceans will increase. Alternately, the threat could decrease if shipping traffic only moves northward and out of areas with higher densities of blue whales.

Ship Strikes off the Sri Lankan Coast: Sri Lankan Population

Blue whales are found year-round off the coast of southern Sri Lanka, an area of very high shipping traffic (Randage *et al.* 2014). Three blue whales were confirmed killed via ship strike between 2012 and 2014 around Sri Lanka (Randage *et al.* 2014, Brownell Jr. *et al.* 2017). A risk assessment found that a 15 nautical mile shift in shipping lanes associated with the Dondra Head traffic separation scheme (TSS) off the southern coast of Sri Lanka could reduce the risk of ship collisions with blue whales by approximately 95% (Priyadarshana *et al.* 2016). To date, Sri Lanka has not brought forward a proposal to the International Maritime Organization to modify the TSS.

Ship Strikes off the Chilean Coast: Chilean Population

Chilean blue whales are also known to be affected by ship strikes. Two blue whales were killed by ship strikes in recent years off southern Chile, an important feeding area for this population (Brownell *et al.* 2014, IWC 2017). In addition to co-occurrence between ships and whales, the whales' behavior may also contribute to their vulnerability to ship strikes. Some whales may be unaware of approaching vessels or may be involved in a vital activity (*i.e.*, mating or feeding) which may reduce the likelihood of an avoidance response (Nowacek *et al.* 2004, Silber *et al.* 2010). In one study, blue whales demonstrated little to no lateral movement in response to close approaches by large commercial ships; they sometimes undertook shallow "response dives," mainly when they were already at the surface, but these were considered likely to be ineffective for avoiding collisions (McKenna *et al.* 2015).

Ship Strikes off the U.S. West Coast: Eastern North Pacific Population

The west coast of the United States has some of the heaviest ship traffic associated with some of the largest ports in the country, including Los Angeles/Long Beach, San Francisco, Seattle, and the Columbia River. Shipping lanes off San Francisco Bay, the Santa Barbara Channel, and Los Angeles/Long Beach in California overlap with important blue whale feeding areas, including identified biologically important areas (Redfern *et al.* 2013, Irvine *et al.* 2014, Calambokidis *et al.* 2015). Nine blue whales were known to be killed and one seriously injured by ship strikes between 2007 and 2010 in California waters (Carretta *et al.* 2013). Additionally, two blue whale ship strike deaths were observed during the 5-year period of 2013-2017 (NMFS 2019). Model estimates of blue whale ship strike mortality off the U.S. West Coast range from 18 to 40 in a single year, significantly exceeding the Eastern North Pacific stock's (Rockwood *et al.* 2017) Potential Biological Removal (PBR) level (Rockwood *et al.* 2017), which is the number of individuals that could be taken as a result of human activities while still allowing a stock to recover to or remain within its optimum sustainable population range. In addition, using estimates from Rockwood *et al.* (2017), Carretta *et al.* (2018) estimated that the vessel strike detection rate of blue whales is approximately one percent. In 2013, IMO-approved changes to the shipping lanes off California became effective (although they have yet to be codified in U.S. Coast Guard (USCG) regulations). The modifications to the TSSs were devised in collaboration between the USCG and National Oceanic and Atmospheric Administration (NOAA) staff at the Cordell Bank, Gulf of the Farallones, Monterey Bay, and Channel Islands National Marine Sanctuaries, and NMFS, and were designed, in part, to reduce the co-occurrence of whales and ships in the area of the TSS (USCG 2011). McKenna *et al.* (2012) found that ship speeds were not affected by a voluntary speed reduction speed in the Santa Barbara Channel (SBC). However, recent efforts in the SBC that offer incentives to ships to reduce speed have been broadly effective, but only reach a small percentage of ships travelling in this region (Freedman *et al.* 2017).

Monnahan *et al.* (2015) evaluated the effects of ship strikes on Eastern North Pacific blue whales and found that they are not threatening the status of the population, although the authors suggest continued monitoring because the levels exceed the stock's PBR. Further, a sensitivity analysis of higher levels of ship strikes, among other factors, found that the Eastern North Pacific population was nearing carrying capacity, which has slowed its growth rate, rather than an impact of ship strikes (Monnahan and Branch 2015). However, Rockwood *et al.* (2017) suggest caution in interpreting the results of Monnahan *et al.* (2015), since the conclusions are based on lower numbers of annual ship strikes than were estimated by Rockwood *et al.* (2017), as well as other assumptions regarding environmental conditions and threats that may not be accurate. The impact to other populations is largely unknown.

Santa Barbara Channel Traffic Separation Scheme Amendment

The IMO amendment to the Santa Barbara Channel TSS (effective June 1, 2013), reduced the width of the separation zone from 2 nautical miles (nm) to 1 nm by shifting the inbound lane shoreward and away from known whale concentrations. The outbound lane remains unchanged (Figure 2). Narrowing the separation zone is aimed to reduce co-occurrence of ships and whales while maintaining navigational safety (Figure 2).

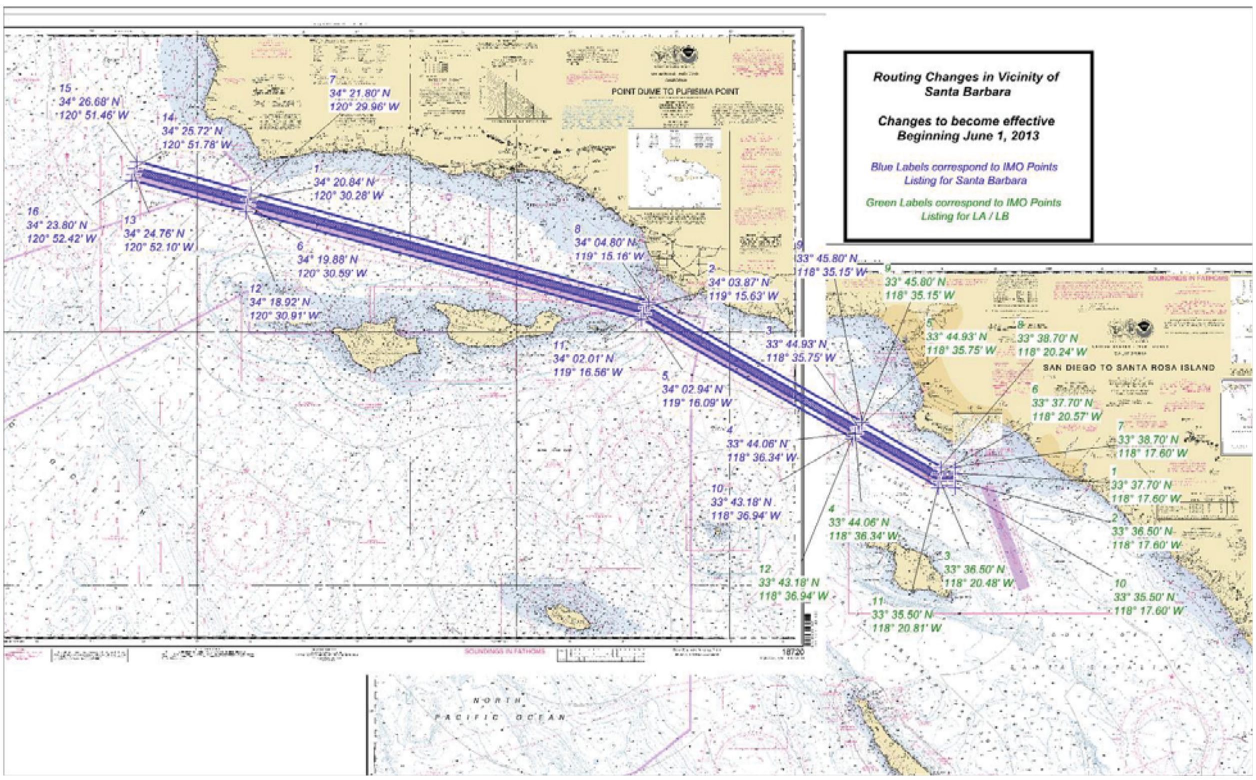

Figure 2. NOAA chart showing the Santa Barbara Channel Traffic Separation Scheme adjustments.

San Francisco Traffic Separation Scheme Amendment

The IMO amendment to the San Francisco TSS (effective June 1, 2013) is located within the Cordell Bank (CBNMS), Greater Farallones (GFNMS), and Monterey Bay (MBNMS) National

Marine Sanctuaries as well as numerous commercial fishing grounds. The USCG maintains a Vessel Traffic Service (VTS) in the port of San Francisco, and the TSS is located entirely within the VTS coverage area (Figure 3). The TSS adjustments (see Figure 3) are aimed to enhance navigational safety and reduce the co-occurrence of whales with commercial vessel traffic.

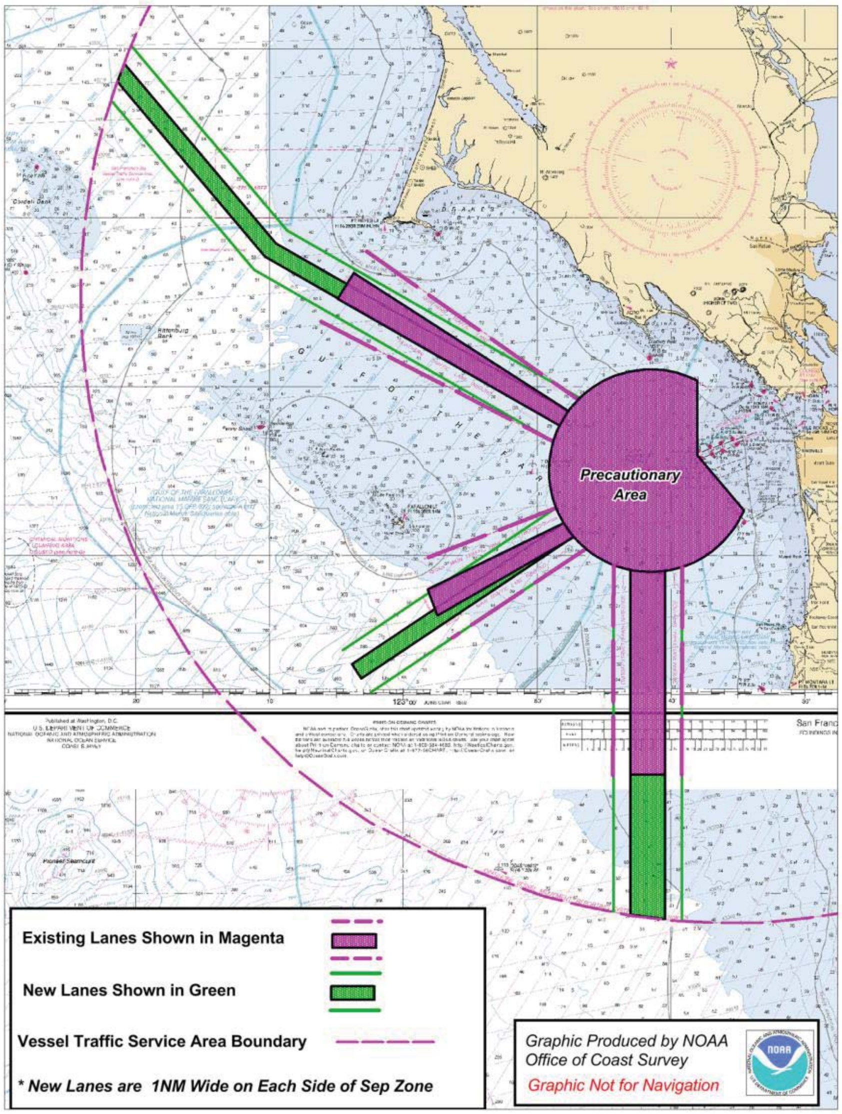

Figure 3. NOAA chart showing the San Francisco Channel Traffic Separation Scheme adjustments. Please note that the term "existing lanes" in this figure refers to the time when this map was published in 2013. Present day "existing lanes" are shown in green.

United States West Coast Region: Measures to Address Ship Strikes

There are a number of conservation actions and research programs being conducted by NOAA's Office of National Marine Sanctuaries West Coast Region (ONMS-WCR) to help mitigate ship strikes. For example, ONMS-WCR and other parts of NMFS (including the NMFS Regional Offices and Science Centers) are currently conducting at-sea surveys, passive acoustic monitoring, and assessments of high-risk ship strike areas. For example, the GFNMS and CBNMS sanctuary staff have partnered with Point Blue Conservation Science to conduct the

Applied California Current Ecosystem Studies (ACCESS) project. This project has monitored seabird and marine mammal distribution and abundance, availability of zooplankton prey, and oceanographic conditions since 2004 (Elliott and Jahncke 2018). ACCESS is able to identify patterns, trends, and anomalies as well as abundance and distribution modeling of blue whale foraging areas within GFNMS, CBNMS, and MBNMS. These models are used to identify areas of highest risk of ship strikes on whales within the sanctuary (Elliott and Jahncke 2018).

United States North Atlantic Region: Measures to Address Ship Strikes

Within other areas of U.S. waters, NMFS (which includes Regional Offices and Science Centers) has established ship speed restrictions, mandatory ship reporting systems, recommended routes, and an extensive sighting advisory system to protect North Atlantic right whales (NMFS 2019). In 2008, NMFS implemented a five-year regulation that required large ships to restrict their speed to 10 knots in North Atlantic right whale seasonal management areas. Reducing vessel speeds was found to reduce the mortality risk for North Atlantic right whales by 80-90% (Conn and Silber 2013). The rule was extended indefinitely in 2013. While these measures were designed to protect right whales specifically, they also are expected to reduce the risk of ship strikes to other marine mammals, including blue whales (NMFS 2008).

Summary

As noted above, ship strikes are a known issue and represent a threat to the Eastern North Pacific population of blue whales off the U.S. West Coast. This blue whale population is vulnerable to ship strikes due in large part to this population seasonally residing in feeding grounds that overlap with shipping routes off southern California. Thousands of large commercial vessels travel in and out of the ports of Los Angeles, Long Beach, Hueneme, and Oakland each year (Redfern *et al.* 2013). Recently, ship strike mortality was estimated for blue whales in the U.S. West Coast EEZ (Rockwood *et al.* 2017) using an encounter theory model (Martin *et al.* 2016) that combined species distribution models of whale density (Becker *et al.* 2016) and vessel traffic characteristics, along with whale movement patterns obtained from satellite-tagged whales in the region to estimate encounters that would result in mortality. The estimated number of annual ship strike deaths was 18 blue whales, which includes only the seasonal period of July-November when blue whales are most likely to be present in the U.S. West Coast EEZ (NMFS 2019). Most observed blue whale ship strikes have been in southern California or off San Francisco, California, where the seasonal distribution of blue whales is in close proximity to shipping ports (Berman-Kowalewski *et al.* 2010).

While there is some information on ship strikes for other blue whale populations (i.e. the Sri Lankan and Chilean population), data is insufficient to determine how these known ship strikes are affecting these populations.

Overall, while we conclude that ship strike is a threat to one population of one subspecies of blue whales, blue whales are listed at the species level and additional information is needed to determine whether and to what extent ship strikes may be impeding recovery of blue whales on a global scale. Therefore, we consider ship strikes to be a potential threat to the globally listed entity. Additional information on how ship strikes are affecting blue whales can be found in the 2020 blue whale 5-year review (NMFS 2020).

H.1.3 Marine Debris and Fishing Gear Ingestion and/or Entanglement

Harmful marine debris consists of plastic garbage and other materials washed or blown from land into the sea, derelict fishing gear lost or abandoned by recreational and commercial fishers, and solid non-biodegradable floating materials (such as plastics) disposed of by ships at sea and from other sources. Whales may become entangled in debris or may ingest it. Plastics and other debris may be consumed incidental to normal feeding, and some marine species may actually confuse plastic bags, rubber, or balloons with prey and ingest them. The debris may cause a physical blockage in the digestive system, leading to internal injuries or other types of significant complications. Stomach obstruction caused by marine debris has not been documented in blue whales, but there are documented cases of ingestion of marine debris in both odontocete and mysticete species including, but not limited to, sperm, pygmy sperm (*Kogia breviceps*), and minke whales (*B. acutorostrata*) (Viale *et al.* 1991, Tarpley & Marwitz 1993).

Very few confirmed cases of blue whale entanglements in fishing gear (derelict or actively fished) have been documented. The first documented blue whale entanglement off the U.S. West Coast occurred off southern California in 2015. Although it was not possible to confirm the entangling gear to a specific fishery, based on the characteristics of the gear, it was considered to be from some type of deep-water trap/pot fishery (Carretta *et al.* 2017b). In 2016, four blue whales were reported entangled in fishing gear, two of which were confirmed to be entangled with Dungeness crab commercial trap fishing gear (NMFS 2017). Scarring has been observed on some blue whales, indicating past interactions with entangling gear (J. Calambokidis, pers. comm.), but no other information on these interactions is available. There have been no observed entanglements of blue whales in the California swordfish drift gillnet fishery in 26 years of observing the fishery (1990-2015) (Carretta *et al.* 2017a). There have been no observed hookings or entanglements of blue whales in the Hawaii-based deep-set or shallow-set longline fisheries since observer coverage began in 1994 (NMFS 2012, NMFS 2014). There have been no observed fishery mortalities or serious injuries of Western North Atlantic blue whales in U.S. fisheries (Waring *et al.* 2010).

In January 2013, an underwater photographer in Sri Lanka documented a whale with a net wrapped through its mouth, along the sides of its body, and wound around its tail (de Vos 2015). This individual was noticeably thin, and unable to dive. Scarring patterns around its caudal peduncle indicated it had been entangled in this gear for an extended period. While attempts to approach the animal for rescue were futile (and dangerous for untrained personnel), the fate of this animal remains unknown, but given the extent of the entanglement, it is likely that this resulted in the death of the whale (de Vos 2015). While not quantified, a proportion of Sri Lankan blue whales do have entanglement scars or trail some evidence of a net on them. However, not all cases appear to be fatal which could be the result of their large size (A. de Vos, pers. comm.).

The small number of documented interactions likely represents only a fraction of interactions with fishing gear and more information is needed to determine if this is a significant cause of mortality. Data on entanglement and entrapment can be largely anecdotal and may not be reported systematically because many fisheries have low or no observer coverage. Like other large whale species, blue whales may break through or carry away fishing gear. Whales carrying gear may die later, become debilitated or seriously injured, or have normal functions impaired, but with no evidence of the incident recorded. Most whales killed by offshore fishing gear likely do not drift far enough to strand on beaches or to be detected floating in the nearshore corridor where most whale watching and other types of boat traffic occur (Heyning & Lewis 1990).

There are also non-lethal effects from entanglements that could affect recovery. Entanglement-related stress may decrease an individual's reproductive success or reduce its life span, which may in turn depress population growth. Additionally, injuries and entanglements that are not initially lethal may result in a gradual weakening of entangled individuals, making them more vulnerable to other causes of mortality (Kenney & Kraus 1993, Moore & Van Der Hoop 2012).

While the number of observed and reported entanglements is currently low, additional information is needed to determine whether entanglement in marine debris and fishing gear is impeding recovery of blue whales, given the uncertainty in the rate/frequency of entanglements and how this may vary across populations. Therefore, we consider this to be a potential threat to the species.

H.1.4 Anthropogenic Noise

Increasing human activity is leading to rising levels of anthropogenic underwater noise, which is changing the acoustic environment and impacting marine species and their habitat through acute, chronic, and cumulative effects (Radford *et al.* 2014). Potential impacts include altering important behavioral patterns, physiological effects such as hearing impairment or stress, and masking critical acoustic cues, and the results of these range from no effect to potentially significant effects on the fitness of marine mammals and their habitat, depending on the context and scale of the noise exposures (Southall *et al.* 2007, NOAA 2016). Below we briefly describe these types of effects, and then discuss several sources of anthropogenic noise: commercial vessels, oil and gas exploration and development, and military sonar and explosives.

Behavioral Response

Exposure to anthropogenic sound can result in a multitude of behavioral effects, ranging from no or minor effects (such as minor or brief avoidance or changes in vocalizations), to those being more potentially severe or sustained (*e.g.*, abandonment of higher quality habitat), and even, in certain circumstances, those that can combine with physiological effects or result in secondary responses that lead to stranding and death. Behavioral reactions to noise can vary not only across species and individuals but also for a given individual, depending on previous experience with a sound source, hearing sensitivity, sex, age, reproductive status, geographic location, season, health, or its current activities or reproductive status (Richardson *et al.* 1995, Ellison *et al.* 2012, Costa *et al.* 2016). Responses might also vary depending on the sound source itself (*e.g.*, its frequency, whether it is moving or stationary), its proximity to the individual, exposure levels, propagation patterns in a particular area, or other factors (Richardson *et al.* 1995). Exposure to noise might disrupt communication, navigation, foraging, and social behavior, and animals may be displaced from habitat for short or long periods. Sensitization (increased behavioral or physiological responsiveness over time) to noise could also exacerbate other effects, while conversely habituation (decreased behavioral responsiveness over time) to chronic noise could result in animals remaining close to noise sources which could result in an increase in physical injuries or other effects (Richardson *et al.* 1995).

Most observations of marine mammal responses to anthropogenic sounds have been limited to short periods, and included the cessation of feeding, resting, or social interactions. Given the many variables involved and complex interaction with sources and animals (*i.e.*, overlap that varies over time, space, and frequency), it has been difficult to link specific behavioral responses to specific sound sources (Southall *et al.* 2007), although more recent controlled exposure studies have illustrated these connections and discerned the importance of more nuanced contextual factors such as the distance of the sound source or the behavioral state of the animal (Southall *et al.* 2016, Dunlop *et al.* 2017). In addition, it is difficult to quantify disturbance or overall, long-term impacts of exposure to noise (National Research Council 2005). National Research Council (2003), National Research Council (2005), and Lusseau and Bejder (2007) present data from three long-term studies illustrating the connections between disturbance from whale-watching boats and population-level effects in cetaceans, ranging from a 15% decrease in abundance (Bejder *et al.* 2006), to reduced reproductive success and increased stillbirths (Lusseau 2004), to bioenergetically modeled decreased energy intake and increased energy output (Williams *et al.* 2006). Following on the 2005 recommendations of the National Research Council, New (2014) outline a conceptual model of the relationships linking disturbance to changes in behavior and physiology, health, vital rates, and population dynamics. Further, scientists have developed state-space energetic models for several species (southern elephant seal, North Atlantic right whale, beaked whale, and bottlenose dolphin), that illustrate how specific information about anticipated behavioral changes or reduced resource availability can potentially be used to effectively forecast longer-term, population-level impacts (New *et al.* 2013a, New *et al.* 2013b, Schick *et al.* 2013, New 2014) when enough data are available. However, more work and data are needed before these sorts of models can be broadly applied for management use.

Masking

Masking, or “auditory interference,” occurs when sounds interfere with an animal’s ability to detect, recognize, or discriminate between acoustic signals of interest. Marine mammals use acoustic signals for a variety of purposes, which differ among species, but include intraspecific communications, navigation, prey detection, predator detection, social interactions, and acquisition of information about their environment (Aroyan *et al.* 2000, Erbe & Farmer 2000). Masking generally occurs when the interfering noise is louder than or comparable to, and of a similar frequency to, the sound that is being detected. Masking of important acoustic cues may affect social signaling and other sound-mediated functions (Erbe & Farmer 2000, Southall *et al.* 2007, McWilliams & Hawkins 2013).

The size of the “zone of masking” for a marine mammal is highly variable and depends on many factors that affect the received levels of the background noise and the sound signal (Richardson *et al.* 1995, Foote *et al.* 2004). Masking is influenced by the amount of time that the noise is present, as well as the spectral characteristics of the noise source. There are still many uncertainties regarding how masking affects marine mammals. For example, it is not known how loud acoustic signals must be for animals to recognize or respond to another animal’s vocalizations (National Research Council 2003). Richardson *et al.* (1995) argued that the maximum radius of influence of an industrial noise (including broadband low frequency sound transmission) on a marine mammal is the distance from the source to the point at which the noise can barely be heard. This range is determined by the hearing sensitivity of the animal and/or the background noise level present.

Animals may alter their behavior in response to masking. These behavior changes may include producing more calls, longer calls, or shifting the frequency of the calls. For example, studies indicate that North Atlantic right whales (Parks *et al.* 2009), blue whales (Di Iorio & Clark 2009), and killer whales (Holt *et al.* 2009) alter their vocalizations (call parameters or timing of calls) in response to background noise levels. Clark *et al.* (2009) developed a model to quantify changes in an animal's acoustic communication space that result from changes in the characteristics of background noise. More recently, Redfern *et al.* (2017) assessed the impacts of chronic noise from commercial shipping in southern California on blue, fin, and humpback whales. However, the potential effects that masking may have on energetic costs or behavior are difficult to quantify and remain poorly understood.

Hearing Damage or Impairment

Exposure to anthropogenic noise, in some cases, may impact whales by damaging body tissue or the inner ear and hearing. Noise-induced threshold shifts are defined as increases in the threshold of audibility (*i.e.*, the sound has to be louder to be detected) of the ear at a certain frequency or range of frequencies (ANSI (American National Standards Institute) 1995, Yost 2000), *i.e.*, a loss in hearing sensitivity, and can be temporary or permanent. As mentioned previously, there are no direct measurements of the hearing abilities of baleen whales, but baleen whales' sensitivity to low-frequency sound has been inferred using a variety of methods, including observed vocalization frequencies, observed reactions to playback of sounds, and anatomical analyses of the auditory system (NOAA 2016). Direct changes in hearing from noise exposure have only been measured in a laboratory on a limited number of species (odontocete and pinniped species only) and for only a handful of individuals within those species (Southall *et al.* 2007, Finneran 2015).

H.1.4.1 Commercial Vessel Noise

Commercial shipping is identified as a major source of of chronic anthropogenic noise in the ocean today (Andrew *et al.* 2002, McKenna *et al.* 2012, and Chion *et al.* 2019). Ship propulsion systems, generators, engine gearing, compressors, bilge and ballast pumps, as well as hydrodynamic flow surrounding a ship's hull contribute to the introduction of noise into the water column by a large vessel. Propeller-driven vessels also generate noise through cavitation, which accounts for approximately 85% or more of the noise emitted by a large vessel (Richardson *et al.* 1995). Ship traffic from tourism, fisheries, and research also contribute to noise in the ocean (Erbe *et al.* 2019). Large vessels tend to generate sounds that are louder and at lower frequencies than small vessels (Polefka 2004).

Surface shipping is the most widespread source of anthropogenic, low frequency (0 to 1,000 Hz) noise in the oceans (Simmonds & Hutchinson 1996, and Southall *et al.* 2017). Ross (1976) estimated that between 1950 and 1975, shipping caused a rise in ambient noise levels of 10 decibels (dB) in the areas where shipping dominates, based on information about the total number of ships at sea, increases in average ship speed, propulsion power, and propeller tip speed. He predicted that this would increase by another 5 dB by the beginning of the 21st century. The National Research Council (2003) estimated that the background ocean noise level at 100 Hz has been increasing by about 1.5 dB per decade since the advent of propeller-driven ships, while others have estimated that the increase in background ocean noise is as much as 3 dB per decade in the Pacific Ocean (McDonald *et al.* 2006a). This rate may have slowed in certain periods in the last decade as patterns in global shipping have changed (Silber *et al.* 2015). Tyack (2008) noted that the increase in ambient noise from shipping likely reduced the detectable range of low frequency whale calls from many hundreds of kilometers in the pre-propeller ocean to tens of kilometers in many settings today. Clark *et al.* (2009) provided information on the effects of sound masking on mysticetes (*i.e.*, fin, North Atlantic right, and humpback whales) exposed to noise from ships and reported that, among other things, projected whale call rates diminished in the presence of passing vessels. More recently, Redfern *et al.* (2017) examined the co-occurrence of blue, fin, and humpback whales with sound from commercial shipping off southern California and identified several regions of overlap where the acoustic habitat of these species was degraded by noise.

Although ship noise may result in negative behavioral, physiological, or auditory effects to blue whales, it is uncertain whether there are consequences at either individual or population levels, though more serious effects are more likely in areas where focused blue whale use or important habitat overlaps with areas of heavy ship traffic, such as shipping lanes. Additional research is needed to determine the degree to which anthropogenic noise from ships is a threat to blue whales.

H.1.4.2 Oil and Gas Exploration and Development

Oil and gas exploration and development activities occur in areas where blue whales are known to feed, breed, or migrate through. A number of activities associated with offshore energy development result in the introduction of underwater sound. Loud sounds from seismic acoustic surveys to locate undersea oil reserves may adversely affect marine mammals. For waters under U.S. jurisdiction, oil and gas exploration, including seismic surveys (e.g., towed airgun arrays), typically operate with marine mammal observers as part of required mitigation measures as required in incidental take permits issued for the activity (NOAA 2011). Baleen whales are known to detect the low-frequency sound pulses emitted by airguns and have been observed, in some cases, reacting to seismic vessels (Stone 2003, Di Iorio & Clark 2009, Blackwell *et al.* 2015). All seismic systems are towed behind ships (multiple ships may be involved), which themselves may impact whales. In addition, a variety of non-tactical sonar or sonar-like devices and technologies are used for purposes of geophysical research and studies of bathymetry that introduce sound energy into the water. Monitoring of fin whale calls during seismic surveys indicated that fin whales changed their vocalizations and may be displaced in response to these types of activities (Castellote *et al.* 2012).

Supply vessels, low-flying aircraft, construction work, and dredging introduce underwater noise during various oil and gas exploration-related activities (Gales 1982, Greene 1987). Drilling for oil and gas generally produces low-frequency sounds with strong tonal components—frequency ranges in which large baleen whales communicate. However, recorded noise from one study of one drilling platform and three combined drilling production platforms found that noise was low volume and almost undetectable alongside the platform at Beaufort scale sea states of three or above. The strongest tones were at low frequencies, near 5 Hz (Richardson *et al.* 1995).

The intense pulses produced by seismic airgun acoustic surveys have the potential to cause direct harm at close distances, but subtler impacts can occur at larger distances. Cerchio *et al.* (2014) noted that the breeding display of humpback whales was disrupted by seismic survey activity in waters off northern Angola when seismic activities were conducted in relatively close proximity. Castellote *et al.* (2012) demonstrated that fin whale singing activity and call features were affected by the presence of seismic survey airgun operations in the western Mediterranean Sea. Blue whales in the St. Lawrence Estuary region called more frequently when seismic surveys using sparkers were being conducted than when they were not, likely indicating a response to the survey work (Di Iorio & Clark 2009). McDonald *et al.* (1995) documented that a blue whale ceased to call when it came within 10 km of a seismic survey. Gedamke and Robinson (2010) suggested a reasonable likelihood that whales a kilometer or more from seismic surveys could be potentially susceptible to a temporary impact to hearing, but also noted the importance of uncertainty and variability in risk assessments. Seismic surveys may also result in deleterious effects to zooplankton—a source of prey for blue whales. McCauley *et al.* (2017) found that airgun exposure significantly decreased zooplankton abundance, as measured by sonar (~3–4 dB drop within 15–30 min) and net tows (median 64% decrease within 1 h), and caused a two- to threefold increase in dead adult and larval zooplankton. These impacts were observed out to the maximum assessed range of 1.2 km. Richardson *et al.* (2017) found similar impacts to zooplankton from exposure to airguns within 15 km, but not on a broader scale. Also, the zooplankton abundance within the 15 km recovered 3 days after exposure. Further studies are needed to understand the impacts, if any, to blue whales as a result of changes in zooplankton abundance.

Although underwater noise generated by oil and gas exploration and development activities may have a detrimental effect on some blue whale social or acoustic behavior, none of the studies discussed above point to definitive consequences at either individual or population levels. Additional research is needed to determine the degree to which anthropogenic noise from oil and gas exploration and development is a threat to blue whales.

H.1.4.3 Military Sonar and Explosives

Military training activities by the U.S. Navy and navies of other countries regularly occur in the Atlantic Ocean, Gulf of Mexico, Mediterranean Sea, Indian Ocean, and Pacific Ocean. These activities include anti-submarine warfare, surface warfare, anti-surface warfare, mine warfare, missiles, ship scuttling, and aerial combat exercises. In addition to these training activities, navies conduct ship shock trials, which involve detonations of high explosive charges to test combat readiness of a ship and its various on-board systems, and other activities involving the use of underwater explosives.

As part of its suite of training activities, the U.S. Navy employs low-, mid-, and high-frequency active sonar systems. The primary low-frequency active sonar system, of which only four are operated by the U.S. Navy worldwide, is the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar system, which produces relatively loud sounds between 100–500 Hz, and has operated in the western and central Pacific Ocean. The U.S. Navy employs fleets across the globe utilizing several mid-frequency sonar systems that range from large systems mounted on the hulls of ships (*e.g.*, sonar devices referred to as AN/SQS-53 and -56), to smaller systems that are deployed from helicopters and fixed-wing aircraft, sonobuoys, and torpedoes. These sonar systems produce relatively loud, 1-10 kHz (or greater) frequency sounds (NMFS and U.S. Department of the Navy 2001, U.S. Department of the Navy 2008). The navies of other countries also employ tactical active sonars across a range of frequencies.

Studies undertaken in 1997–98 pursuant to the U.S. Navy's Low-Frequency Sound Scientific Research Program found only short-term responses to low frequency sound by mysticetes (fin, blue, and humpback whales), including changes in vocal activity and avoidance of the source vessel (Clark & Fristrup 2001, Croll *et al.* 2001a, Fristrup *et al.* 2003, Nowacek *et al.* 2007). The effect of sonar on blue whales remains uncertain; however, sonar associated with naval training activities might adversely affect blue whales in ways previously described (*i.e.*, hearing damage/impairment, behavioral response, and masking). Melcon *et al.* (2012) observed a decrease in blue whale calls in the Southern California Bight in the presence of mid-frequency active (MFA) sonar (U.S. Department of the Navy 2008). More recently, Goldbogen *et al.* (2013) and DeRuiter *et al.* (2017) found that exposure to simulated MFA sonar interrupted blue whale feeding, especially when animals were in the deep feeding mode. Responses in this study were heavily dependent on the animal's behavioral state and are illustrative of the complexity of understanding the impacts of sound on marine mammals.

Underwater detonations associated with military training activities include ship scuttling/sinking; missile, gunnery, and mine-neutralization exercises; and the disposal of unexploded ordnance and grenades. Underwater transmission of explosions includes an initial shock pulse followed by a succession of oscillating bubble pulses and sound fields of varying size. Whales very close to a large detonation might be killed or seriously injured; more distant whales might suffer lesser but nonetheless nearly debilitating injury (*e.g.*, tympanic membrane rupture, slight to extensive lung injury), while distant whales might experience physiological stress responses or behavioral disturbance, with severity of the reaction dependent on their distance from the detonation.

Various measures have been developed to reduce marine mammal exposure to sonar transmissions or underwater detonations during testing and training exercises. For example, U.S. Navy exercises involving the SURTASS LFA sonar observe closures to reduce impacts in important areas and times, and also employ visual monitoring for marine mammals during daylight hours, passive sonar to listen for vocalizing marine mammals, and a high-frequency sonar that allows the U.S. Navy to detect large and most small cetaceans. If marine mammals are detected, the U.S. Navy is required to cease use of LFA sonar transmissions until whales have moved away from the area. Prior to and during MFA sonar operations and when explosives may be used, the Navy uses trained Lookouts to look for whales in the vicinity. In addition to Lookouts, there are also mitigation zones and requirements for shutdown and delaying resumption of activities for other (non-SURTASS LFA) low, medium, and high frequency sonar and explosives testing and training activities by the U.S. Navy.

The United Kingdom's Royal Navy also utilizes various mitigation measures to help reduce marine mammal exposure to sonar transmissions. When operating, the environmental impact of Royal Naval activity is limited through the use of appropriate Standard Operating Procedures. The procedures have environmental protection elements embedded within them and include routine on board practices such as the posting of marine mammal observers on ships before and during active sonar use (Royal Navy 2013). Other standard operational control measures include the assessment of environmental impacts at military sites which leads to mitigation being included in such things as local Port Authority instructions or Firing Range Orders (Royal Navy 2013).

As noted above for other anthropogenic sound sources, military sonar and explosives may have a detrimental effect on some blue whale social or acoustic behavior, but there is currently no evidence of definitive consequences at either individual or population levels. Additional research is needed to determine to what degree anthropogenic noise from military sonar and explosives is a threat to blue whales.

H.1.5 Loss of Prey Base Due to Climate and Ecosystem Change

Climate change has received considerable attention in recent years, with growing concerns about warming ocean temperatures and influences on natural climatic oscillations, such as the Pacific Decadal Oscillation or El Niño and La Niña conditions. Evidence suggests that productivity in the North Pacific (Quinn II and Niebauer 1995, Mackas *et al.* 1998) and other ocean areas could be affected by changes in the environment. Increases in global temperatures are expected to have profound impacts on arctic and subarctic ecosystems, and the ecosystem changes in these regions are projected to accelerate during this century (Aguilar *et al.* 2002, Anisimov *et al.* 2007). Climate and oceanographic change may affect habitat and food availability of blue whales. Whale migration, feeding, and breeding locations may be influenced by changing ocean currents and water temperatures, although the extent of potential change is not known. For example, decadal scale climatic regime shifts have been related to changes in zooplankton in the North Pacific (Brodeur and Ware 1992, Francis *et al.* 1998), and long-term trends of warming sea surface temperatures in the California Current Ecosystem have been linked to major changes in zooplankton abundance (Roemmich and McGowan 1995). Such changes could affect blue whales if prey resources undergo changes in occurrence or densities.

In the Southern Ocean, krill abundance fluctuates with oceanographic conditions, most notably variations in winter sea ice, and is susceptible to environmental change (Braithwaite *et al.* 2015). However, we cannot yet predict how inter-regional variability in the effects of climate change on factors that affect Antarctic krill will affect productivity, and while models indicate that krill biomass will decline with continued surface warming, there is low confidence in the predictions (Larsen *et al.* 2014).

In the North Atlantic, the distribution of copepods (a prey item of some North Atlantic krill species) has shown signs of shifting due to climate change (Hays *et al.* 2005). Doniol-Valcroze *et al.* (2012) noted that blue whale feeding depth and behavior varied across suitable habitats in the Gulf of St. Lawrence. These habitats were used preferentially at different times of the tidal cycle and appeared linked to known prey aggregation mechanisms. Oceanographic conditions might become less favorable to species such as Arctic krill (the preferred prey of blue whales) in higher latitudes like the Gulf of St. Lawrence (Walther *et al.* 2002, Hays *et al.* 2005). How this will influence prey availability and distribution and abundance of blue whales remains uncertain and should be closely monitored (Gavrilchuk *et al.* 2014).

In addition to changes in ocean temperatures, ocean acidification may adversely affect blue whale prey. As increasing amounts of carbon dioxide are released into the atmosphere, more carbon dioxide is absorbed by the oceans, which reduces its pH. Between 1750 and 1994, ocean surface pH decreased by 0.1 (with highest decreases at high latitudes), which corresponds with a 26% increase in acidity (Bindoff *et al.* 2007). Krill embryonic development (Kawaguchi *et al.* 2011), hatch rates (Kawaguchi *et al.* 2013), and post-larval metabolic physiology (Saba *et al.* 2012) are likely to be affected by increasingly acidic conditions. Projections of future acidification indicate large portions of Antarctic krill's present range will be at damaging levels, with potential collapse of the krill population there by 2300 (Kawaguchi *et al.* 2013).

The feeding range of blue whales is broadly distributed geographically and, consequently, it is likely that the blue whale may be more resilient to climate change, should it affect prey, than a species with a narrower range (Silber *et al.* 2016). A potential exception to this is the Northern Indian Ocean population, which is restricted geographically and cannot move north as ocean temperatures increase (Thomas *et al.* 2016). Additionally, a recent study cites that the Indian Ocean has lost 20% of phytoplankton over the past six decades, and future climate projections suggest the Indian Ocean will continue to warm, driving this productive region into an ecological desert (Roxy *et al.* 2016). This could likely result in a decrease in the species that the Northern Indian Ocean population depends on.

Globally, blue whales have a relatively specialized diet (eating mainly krill), which might make them more vulnerable to climate change impacts on their prey, compared to species with generalist foraging strategies that might adapt to changing conditions by prey switching. The effects of climate-induced shifts in productivity, biomass, and species composition of prey on the foraging success of blue whales have received little attention and more research is needed to understand possible impacts and the extent to which these impacts might impede blue whale recovery. Therefore, we consider loss of prey base due to climate and ecosystem change to be a potential threat to the species.

H.2 Stressors Evaluated but Determined Not to be Threats

H.2.1 Environmental Debris, Contaminants, and Pollutants

The manner in which pollutants might negatively impact animals is not well understood, particularly in animals for which many of the key variables and physiological pathways are unknown (Aguilar 1987, O'Shea & Brownell 1994) such as blue whales. Organic chemical contaminants are generally considered less of a concern for mysticetes than odontocetes (Reijnders *et al.* 1999) because baleen whales generally feed at lower trophic levels with less opportunity for bioaccumulation, and contaminants are not considered to be primary factors in slowing the recovery of any populations of large whale species (O'Shea & Brownell 1994). O'Shea and Brownell (1994) indicated that concentrations of organochlorine and metal contaminants in tissues of baleen whales were low, and lower than other marine mammal taxa, in both local and global comparisons. They further stated that there was no firm evidence that levels of organochlorines, organotins, or heavy metals in baleen whales generally were high enough to cause toxic or other damaging effects. However, individual marine mammals with higher contaminant levels in tissues show increased susceptibility to infections, lesions, impairments, and even reproductive failure (De Guise *et al.* 1995, Moore *et al.* 1998, Aguilar *et al.* 2002, Jenssen *et al.* 2003).

Other studies confirm low levels of contaminants in some marine mammal populations. In a review of organochlorine and metal pollutants in southern Pacific marine mammals (Franciscana dolphins, *Pontoporia blainvillei*, from Argentina and pantropical spotted dolphins, *Stenella attenuata*, from the eastern tropical Pacific), Borrell and Aguilar (1999) noted that organochlorine levels suggested low exposure compared to other regions of the world. Although information is extremely scarce, concentrations of organochlorines in marine mammals occurring in the tropical and equatorial fringe of the Northern Hemisphere and throughout the Southern Hemisphere appear to be low. Aguilar *et al.* (2002) found that organochlorine concentrations in marine mammals off South America, South Africa, and Australia were invariably low, with the lowest organochlorine concentrations in cetaceans found in the polar regions of both hemispheres. However, due to the systematic long-term transfer of airborne pollutants toward higher latitudes, it is expected that concentrations of organochlorines will increase in the Arctic and Antarctic in the future, warranting long-term monitoring of polar regions (Aguilar *et al.* 2002).

More specific to baleen whales, in a study of organochlorine exposure and bioaccumulation in the North Atlantic right whale, Weisbrod *et al.* (2000) noted that biopsy concentrations of organochlorines were an order of magnitude lower than concentrations in the blubber of seals and odontocetes. They concluded that there was no evidence to indicate that right whales bioaccumulate hazardous concentrations of organochlorines, and further noted that this was consistent with similar studies of baleen whales (Weisbrod *et al.* 2000). More recently, Bengtson-Nash *et al.* (2013) found that fluctuations in lipid energy stores can affect the "toxicokinetics of lipophilic organochlorine compound (OC) burdens" of southern hemisphere humpback whales. This may be consequential for baleen whales, including blue whales, that experience the energetic demands of migration and the resulting physiological response of lipid metabolism and, as a result, mobilization and redistribution of OCs. In addition, the typical distribution of OCs in baleen whale blubber has been found to differ in lactating female humpback whales (Waugh *et al.* 2014); the consequences of these findings have yet to be explored but have the potential to lead to population-level effects if they negatively impact weaning or indirectly lead to effects on calf health. Moreover, sublethal health effects are amplified in small or resident populations to a point where they may be more likely to lead to population-level effects. For example, in the isolated population of fin whales found in the Gulf of California, maximum values of OC concentrations found in the blubber biopsies were higher than those associated with reproductive effects in whales (Nino-Torres *et al* 2009). Health effects for this small and isolated population could readily translate into population-level effects. The small resident populations of blue whales found off Sri Lanka (de Vos *et al.* 2016) and potentially other regions may be similarly disproportionately at greater risk, however further research needs to be undertaken to assess the environmental contaminant burden of these populations.

Recently, researchers used the earwax of a male blue whale killed by a collision with a ship off the coast of California to investigate contaminants and hormone profiles. Earwax is continuously deposited throughout a blue whale's lifetime, but forms alternating light and dark layers at approximately 6-month intervals (Trumble *et al.* 2013). The light corresponds to periods in the blue whale's lifecycle when it is feeding, while the dark represents times of fasting and migration. Using the technique of analyzing blue whale earwax, Trumble *et al.* (2013) found markers of the stress hormone cortisol, growth-inducing testosterone, and contaminants such as pesticides, flame retardants, and mercury. The reconstructed persistent organic pollutant (POP) profiles of the ship-struck male blue whale demonstrated that a substantial maternal transfer occurred during gestation and/or lactation, approximately 20% of its total lifetime burden (Trumble *et al.* 2013). A review by Wagemann and Muir (1984) highlighted similar maternal transfer of contaminants in a large number of marine mammals throughout the Northern Hemisphere. In blue whales in the Gulf of St. Lawrence, Canada, concentrations of PCBs, dichlorodiphenyl trichloroethane (DDT), and metabolites and several other organochlorine compounds were present at higher concentrations in the blubber of males relative to females; reflecting maternal transfer of these persistent contaminants from females into young (Metcalfe *et al.* 2004). The impact from the chronic and acute POP exposure on baleen whales is largely unknown, but may potentially be positively correlated with cortisol.

Anthropogenic mercury is common in the environment and has received much attention among ecologists, environmental chemists, and toxicologists because of its ability to bioaccumulate and impair neurological development. Well-documented research involving humans reveals maternal transfer of mercury in utero and then to the neonate during lactation (Vieira *et al.* 2013). Mercury profiles in the ship-struck male blue whale do not mirror maternal transfer to the same degree as the POPs. Because this blue whale appeared to routinely traverse the coast of California (ship stuck near Santa Barbara, CA), Trumble *et al.* (2013) speculated that pulse events of mercury accumulation may be associated with regional environmental and/or anthropogenic increases of mercury.

An emerging threat to baleen whales, is the presence of microplastics (plastic fragments smaller than 5 mm) in the marine environment (Germanov *et al.* 2018). Microplastics are now widespread in the oceans and sediments, and have been found to interact with persistent organic pollutants and contaminate marine life when ingested (Ivor do Sul and Costa 2014). The marine food web might be affected by microplastic biomagnification, and baleen whales are at particular risk from microplastic ingestion as a result of their filter-feeding activity, particularly as microplastics are also absorbed and ingested by their planktonic prey (Fossi *et al.* 2012). High concentrations of phthalates (di-(2-ethylhexyl)phthalate (“DEHP”) and mono-(2-ethylhexyl)phthalate (“MEHP”)) were detected in neustonic/planktonic samples from the Mediterranean Sea, and concentrations of MEHP was found in the blubber of stranded fin whales (Fossi *et al.* 2012). Microplastic contamination and ingestion may represent a potentially serious emerging issue for baleen whale species, including blue whales.

As noted above, marine mammals with higher contaminant levels may experience sublethal health effects, but there is currently no evidence that the effects are manifesting at a population or species level relevant to recovery of blue whales.

Oil Spills and Spill Responses

Oil spills can injure or kill marine mammals. Dispersants used in oil spill response may also cause injury. Actual impacts would depend on factors such as the extent and duration of contact and the characteristics (*e.g.*, the type and degree of weathering) of the oil, but dermal exposure to oil and other chemicals could cause irritation, lesions, or burns, which may increase susceptibility to infection (Deepwater Horizon Natural Resource Damage Assessment Trustees 2016). Animals may also inhale, ingest, or absorb petroleum compounds or dispersants, which can injure their respiratory or gastrointestinal tracts or affect liver or kidney functions (Geraci

1990, Schwacke *et al.* 2014). Oil could also foul baleen, which would reduce its filtration efficiency during feeding (Lambertsen *et al.* 2005). Sub-lethal effects may include impaired health and reproduction and increased susceptibility to other diseases (Harvey & Dahlheim 1994). There are likely to be continuing effects even after clean-up has ended, such as exposure to compounds in oil that persist in the environment and effects on habitat and prey resources (Deepwater Horizon Natural Resource Damage Assessment Trustees 2016).

We do not know the consequences of oil spills that have occurred in the blue whale's range, nor do we know the extent to which these or any future spills may affect blue whales. However, oil spill impacts to another baleen whale population suggest that, in some circumstances, impacts could be severe. Damage assessments following the April 2010 Deepwater Horizon major oil spill and subsequent response efforts estimated that 17% (95% confidence interval (CI) 7%–24%) of the small, resident Gulf of Mexico population of Bryde's whales was killed. Further, the spill was estimated to have caused 22% (95% CI 10% –31%) of the population's reproductive females to experience reproductive failure and 18% (95% CI 7% –28%) of the population to suffer adverse health effects (Deepwater Horizon Natural Resource Damage Assessment Trustees 2016).

Individual blue whales may experience potentially severe health effects from exposure to oil and other chemicals involved in spill response. Additionally, small populations of blue whales resident to Sri Lankan waters may be negatively impacted from oil and gas development and pollution (de Vos *et al.* 2016). While the potential impact of oil spills on small resident populations could affect their recovery, the majority of blue whale populations have a broad distribution and wide-ranging movements, which would be expected to lessen the population-, sub-species-, or species-level impact of such spills. For this reason, oil spills are not considered to be impeding the recovery of blue whales as listed throughout their range.

H.2.2 Disease

Harmful algal blooms are increasing in frequency and global distribution (Van Dolah 2000), potentially due to human activities' effects on the ecosystem such as nutrient loading from runoff or sewage (Sellner *et al.* 2003) or climate change (Moore *et al.* 2008). Biotoxins produced in the blooms have caused an increasing number of mass mortalities of cetaceans, pinnipeds, and mustelids (Gulland & Hall 2007, Landsberg *et al.* 2014). For example, in March 2015, at least 343 whales, primarily sei whales, likely died from a harmful algal bloom that occurred in a gulf in Southern Chile (Häussermann *et al.* 2017). The region of the mass stranding event is just south of the Chiloé-Corcovado region in Chile, which is an important feeding and nursing ground for blue whales. In 1987 and 1988, fourteen humpback whales in the western North Atlantic died after eating mackerel that contained saxitoxin, a neurotoxin that can cause paralytic shellfish poisoning in humans (Geraci *et al.* 1989). Saxitoxin and another neurotoxin, domoic acid, were also detected in two and three humpback whales, respectively, that were associated with a 2003 unusual mortality event in Maine that killed 16 humpback whales, one fin whale, one minke whale, one pilot whale, and two individuals of unknown species (Gulland & Hall 2007). Domoic acid can cause amnesic shellfish poisoning in humans and has been linked to marine mammal and seabird mass-mortality events, particularly off the U.S. West Coast (reviewed in Landsberg *et al.* 2014). Domoic acid is likely passed on to krill (Bargu *et al.* 2002), a common food of many baleen whales, including blue whales. Lefebvre *et al.* (2002) found that humpback and blue whales were exposed to the toxin and consumed domoic acid contaminated prey. However, it is unknown how the pervasiveness of biotoxins such as domoic acid affects baleen whales like the blue whale since data is limited. There is currently no evidence linking these toxins to acute impacts (including death) or chronic health problems in blue whales.

It is not known whether blue whales suffer from stress-induced bacterial infections similar to those observed in captive cetaceans (Buck *et al.* 1987). Brownell *et al.* (2007) described three types of skin lesions in blue whales in Chile: 1) resulting from cookie-cutter shark, *Isistius brasilensis*, bites; 2) vesicular or blister lesions; and 3) a tattoo-like skin disease. The authors note that the presence of blister lesions in 2006 and 2007 may indicate that these skin lesions will be present in the population for a long time. It is unknown if these lesions contribute to mortality of blue whales frequenting Chilean waters, but the tattoo-like skin lesions, if shown to be a pox virus, could cause neonatal and calf mortality (Brownell *et al.* 2007). There is currently no evidence to suggest that the lesions pose a conservation risk to blue whales in general or the Chilean subspecies in particular. There is limited data on the status of morbillivirus or *Brucella* sp. infections in blue whales. Both of these diseases have caused significant impacts in other cetacean species (Guzmán-Verri *et al.* 2012, Van Bressem *et al.* 2014) and should be monitored in stranded blue whales to provide baseline data for future assessments.

Based on the above information, disease is not currently considered to be limiting blue whale recovery.

H.2.3 Behavioral Disturbance from Vessel and Unmanned Aircraft System (UAS) Interactions

Blue whales are increasingly a target species for educational or recreational activities, including whale watching operations. As a result, individual and groups of blue whales may be closely accompanied by vessels on a regular basis. In addition to generating noise (discussed in Section I.H.1.4.1 above) and presenting a risk of vessel strike (discussed in Section I.H.1.2 above), vessel-based whale watching activities and other types of close approach may disturb the whales' behavior.

Short-term behavioral changes made in response to whale watching activities have been documented in a number of cetacean species (Parsons 2012), including blue whales (Lesage et al 2017). These include changes in surfacing and diving behavior, other active behavior, swim speed or direction, amount of time spent foraging or resting, and vocalization patterns (Parsons 2012). Animals' reactions likely depend on a number of factors such as their behavioral context (e.g., feeding versus traveling), the number of vessels approaching, vessel approach distance, and duration of the encounter. A recent meta-analysis revealed consistent responses to whale-watching activities across cetacean species, including that individuals were more likely to travel and less likely to rest and forage in the presence of vessels (Senigaglia *et al.* 2016). Additionally, individuals were more likely to increase their path sinuosity rather than traveling linearly between locations (Senigaglia *et al.* 2016). Some studies have linked these behavioral responses to changes in respiration rate. For example, respiration rates in minke whales were found to be higher during interactions with whale watching boats at any given speed, suggesting that boat presence elicited a stress response in the animals, resulting in a 23.2 percent increase in estimated energy expenditure (Christiansen *et al.* 2014). Swim speed also increased during whale watching interactions, resulting in an additional 4.4 percent increase in energy expenditure (Christiansen *et al.* 2014). These additional energy expenditures are exacerbated by loss of feeding opportunities also resulting from disturbance. It is unclear whether or how short-term changes translate to long-term effects on individuals or populations, such as changes in distribution (including abandonment of important feeding or breeding habitat, use of higher risk areas) or reduced reproductive success. There is currently no evidence indicating that these effects are detrimental to blue whales at the population level, but long-term monitoring would be important to understand any impacts of disturbance.

Unmanned aircraft systems (UAS), also known as model aircraft or drones, are a new way to obtain unique views of wildlife and natural landscapes. In recent years, there has been an increase in the recreational use of UAS, particularly to view marine mammals. Several federal statutes require scientists to obtain research permits to closely approach protected species of wildlife, such as marine mammals, but the lack of available information on the effects of UAS operations on these species has made it difficult to evaluate and reduce possible impacts (Smith *et al.* 2016). UAS can be disruptive to both people and animals if not used safely, appropriately, or responsibly. In the United States, the Federal Aviation Administration provides hobbyists with some basic guidance for operating UAS to address safety and privacy concerns[5]. The U.S. National Park System has also recently prohibited the use of UAS in United States National Parks[6] (some of which provide habitat to marine mammals).

Scientists and wildlife managers are concerned that acute or chronic disturbances of wildlife can impact the animals' health and fitness by disrupting migratory patterns, breeding, feeding, and sheltering. However, there is currently no evidence to suggest adverse effects to blue whale recovery from the use of UAS.

H.2.4 Research

Scientific research can involve close interactions with blue whales. In many countries, directed research activities typically require permits and are closely monitored to ensure any potential negative impacts are minimized. The potential for disturbance or harassment from observing or approaching whales for behavioral studies, photography, tagging, and data collection (including biopsy samples collected for health and genetic analysis) is likely minimal and is far outweighed by the benefits of gaining information that could prove critical in helping manage and recover the species.

The use of UAS offers a new method for scientific researchers and emergency responders to obtain important information about marine mammals that can further support the conservation of these protected species. NMFS continues to evaluate applications for scientific research and other activities to ensure that the potential hazards of UAS use do not outweigh the benefits, and

[5] https://www.faa.gov/uas/
[6] https://www.nps.gov/orgs/aviationprogram/upload/unmanned-aircraft-in-national-parks.pdf

other types of public activity that have the potential to negatively impact protected marine species[7].

We address the effects of research activities that do not involve the direct study of blue whales in other subsections of the Plan's threats analysis section, such as vessel interactions, anthropogenic noise, contaminants and pollutants, oil and gas exploration, and military sonar and explosives.

H.2.5 Predation and Natural Mortality

While there are records of killer whale attacks on blue whales and some shark species likely take individual blue whales, there is no evidence that this is a threat to the species.

H.2.6 Competition for Resources

Many sympatric baleen whale species target similar resources and may interact ecologically. Sympatric baleen whales may develop species-specific foraging behaviors to reduce competition; for example, Friedlaender *et al.* (2009) found that humpback and minke whales may partition resources vertically. However, off central California, sympatric blue and fin whales were not found to feed at significantly different depths when targeting the same prey patch (Friedlaender *et al.* 2015).

Prey distribution and abundance is a primary driver of baleen whale distribution and feeding behavior (Croll *et al.* 2005, Friedlaender *et al.* 2006). While competitive interactions are possible, there is no basis to assume that competition for food among baleen whales is affecting the blue whale's population trend and abundance. Rather, the presence of food may influence the distribution or occurrence of blue whales in certain areas. For example, when large predatory fish declined in the Northeast Atlantic, their prey (herring, capelin, shrimp, and snow crab) eventually increased in abundance (Lilly 1991, Berenboim *et al.* 2000, Garrison & Link 2000, Koeller 2000, Lilly *et al.* 2000, Bundy 2005), and as a consequence, prey needs increased, resulting in changes in the trophic structure in the Gulf of St. Lawrence. During this time, blue whale sightings in the northwestern Gulf of St. Lawrence declined. Gavrilchuk *et al.* (2014) indicated that the effects on non-target species following the collapse of the groundfish fishery in the early 1990s might be less favorable for the blue whale, which have a relatively species-specific diet, compared to baleen whales with generalist foraging strategies. Thus, the enhanced competition for krill between blue whale and species at various trophic levels following changes in the structure and dynamic of the northern Gulf of St. Lawrence ecosystem appeared sufficient to account for the decline in food availability for blue whales and their departure from the area (Comtois *et al.* 2009, Comtois *et al.* 2010).

Krill fisheries have the potential to reduce blue whale prey. In the Northern Hemisphere, krill fisheries occur around Japan and off British Columbia, while krill harvest off the U.S. West Coast and Alaska are prohibited. Nicol *et al.* (2012) consider the Antarctic likely to be the main source of krill harvest in the future. In the Southern Ocean, biomass of *Euphausia superba* is currently estimated to be 379 million tons (Atkinson *et al.* 2009). The Commission for the

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[7] https://www.fisheries.noaa.gov/national/marine-life-viewing-guidelines/permitting-scientific-research-using-small-unmanned

Conservation of Antarctic Marine Living Resources sets precautionary harvest limits to ensure a sustainable fishery while minimizing impacts on the ecosystem. From a catch limit of 620,000 tons, an estimated 260,151 tons of *E. superba* were caught in the Southern Ocean in 2016 (CCAMLR 2017). Overfishing of krill could impact the availability of blue whale prey, but this is considered unlikely given management measures in place.

In summary, there is limited information on blue whale competition for prey with sympatric species, but there is also no evidence that competition with sympatric species is a threat for any large whale species. Indeed, Clapham and Brownell (1996) reviewed evidence for interspecific competition in baleen whales and concluded that it was not possible to establish inter-specific competition as an important factor in the population dynamics of large whales. In addition, changes in trophic structure may affect the prey availability for blue whales, but there is no evidence that this is a threat to blue whales. Krill fisheries, mainly in the Antarctic, compete with blue and other whales for prey, but given the precautionary management and harvest limits, are not considered to be limiting blue whale prey. Therefore, competition for resources is not considered to be a threat to blue whale recovery.

I. Conservation Measures

The blue whale is protected under both the ESA and the MMPA. The blue whale was listed as endangered throughout its range under the precursor to the ESA, the Endangered Species Conservation Act of 1969 (35 FR 8491; June 2, 1970), and remained on the list of threatened and endangered species after the passage of the ESA in 1973. The blue whale is automatically designated as depleted under the MMPA due to its status as endangered under the ESA. The Secretary of Commerce (as delegated to NMFS) administers the ESA for most endangered marine species, including blue whales. NMFS has lead responsibility for developing and implementing a recovery program for this species.

Blue whales are also listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the Convention on the Conservation of Migratory Species of Wild Animals (CMS). The CITES classification is intended to ensure that commercial trade in the products of blue whales does not occur across international borders and are not introduced from the sea. The CMS, also known as the Bonn Convention, aims to conserve terrestrial, aquatic, and avian migratory species throughout their range.

Through amendments to the Schedule to the ICRW, blue whales received complete protection from whaling throughout the North Atlantic Ocean in 1955, the North Pacific Ocean in 1966, and the entire Southern Hemisphere in 1968 (Best 1993). In 1982, the IWC set catch limits for all commercial whaling to zero. These catch limits went into effect in 1986, beginning a commercial whaling moratorium that remains in effect today. However, Norway and Iceland continue to commercially take whales under formal objections or reservations to the moratorium. The Russian Federation has also objected to the moratorium but does not exercise it. There have been no recorded commercial catches of blue whales since 1978 (Branch *et al.* 2008). Japan used to conduct special permit whaling (also called scientific whaling) under Article VIII of the ICRW but has no recorded catches of blue whales. On June 30, 2019 Japan withdrew from the ICRW and resumed commercial whaling in its exclusive economic zone. However, there is no indication that Japan is targeting or harvesting blue whales.

II. RECOVERY STRATEGY

Commercial whaling was the main cause of blue whales' historical decline, and is not a current operative threat because an international moratorium remains in place. While Iceland and Norway do not adhere to the international moratorium since both countries filed objections or reservations to it, there is no evidence of whaling of blue whales in recent years. Additionally, while Japan withdrew from the ICRW effective June 30, 2019, it is only harvesting whales within its exclusive economic zone at levels considered sustainable by the IWC Scientific Committee, and there is no evidence that Japan is targeting or taking blue whales. Therefore, a primary strategy of this Revised Recovery Plan is to maintain the international ban on commercial hunting that was instituted in 1986, additionally we will take a multinational approach to the recovery strategy. This Plan provides a strategy to improve our understanding of how potential threats may be limiting blue whale recovery and to implement actions where populations may be vulnerable. Finally, this Plan provides a research strategy to obtain data necessary to determine blue whale taxonomy, population structure, distribution, and habitat, which can then inform estimation of population abundance and trends. Once the populations and their threats are more fully understood, this Plan will be modified to include actions to minimize any threats that are determined to be limiting recovery. Because blue whales move freely across international borders, it would be ineffective to confine recovery efforts to U.S. waters, and this Plan stresses the importance of a multinational approach to management.

III. RECOVERY GOALS, OBJECTIVES, AND CRITERIA

A. Goals

The goal of this Revised Recovery Plan is to promote recovery of blue whales to a level at which it becomes appropriate to downlist the species from endangered to threatened status, and ultimately to delist, or remove the species from the list of Endangered and Threatened Wildlife and Plants, under the provisions of the ESA. The Act defines an "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." A "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."

B. Management Units

For purposes of this Revised Recovery Plan, we identify nine blue whale management units:

1. Northern subspecies (*B. m. musculus)* - North Atlantic population
2. Northern subspecies (*B. m. musculus)* - Eastern North Pacific population
3. Northern subspecies (*B. m. musculus)* - Western/Central North Pacific population
4. Northern Indian Ocean subspecies (*B. m. indica*)
5. Pygmy subspecies (*B. m. brevicauda*) - Madagascar population
6. Pygmy subspecies (*B. m. brevicauda*) - Western Australia/Indonesia population
7. Pygmy subspecies (*B. m. brevicauda*) - Eastern Australia/New Zealand population
8. Chilean subspecies (*B. m.* unnamed subsp.)
9. Antarctic subspecies (*B. m. intermedia)*

As described in Section I.B.3, blue whale subspecific taxonomy has not been fully resolved and is an area of active research. The Society of Marine Mammalogy's (SMM) Taxonomy Committee currently recognizes five subspecies: *B. m. musculus*, *B. m. intermedia*, *B. m. indica*, *B. m. brevicauda*, and an unnamed subspecies off Chile (Committee on Taxonomy 2016). However, there are continuing discussions in the scientific literature regarding whether *B. m. indica* is a subspecies separate from *B. m. brevicauda*, and whether the blue whales off Chile are a separate sub-species. We identify at least one management unit (and associated recovery criteria) for each of the five subspecies recognized by SMM.

We also identify management units within two subspecies. In the Northern subspecies, *B. m. musculus*, we identify one North Atlantic and two North Pacific management units. In general, individuals from different ocean basins are unlikely to interbreed when mature, and if a basin population were extirpated, the area would likely not be recolonized in a time period that is meaningful for management purposes (Angliss *et al.* 2002). As described in Section I.D.1, it is unclear whether blue whales in the eastern and western portions of the North Atlantic Ocean belong to the same population. Until separation is more strongly supported, this Revised Recovery Plan considers blue whales in the North Atlantic to comprise one management unit, based on the IWC blue whale stock definition and the current understanding that there is only one blue whale song type in the North Atlantic. The IWC also considers blue whales in the North Pacific to be one stock, but we define two management units there based on multiple lines of evidence (song types, length-frequency data, and movement data from satellite tags and photo-identification), summarized in Section I.E.1, indicating there are at least eastern and western/central populations. In the pygmy blue whale subspecies, *B. m. brevicauda*, we identify three management units corresponding with "acoustic populations," following recommendations of the IWC (IWC 2016a).

Despite the uncertainties, the delineation of these nine units reflects our current understanding of blue whale taxonomy and population structure and we consider them to be the appropriate unitsfor recovery. We consider recovery of all nine units to be important for achieving geographic and ecological representation of blue whales in the world's oceans, and to ensure conservation of the breadth of blue whale' genetic variability.

C. Objectives and Criteria

The two main objectives for blue whales are to 1) increase blue whale resiliency and ensure geographic and ecological representation by achieving sufficient and viable populations in all ocean basins and in each recognized subspecies, and 2) increase blue whale resiliency by managing or eliminating significant anthropogenic threats. A prerequisite to achieving these objectives is obtaining sufficient data to determine whether they have been met, so many of the recovery actions in Section IV below focus on data collection.

The recovery criteria take two forms: 1) those that reflect the status of the species itself and 2) those that indicate effective management or elimination of threats. The criteria include specific targets for each of nine management units to support the objectives of species' viability (e.g., resiliency, redundancy, and representation).

Population viability analyses (PVAs) or other quantitative assessments for predicting a species' or population's future status can be useful in evaluating extinction risk. PVAs have been used in some recent marine mammal status reviews (e.g., (Krahn *et al.* 2004, Oleson *et al.* 2010), but not in others (e.g., (Boveng *et al.* 2009, Boveng *et al.* 2013, Bettridge *et al.* 2015), and are a component of several other large whale recovery plans (e.g., (NMFS 2010a, NMFS 2010b, NMFS 2011, NMFS 2013). Although not required to meet the criteria below, should sufficient data become available, a quantitative PVA demonstrating a low probability of extinction over a reasonable timeframe (e.g., scaled to blue whale generation time, see Taylor *et al.* 2007) could be used to further support downlisting or delisting decisions.

C.1 Downlisting Objectives and Criteria

The Blue whale (listed throughout its range; 35 FR 8491 6/2/1970) may be considered for reclassifying to threatened when all of the following have been met.

Objective 1: Increase blue whale resiliency and ensure geographic and ecological representation by achieving sufficient and viable populations in all ocean basins and in each recognized subspecies. As stated above, we consider recovery of all nine units to be important for achieving geographic and ecological representation of blue whales in the world's oceans, and to ensure conservation of the breadth of genetic variability.

Criteria: In each of the nine management units:

1. The minimum abundance is:
    a. North Atlantic: 2,000 whales
    b. Eastern North Pacific: 2,000 whales
    c. Western/Central North Pacific: 2,000 whales
    d. Northern Indian Ocean: 500 whales
    e. Madagascar: 2,000 whales
    f. Western Australia/Indonesia: 2,000 whales
    g. New Zealand: 500 whales
    h. Chilean: 2,000 whales
    i. Antarctic: 2,000 whales

    The 2015 status review for humpback whales (Bettridge *et al.* 2015) reviews scientific literature on the relationship between population size and extinction risk. Bettridge *et al.* (2015) describe scientific agreement that total population sizes greater than approximately 2,000-2,500 are sufficiently large to maintain genetic diversity and protect against the effects of demographic and environmental stochasticity and natural catastrophes. For management units that are known or believed to have had at least 2,500 individuals prior to the onset of commercial whaling, we adopt the lower end of this range (2,000) as a downlisting criterion, and the upper end (2,500) as a delisting criterion (see Section III.C.2 below). For management units that are known or believed to have had fewer than 2,500 individuals prior to the onset of commercial whaling, we specify lower minimum abundance criteria: 500 individuals as a downlisting criterion and 1,000 individuals as a delisting criterion. As described in Bettridge *et al.* (2015), an abundance of more than 500 individuals provides protection against the genetic risks of inbreeding and against moderate levels of environmental variance. For both sets of minimum abundance criteria, approximately half of the total population of each management unit is assumed to be mature individuals capable of reproduction (Taylor *et al.* 2007).

Based on information summarized in the Background sections of this Revised Recovery Plan, the pre-exploitation abundances of blue whales in the (*a*) North Atlantic, (*c*) Western/Central North Pacific, (*e*) Madagascar, (*f*) Western Australia/Indonesia, and (*i*) Antarctic management units very likely exceeded 2,500, while pre-exploitation abundance in the (*d*) Northern Indian Ocean management unit was very likely below 2,500. Pre-exploitation abundance estimates for the (*b*) Eastern North Pacific (2,210 individuals, 95% Bayesian credible interval 1,823-3,721; Monnahan *et al.* 2015) are below 2,500 and warrant using a lower threshold. For (*h*) Chilean blue whales, pre-exploitation abundance (2,100-3,600 individuals, Jackson 2016; or 1,500-5,000 individuals, Williams *et al.* 2011a, erratum 2017) is a minimum estimate and most of the estimate falls above 2,500. Therefore, 2,000/2,500 should be used for assessing whether the Chilean management unit meets the threshold for downlisting/delisting the species. There are no estimates of pre-exploitation abundance for blue whales around (*g*) New Zealand, but an estimated minimum current abundance of 718 (95% CI 279-1,926; Barlow *et al.* 2018) combined with relatively low historical catches of 421 in all years (Branch *et al.* 2018b) suggest pre-exploitation abundance is likely well below 2,500.

Although we use pre-exploitation abundances to assign management units to one of two sets of minimum abundance down- and de-listing criteria, the minimum abundance thresholds themselves are not linked to historical abundance. Because of this, a management unit meeting its minimum abundance criterion might remain a fraction of its pre-exploitation numbers. This is particularly true for Antarctic blue whales, which numbered in the hundreds of thousands prior to commercial whaling. While we acknowledge these thresholds as a minimum abundance necessary to prevent extinction due to low abundance *alone*, we must also ensure population stability and growth over time (criterion 2 below). Finally, we must maintain the whaling moratorium and minimize other known threats (Objective 2 Factors A through E below) to achieve recovery. Beyond the ESA recovery goal, continued management under the MMPA and the IWC are expected to encourage population growth and ultimately achievement of optimum sustainable population levels (or greater), which would further strengthen the likelihood that blue whales would fully reclaim their previous ecosystem function.

2. The trend in abundance, over the most recent 30-year period assessed, for each of the nine blue whale management units is:

    a. North Atlantic: stable or increasing
    b. Eastern North Pacific: stable or increasing
    c. Western/Central North Pacific: stable or increasing
    d. Northern Indian Ocean: stable or increasing
    e. Madagascar: stable or increasing
    f. Western Australia/Indonesia: stable or increasing
    g. New Zealand: stable or increasing
    h. Chilean: stable or increasing
    i. Antarctic: increasing

Trends in abundance are an important measure of a population's viability. This criterion could be met for a particular subspecies or population if a peer-reviewed analysis demonstrates that population is stable or increasing over 30 years, which is the estimated blue whale generation length under pre-disturbance conditions with an assumed stable population (Taylor *et al.* 2007). The exception is the Antarctic blue whale where the population trend must be increasing over 30 years. The historical abundance for the Antarctic blue whale is estimated to be 239,000 (CI 202,000-311,000; Branch 2008c) and its current abundance is estimated to be 2,280 (Branch 2007). Thus, if the Antarctic blue whale only maintained abundance of about 1 percent of its historical capacity and slightly above its current abundance over 30 years, we would expect that some biological and/or anthropogenic factor is still affecting the population; thus, impeding recovery of the blue whale throughout its range by reducing geographic and ecological representation and genetic variability. The specific 30-year time period may differ by management unit, depending on when abundance surveys or analyses have been conducted.

Objective 2: Increase blue whale resiliency by minimizing anthropogenic threats.

3. *Criteria*: In each of the nine management units:

Anthropogenic threats have been identified and demonstrably minimized; i.e., there is information indicating they are not contributing to the species being in danger of extinction throughout all or a significant portion of its range. Information we will assess in determining whether the criteria have been met will include published literature, technical memorandums, stranding and population monitoring results, and other credible sources. Specifically, the factors in 4(a)(l) of the ESA described below have been addressed:

Factor A: The present or threatened destruction, modification, or curtailment of a species' habitat or range.

- Effects of anthropogenic noise, ingestion and/or entanglement in marine debris, and reduced prey abundance due to climate change have been evaluated, and, if determined by NMFS to be impeding blue whale recovery, measures have been taken to minimize effects. Following this same evaluation and where effects to specific management units are known, management unit specific measures have been taken to minimize effects.

Factor B: Overutilization for commercial, recreational, or educational purposes.

- The international ban on commercial hunting has been maintained.
- Any subsistence or scientific hunting that has the potential to overutilize the species is restricted to levels that are sustainable, precautionary, and in accordance with the advice of the IWC's Scientific Committee.

Factor C: Disease or Predation.

- There is no information at this time indicating disease or predation is a threat to blue whale recovery.

Factor D: The inadequacy of existing regulatory mechanisms.

- Hunting is addressed under Factor B; climate change is addressed under Factor A.

Factor E: Other natural or manmade factors affecting its continued existence.

- Ship strikes have been evaluated, and, if determined by NMFS to be impeding blue whale recovery, measures have been taken to minimize effects. Following this evaluation and where effects to specific management units are known, management unit specific measures have been taken to minimize effects.
- Entanglement with fishing gear has been evaluated, and, if determined by NMFS to be impeding blue whale recovery, measures have been taken to minimize effects. Following this evaluation and where effects to specific management units are known, management unit specific measures have been taken to minimize effects.

As noted in Section I.H above, there are no currently operating threats to the species beyond whaling (if unsustainable commercial whaling were to resume), but there are numerous potential threats. These criteria, therefore, require that additional research be conducted to understand whether and to what extent any of the potential threats are impacting the recovery of the blue whale throughout its range. For any potential threat that is found to be impeding blue whale recovery, measures must be taken to minimize or eliminate its impact.

C.2 Delisting Objectives and Criteria

Blue whales (listed throughout its range; 35 FR 8491 6/2/1970) will be considered for delisting when all of the following criteria are met.

Objective 1: Increase blue whale resiliency and ensure geographic and ecological representation by achieving sufficient and viable populations in all ocean basins and in each recognized subspecies.

Criteria: In each of the nine management units:

1. The minimum abundance is:
    a. North Atlantic: 2,500 whales
    b. Eastern North Pacific: 2,500 whales
    c. Western/Central North Pacific: 2,500 whales
    d. Northern Indian Ocean: 1,000 whales
    e. Madagascar: 2,500 whales
    f. Western Australia/Indonesia: 2,500 whales
    g. New Zealand: 1,000 whales
    h. Chilean: 2,500 whales
    i. Antarctic: 2,500 whales

    See Section III.C.1 above for the justification for the selection of a minimum abundance criterion for each management unit. Based on the minimum abundance delisting thresholds described here, management units meeting this criterion are not likely to be at risk of extinction within the foreseeable future due to low abundance alone.

2. The trend in abundance, over the most recent 30-year period assessed, for each of the nine blue whale management units is:
    a. North Atlantic: increasing

b. Eastern North Pacific: stable or increasing
c. Western/Central North Pacific: stable or increasing
d. Northern Indian Ocean: stable or increasing
e. Madagascar: stable or increasing
f. Western Australia/Indonesia: stable or increasing
g. New Zealand: stable or increasing
h. Chilean: stable or increasing
i. Antarctic: increasing

See Section III.C.1 above for the justification for the selection of the population trend criterion for each management unit except for the North Atlantic management unit. The North Atlantic management unit, similar to the Antarctic, should be increasing to be considered for delisting. The pre-exploitation abundance for the North Atlantic is estimated to be 15,000 (Sergeant 1966, Allen 1970, Rørvik & Jonsgård 1981). If the North Atlantic blue whale only maintained an abundance of about 16 percent of its historical capacity and less than double its current abundance over 30 years, we would anticipate some biological and/or anthropogenic factor is affecting the population; thus, impeding recovery of the blue whale throughout its range by reducing geographic and ecological representation and genetic variability.

Objective 2: Increase blue whale resiliency by ensuring anthropogenic activities are not contributing to the species being in danger of extinction within the foreseeable future throughout all or a significant portion of its range.

3. *Criteria*: In each of the nine management units:

Anthropogenic threats have been identified and demonstrably minimized or eliminated; i.e.,there is information indicating they are not contributing to the species being in danger of extinction within the foreseeable future throughout all or a significant portion of its range. Information we will assess in determining whether the criteria have been met will include published literature, technical memorandums, stranding and population monitoring results, and other credible sources. Specifically, the factors in 4(a)(l) of the ESA described below have been addressed:

Factor A: The present or threatened destruction, modification, or curtailment of a species' habitat or range.

- Effects of anthropogenic noise, ingestion and/or entanglement in marine debris, and reduced prey abundance due to climate change have been evaluated, and, if determined by NMFS to be impeding blue whale recovery, measures have been taken to minimize effects. Following this same evaluation and where effects to specific management units are known, management unit specific measures have been taken to minimize effects.

Factor B: Overutilization for commercial, recreational, or educational purposes.

- The international ban on commercial hunting has been maintained.
- Any subsistence or scientific hunting that has the potential to overutilize the species is restricted to levels that are sustainable, precautionary, and in accordance with the advice of the IWC's Scientific Committee.

Factor C: Disease or Predation.

- There is no information at this time indicating disease or predation is a threat to blue whale recovery.

Factor D: The inadequacy of existing regulatory mechanisms.

- Hunting is addressed under Factor B; climate change is addressed under Factor A.

Factor E: Other natural or manmade factors affecting its continued existence.

- Ship strikes have been evaluated, and, if determined by NMFS to be impeding blue whale recovery, measures have been taken to minimize effects. Following this evaluation and where effects to specific management units are known, management unit specific measures have been taken to minimize effects.
- Entanglement with fishing gear has been evaluated, and, if determined by NMFS to be impeding blue whale recovery, measures have been taken to minimize effects. Following this evaluaton and where effects to specific management units are known, management unit specific measures have been taken to minimize effects.

As noted in Section I.H above and in the description of downlisting criteria above, there are no currently operating threats to the species beyond whaling (if unsustainable commercial whaling were to resume), but there are numerous potential threats. These criteria, therefore, require that additional research be conducted to understand whether and to what extent any of the potential threats are impacting the recovery of each blue whale management unit. For any potential threat that is found to be impeding blue whale recovery, measures must be taken to minimize or eliminate its impact, and there must be information indicating it is no longer limiting blue whale recovery.

IV. RECOVERY PROGRAM

A. Recovery Action Outline

Recovery actions in this outline are not in order of priority. Priorities are identified in the Implementation Schedule (Section V below). More detail about each recovery action appears in the Recovery Action Narrative in Section IV.B below. Unless otherwise indicated, the relevant "site" for each recovery action is throughout all nine management units.

1.0 Coordinate Federal and International Measures to Maintain International Regulation of Whaling for Blue Whales

2.0 Determine Blue Whale Taxonomy, Population Structure, Occurrence, Distribution, and Range

2.1 *Conduct studies to investigate population discreteness and population structure of blue whales.*

2.2 *Conduct studies to assess blue whale occurrence, daily and seasonal movements, and inter-area exchange.*

2.3 *Support the development of models to yield robust predictions of blue whale distribution.*

3.0 Estimate Population Size and Monitor Trends in Abundance

3.1 *Establish collaborative agreements with relevant national governmental bodies and scientific institutions to develop plans for estimating abundance and monitoring trends in abundance.*

3.2 *Conduct surveys to estimate blue whale abundance and monitor trends in abundance worldwide.*

3.3 *To the extent possible, work with appropriate government agencies in other countries to develop and maintain blue whale photo-identification programs, and educate and involve the public about contributing information about live, dead, entangled, or ship-struck whales, to continue to support or establish international databases.*

4.0 Identify, Characterize, Protect, and Monitor Habitat Important to Blue Whale Populations

4.1 *Characterize blue whale habitat.*

4.2 *Monitor important habitat features and blue whale use patterns to assess potentially detrimental shifts in habitat features that might reflect disturbance or degradation of habitat.*

4.3 *Promote measures to identify and protect important habitat throughout the species' range.*

5.0 Investigate Human-Caused Potential Threats and, Should They Be Determined to Be Limiting Blue Whale Recovery, Take Steps to Minimize Their Occurrence and Severity

5.1 *Anthropogenic noise*

5.1.1 Conduct studies to determine whether anthropogenic noise is adversely affecting blue whale distribution, behavior, or vital rates.

5.1.2 Take steps to minimize anthropogenic noises that are found to be detrimental to blue whale distribution, behavior, or vital rates.

5.2 *Vessel collisions*

5.2.1 Maintain database of known ship strikes of blue whales.

5.2.2 Review photographic databases for evidence of injuries to blue whales from ship strikes to better characterize these events.

5.2.3 Conduct studies to identify areas of high risk for blue whale ship strikes and monitor high risk areas in order to evaluate the effect on blue whales.

5.2.4 Conduct studies to determine whether collisions with ships are adversely affecting blue whale abundance and recovery.

5.2.5 If ship strikes are determined to be detrimental to blue whale abundance and recovery, work with mariners, the shipping industry, and appropriate state, federal, and international agencies to develop and implement measures to reduce the threat of ship strikes, and report strikes, should they occur. Maintain the traffic separation schemes off the U.S. West Coast, and evaluate and adjust, as appropriate.

5.3 *Marine debris*

5.3.1 Identify if blue whale habitat and significant deposits of marine debris coincide and evaluate the effect on blue whales.

5.3.2 Conduct studies to determine whether marine debris is adversely affecting blue whale abundance and recovery.

5.3.3 If found to be detrimental to blue whale abundance and recovery, develop and implement means to reduce marine debris, including lost fishing gear, and improve the reporting of lost gear.

5.4 *Fishing gear entanglement*

5.4.1 Review data on blue whale entanglement in fishing gear, including reports from fishermen and fishery observers.

5.4.2 Review photographic databases for evidence of injury to blue whales caused by fishing gear entanglement.

5.4.3 Conduct studies to determine if fishing gear entanglement is adversely affecting blue whale abundance and recovery.

5.4.4 If found to be detrimental to blue whale abundance and recovery, develop means to reduce entanglements, and enhance the effectiveness of disentanglement of individual blue whales in fishing gear. Determine whether measures to reduce entanglements are effective.

5.5 *Climate change*

5.5.1 Conduct research and perform analyses to understand whether climate change is adversely affecting blue whale distribution, abundance, or fecundity.

5.5.2 If found to be detrimental to blue whale distribution, abundance, or fecundity, take steps to minimize climate change impacts.

6.0 Maximize Efforts to Acquire Scientific Information from Dead, Stranded, and Entangled or Entrapped Blue Whales

6.1 *Make every effort to necropsy stranded blue whales located in U.S. waters to determine cause of death.*

6.2 *Review, analyze, and summarize data on dead blue whales and causes of death.*

6.3 *Establish reliable sources of funding for necropsy (including sites to conduct the necropsy), tissue collection, and analysis efforts.*

B. Recovery Action Narrative

Recovery actions in this outline are not in order of priority. Priorities are identified in the Implementation Schedule (Section V below). Unless otherwise indicated, the relevant "site" for each recovery action is throughout all nine management units.

1.0 Coordinate Federal and International Measures to Maintain International Regulation of Whaling for Blue Whales

Work through the IWC and other relevant international bodies or agreements to ensure that the moratorium on blue whale commercial hunting is maintained and manage subsistence or scientific hunting in consultation with the IWC's Scientific Committee to ensure that hunted whale populations are maintained at (or returned to) sustainable levels. The international regulation of whaling is vital to the recovery of whale populations. A full assessment of present status has not been conducted and there is a lack of sufficient information on blue whale population size, trends, and structure to justify the resumption of exploitation.

This action is expected to involve staff time (see Table 2); costs associated with travel to IWC meetings, for example, is included in other large whale recovery plans (NMFS 2010a, NMFS 2010b).

2.0 Determine Blue Whale Taxonomy, Population Structure, Occurrence, Distribution, and Range

Existing knowledge of the population structure of blue whales is insufficient, and a more comprehensive understanding is essential for developing strategies to promote recovery and for classifying the populations according to their recovery status. Subspecies taxonomy remains unresolved, but it is almost certain that the global listing inadequately captures the current population structure.

Analyses should be directed at examining trends over time, and attempts should be made to correlate observed changes in whale populations with physical, biological, or human-induced changes in the environment. As much as possible, data should be presented in peer-reviewed journals and other open publications to ensure that research programs benefit from regular peer scrutiny.

2.1 Conduct studies to investigate population discreteness and population structure of blue whales

This action will improve understanding and management of the species. It cannot be given a Priority 1 ranking because basic studies of population structure would not contribute to preventing extinction.

Researchers equipped to sample other whale species (*e.g.*, fin, right, and humpback whales), particularly in more remote areas where blue whale samples have not previously been obtained, should be encouraged to take advantage of opportunities to obtain samples from blue whales, on an opportunistic basis. Collaborative efforts with agencies, organizations, and researchers in other nations will be necessary to obtain sufficient samples over sufficiently broad areas for conclusions regarding population structure. Standardized sampling protocols and analytical procedures should be developed and used. Genetics work should be complemented by a thorough review of existing data from whaling and other sources. This might include investigation of geographical variation in morphology and acoustics of blue whales. New methods examining stable isotopes and fatty acids have also proven effective auxiliary data in cases where there is population mixing (*i.e.*, genetically distinct groupings mixing spatially on feeding grounds). Any such methods that can assist in resolving population structure should be encouraged.

Costs in the implementation schedule (Table 2) include equipment used and analysis of genetic and other data, as well as costs for opportunistic data collection during ship-based surveys (see 3.2 for additional costs associated with dedicated ship-based surveys).

2.2 Conduct studies to assess blue whale occurrence, daily and seasonal movements, and inter-area exchange

Telemetry studies using satellite-linked and radio tags can be useful in investigating patterns and ranges of daily, seasonal, and longer-term movements of individual blue whales. Tagging studies are also useful for determining habitat use and identifying locations of any unknown breeding and feeding grounds. Exchange rates between populations might also be addressed to some degree by telemetry studies. Long-term efforts at photo-identification should also be encouraged to continue and opportunistic efforts to photo-document sightings could contribute to knowledge of movements by individuals and residency times. A central repository for blue whale photographs, and a system for curating and analyzing them, should be established. Photographs should be supplemented whenever possible by tissue samples (whether sloughed skin or biopsies) for DNA fingerprinting (Amos & Hoelzel 1992).

Like other baleen whales, blue whales make low-frequency vocalizations that are audible over long distances. Detection of underwater calls of a number of cetacean species has been used in studies of cetacean occurrence and distribution. Large whale species tend to vocalize rather often, depending on behavioral, social, and other contexts, and the technique has proven effective in determining presence (but not absence) of large whales. With arrays of three or more detection elements (to enable "triangulation"), information on distribution, and in some cases abundance, and habitat use can be determined. Bottom-mounted recording systems have been used to detect baleen whales with considerable success. Particularly when considered relative to vessel- or aircraft-based observer surveys, passive acoustic techniques are highly cost-effective, are less limited by poor weather conditions and thus are able to make observations more consistently, and pose fewer risks to human observers. Therefore, and particularly with regard to their cost-effectiveness, passive acoustic studies should be used, if feasible, in attempts to determine blue whale occurrence, distribution, abundance, trends in abundance, and possibly response to some threats (*e.g.*, anthropogenic underwater noise).

The distribution and habitat use of marine mammals, including blue whales, can be studied along predetermined transect lines using autonomous gliders equipped with instrumentation to: 1) record low and mid-frequency marine mammal vocalizations; 2) detect, classify, and remotely report vocalizations of interest; and 3) measure high-frequency acoustic backscatter, chlorophyll fluorescence, and oceanographic conditions. Therefore, passive acoustic data can be used to document the distribution of acoustically active marine mammals, including blue whales, and accompanying environmental and oceanographic measurements. Autonomous gliders allow researchers to collect data in areas they are not able to access or in seasons they cannot survey using other means. Onboard detectors for baleen whales currently exist for gliders.

Costs in the implementation schedule (Table 2) include equipment deployed and data analysis.

2.3 Support the development of models to yield robust predictions of blue whale distribution.

A number of species distribution models have been developed, using various methods and data sets. The modelling community has recognized the value of using predictions from a set ("ensemble") of models rather than those from a single model because multi-model weighted averages often yield more robust predictions (Pérez-Jorge *et al.* , Wintle *et al.* 2003, Johnson & Omland 2004, Araujo & New 2007, Forney *et al.* 2015, Jones & Cheung 2015). For blue whales in the Eastern North Pacific and the California Current, the recent creation of species distribution models makes this a feasible candidate for generating robust predictions using ensemble averaging. Once this has been developed for the Eastern Pacific blue whale stock, the applicability of this type of work should be considered for blue whales that inhabit other areas.

Please note that there are no specific costs associated with this action, as it is covered by NMFS staff time only (Table 2).

3.0 Estimate Population Size and Monitor Trends in Abundance

Along with determining population structure, assessing population abundance and trends in abundance are a priority action in this plan. Although abundance estimates are available for some management units, estimates are not available for others, or may be imprecise or limited to geographic areas rather than population units. Ongoing work to assess blue whales in the U.S. and in other parts of the world should also be encouraged and supported.

3.1 Establish collaborative agreements with relevant national governmental bodies and scientific institutions to develop plans for estimating abundance and monitoring trends in abundance.

For accurate abundance estimates, it will be necessary for U.S. agencies and scientists to promote and participate in cooperative surveys with scientists from other countries. A primary goal should be to foster international collaboration and cooperation in the study and protection of the worldwide population of blue whales.

Please note that there are no specific costs associated with this action, as it is covered by NMFS staff time only (Table 2).

3.2 Conduct surveys to estimate blue whale abundance and monitor trends in abundance worldwide.

Systematic surveys should be conducted to assess abundance in areas known, primarily from historic whaling data and large-scale sighting surveys, to have been inhabited regularly by blue whales in the past. The planning of such surveys would be important to capture and understand the occurrence and locations of these whales' annual migrations. Findings from population structure studies identified in action 2.0, above, will be useful in interpreting survey results, because abundance and growth rates may differ between populations. Long-term studies should be anticipated to fully capture population growth rates and possible inter-annual variation in regional occurrence. Potential cost savings might be achieved by combining these studies with other large ship-based research projects and other objectives listed in this Revised Recovery Plan. Population models should be developed to assess past, present, and future trends to better understand the role human-induced mortality and identified threats contribute to blue whale extinction risk.

Costs in the implementation schedule (Table 2) include equipment used and analysis of systematic surveys to assess abundance in known areas, as well as costs associated with ship-based surveys and large-scale sighting surveys. As mentioned above, cost savings may be realized from combining these studies with other large ship-based resource projects. Additionally, costs include development of population models to assess past, present, and future trends to better understand the role human-induced mortality and identified threats contribute to blue whale extinction risk.

3.3 To the extent possible, work with appropriate government agencies in other countries to develop and maintain blue whale photo-identification programs, and educate and involve the public about contributing information about live, dead, entangled, or ship-struck whales, to continue to support or establish international databases

In addition to systematic survey data, photo-identification and other data are useful in assessing abundance and monitoring trends. Any existing photo-identification catalogs for blue whales (*e.g.*, Cascadia Research Collective, Baja CA Catalog) should be maintained. Photo-identification data may exist or may be gathered for other locations and habitats and populations. Therefore, efforts should be made to work with appropriate agencies in other countries to solicit the gathering, housing, and maintaining of blue whale photo-identification data and to make these data available to researchers engaged in related studies. Efforts should also be made to educate and to solicit information from the public regarding live, dead, or injured whales. The scientific importance of such catalogs and data bases has been demonstrated with numerous species, and the possibilities for obtaining information about managing the species will increase as more information is obtained. The public and trained citizen scientists, such as the Channel Islands Naturalist Corps, can add sighting and photographic information on live blue whales to augment systematic surveys to help assess populations. The use of the WhaleAlert and Whale Spotter applications facilitate the contribution of whale sighting data and should be promoted.

Costs in the implementation schedule (Table 2) include equipment used for gathering and housing photo-identification and other data useful in assessing abundance and monitoring trends and maintaining any existing photo-identification catalogs for blue whales. Additionally, costs include making the photo-identification data available to researchers engaged in related studies as well as educating and soliciting information from the public regarding live, dead, or injured whales.

4.0 Identify, Characterize, Protect, and Monitor Habitat Important to Blue Whale Populations

Identifying important habitat and reducing potential threats to blue whale habitat is integral to recovery. Important habitat may or may not qualify as critical habitat under the ESA. Information is needed on environmental factors that influence blue whale distribution. In addition, adequate protective measures are needed to reduce or eliminate human-related impacts to blue whale habitat.

4.1 Characterize blue whale habitat.

Areas where blue whales are consistently seen and heard are assumed to be important to their survival. Areas used infrequently or for short periods may also be linked to population fitness. Some areas are known to be important habitat while others may be discovered during survey work discussed in actions 2.0 and 3.0, above. More research is needed to define rigorously and specifically, the environmental features that make an area important to blue whales. Relevant physical, chemical, biological, fishery, and other data should be collected or compiled to characterize features of important habitats and potential sources of human-caused degradation of what are determined to be important areas for blue whales. Habitat characterization also involves, among other things, descriptions of prey types, densities, and abundances, and of associated oceanographic and hydrographic features. It may also involve characterization of the underwater soundscape, including natural and anthropogenic inputs. Inter-annual variability in habitat features, and in blue whale habitat use, is an important component of habitat characterization. A predictive framework for identifying blue whale habitat is already being used as a management tool in the California Current (Hazen *et al.* 2016). Only with information on the ecological needs of the species will managers be able to provide necessary protections.

Research and analyses to characterize blue whale habitat may also inform evaluation of the effects of climate change, described in 5.5.1 below.

Costs in the implementation schedule (Table 2) include collection of data (*e.g.*, during ship-based surveys, see 3.2), collection of data environmental parameters, and analysis.

4.2 Monitor important habitat features and blue whale use patterns to assess potentially detrimental shifts in habitat features that might reflect disturbance or degradation of habitat.

After baseline data are obtained and analyzed, ongoing studies should be conducted to determine if shifts or changes are occurring in essential habitat components, which might explain or predict changes in blue whale distribution or abundance. Blue whale habitat should be assessed periodically. Shifts in distribution or habitat use should be assessed. Similarly to action 4.1, research and analyses to assess shifts in habitat features may inform evaluation of the effects of climate change, described in 5.5.1 below.

Costs associated with this action (Table 2) are listed as TBD (to be determined) and occurring in FY6 or beyond because baseline data and modeling results from action 4.1 are first needed to determine which aspects of blue whale habitat are most influential in resulting in its use and to inform development of habitat monitoring studies.

4.3 Promote measures to identify and protect important habitat throughout the species' range.

Support efforts to collect and compile data on habitat use patterns, and promote measures to protect and reduce threats, if identified, to important blue whale habitat. Blue whale ranges include international waters, therefore, collaboration with foreign governments should be encouraged including the use of multi-lateral agreements to protect blue whale habitat in multiple EEZs. International efforts to collect and compile data on habitat use patterns for the blue whale population should be supported. Human activities adversely affecting blue whales should be reduced or mitigated, and the United States should support and endorse such efforts. Validation of those areas where blue whales are thought to occur and protection of those areas that are determined as important areas warranting habitat protection should be supported. Finding means to reduce pollution, protect prey resources, and ensure blue whale habitat integrity on large geographic scales and involving multiple nations may be key to the long-term conservation of blue whale populations. The United States should also support, endorse and export knowledge threat reduction efforts employed in the United States (e.g. speed reduction incentive programs, alteration of TSSs, and Areas to Be Avoided adjustments) (Abramson *et al.* 2011; Vessel Strikes and Acoustic Impacts 2012; Hastings *et al.* 2016). Additionally, the West Coast Regional Office of the National Marine Sanctuaries and partners have conducted a wide range of relevant research and monitoring activities (e.g. collecting opportunistic marine mammal sightings since 1996, conducting standardized at-sea surveys for marine mammal distribution and abundance and habitat assessments in central and north-central California since 2004 and employing electronic data collection applications). Since current and future science-based research and monitoring will help refine understanding of whale distribution, applying an adaptive management approach for implementing threat reduction efforts is key (Abramson *et al.* 2011).

Please note that there are no specific costs associated with this action, as it is covered by NMFS staff time only (Table 2).

5.0 Investigate Human-Caused Potential Threats and, Should They Be Determined to Be Limiting Blue Whale Recovery, Take Steps to Minimize Their Occurrence and Severity

5.1 Anthropogenic noise

Blue whales may be disturbed by loud or unfamiliar noises. The scale of their movements may expose them to an array of human activities, including shipping or other commercial vessel traffic, mineral exploration and exploitation (*e.g.* seismic surveys, drilling activities), military operations, and research using acoustic sampling. It is therefore important to understand and reduce the effects of anthropogenic noise on these animals.

5.1.1 Conduct studies to determine whether anthropogenic noise is adversely affecting blue whale distribution, behavior, or vital rates

It is important that the effects of underwater noise on baleen whales become better understood. Studies, such as playback experiments, are needed to assess potential adverse effects of underwater noise (including ship noise) on blue whales, including, but not limited to, disturbance of intraspecific communication, disruption of vital functions, distributional shifts, and stress from chronic or frequent exposure to loud noise. Noise sources studied should include, but are not limited to, industrial and shipping activities, oceanographic experiments, and military-related activities.

Additionally, NOAA's ONMS-WCR are studying ocean acoustics to help understand how anthropogenic noise in the ocean may impact sanctuary resources including blue whales. Several efforts are currently underway. In partnership among ONMS-WCR, NMFS, and NOAA's Pacific Marine Environmental Laboratory (PMEL), NOAA noise reference station nodes have been deployed in or just outside CBNMS, GFNMS, Channel Islands National Marine Sanctuary (CINMS), and Olympic Coast National Marine Sanctuary (OCNMS). CINMS is working with Scripps Institute of Oceanography, and NMFS West Coast Regional Office, to continue to support long-term underwater ocean noise studies in the Santa Barbara Channel. Monterey Bay Aquarium Research Institute (MBARI) has a cabled hydrophone in MBNMS providing monitoring of ocean acoustics in the area including whale calls.

Costs in the implementation schedule (Table 2) include support for research such as a behavioral response studies (*e.g.,* (Southall *et al.* 2012) and data analysis.

5.1.2 Take steps to minimize anthropogenic noises that are found to be detrimental to blue whale

If particular sources or types of underwater noise are found to adversely affect blue whale abundance and recovery, develop and implement appropriate management measures to reduce the threat. In countries, including the U.S., that issue permits and/or otherwise review activities conducted by their citizens, continue existing permitting and consultation processes to review project applications for acoustic impacts to blue whales, and require appropriate monitoring and mitigation measures.

Costs in the implementation schedule (Table 2) are listed as TBD because the step(s) taken to minimize noise found to be detrimental to blue whales (beyond those associated with ongoing permitting and consultation processes) will depend on the findings from 5.1.1 and a determination of whether anthropogenic noise is impeding blue whale recovery.

5.2 Vessel collisions

5.2.1 Maintain database of known ship strikes of blue whales.

Consolidate records and maintain a database of known ships strikes to support analyses described below.

Please note that there are no specific costs associated with this action, as it is covered by NMFS staff time only (Table 2).

5.2.2 Review photographic databases for evidence of injuries to blue whales from ship strikes to better characterize these events.

Existing databases, especially those with extensive photographic records of blue whale observations, should be searched for evidence of ship strikes. Although the records may not be sufficient to quantify blue whale injury or mortality rates from this source, such a review might help characterize types of vessels and locations that are prone to ship strike interactions. This, in turn, will help in developing threat-reduction measures.

Please note that there are no specific costs associated with this action, as it is covered by NMFS staff time only (Table 2), as well as costs identified for action 3.3.

5.2.3 Conduct studies to identify areas of high risk for blue whale ship strikes and monitor high risk areas in order to evaluate the effect on blue whales.

Areas where high vessel traffic and whale densities overlap should be identified (which has already been done off the California coast, as noted in section 4.3). Areas where ship strikes of blue whales are relatively frequent should also be identified, and high risk areas should be monitored.This information will help determine the severity of ship strike risk and facilitate developing and implementing measures to reduce ship strikes.

Initial costs associated with this action include NMFS and USCG staff costs associated with identification of areas where high vessel traffic and whale densities overlap, as well as identification of areas where ship strikes of blue whales are relatively frequent. Costs for the remaining fiscal years will be covered by NMFS staff time only (Table 2).

5.2.4 Conduct studies to determine whether collisions with ships are adversely affecting blue whale abundance and recovery.

Evaluate the magnitude of the risk of ship strikes on blue whale populations to determine the relative impact to recovery. Studies similar to that done by Monnahan *et al.* (2015) could be conducted for blue whale populations in various locations.

Please note that there are no specific costs associated with this action, as it is covered by NMFS staff time only (Table 2).

5.2.5 If ship strikes are determined to be detrimental to blue whale abundance and recovery, work with mariners, the shipping industry, and appropriate state, federal, and international agencies to develop and implement measures to reduce the threat of ship strikes, and report strikes, should they occur. Maintain the traffic separation schemes off the U.S. West Coast, and evaluate and adjust, as appropriate.

The practicality and effectiveness of options to reduce ship strikes should be assessed within the U.S. and to the maximum extent at an international scale as well. Ship strike reduction management programs and seasonal speed reduction recommendations for large commercial vessels have been developed for National Marine Sanctuaries (e.g., Channel Islands Advisory Council; Abramson *et al.* 2011, Hastings *et al.* 2016) and should be supported elsewhere to pursue spatial management, vessel speed reduction (VSR), and technology that could reduce the impact of ship strikes. Methods and measures developed for other endangered whales (*e.g.*, North Atlantic right whales) should be considered for their possible application to blue whale populations, as should any current options to reduce ship strikes that have been applied to blue whales in various locations.

Costs in the implementation schedule (Table 2) are listed as TBD because the step(s) taken to address risk of ship strikes will depend on the findings from the other actions in 5.2 and a determination of whether ship strikes are impeding blue whale recovery.

5.3 Marine debris

5.3.1 Identify if blue whale habitat and significant deposits of marine debris coincide and evaluate the effect on blue whales.

Harmful marine debris can include plastics and other materials washed or blown from land into the sea, abandoned or lost fishing gear, and solid non-biodegradable materials disposed of by ships at sea. As mentioned in section H.1, stomach obstruction caused by marine debris has not been documented in blue whales, but there are documented cases of marine debris ingestion in other whale species (Viale *et al.* 1991, Tarpley & Marwitz 1993). Aside from the threat of entanglement described below, lost/abandoned gear may also be ingested by blue whales, and cause physical blockage in the digestive system leading to internal injuries or death. Areas with a high concentration of marine debris should be identified and monitored, particulary where marine debris and blue whale densities overlap. This information will help determine whether marine debris is a threat to blue whales. Furthermore, research should be carried out to determine if and how marine debris affects blue whale health and survival.

Costs in the implementation schedule (Table 2) include staff costs associated with the studies described above, including the identification of areas where marine debris and whale densities overlap, as well as identification of areas where ingestion of marine debris by blue whales is relatively frequent. Studies should also consider the effects of marine debris ingestion on blue whale health and survival.

5.3.2 Conduct studies to determine whether marine debris is adversely affecting blue whale abundance and recovery.

Evaluate the magnitude of the risk of marine debris ingestion on blue whale populations to determine the relative impact to recovery.

Please note that there are no specific costs associated with this action, as it is covered by NMFS staff time only (Table 2). Cost savings may be realized from combining this work with actions 2.0 and 3.0.

5.3.3 If found to be detrimental to blue whale abundance and recovery, develop and implement means to reduce marine debris, including lost fishing gear, and improve the reporting of lost gear.

If marine debris is determined to be significantly detrimental to blue whales, research and management measures are recommended to better address the potential threat posed by marine debris. If fishing gear ingestion is found to be detrimental to blue whales, methods to reduce fishing gear loss and improve the reporting of lost gear should be implemented.

Costs in the implementation schedule (Table 2) will depend on the findings from the other actions in 5.3. If it is determined that marine debris and/or fishing gear ingestion are impeding blue whale recovery, costs will include NMFS staff costs for the development of methods to reduce marine debris and/or fishing gear loss, and development of reporting mechanisms (in consultation with international partners) to improve reporting of lost gear. Cost savings may come from combining this work with action 5.4.4.

5.4 Fishing gear entanglement

5.4.1 Review data on blue whale entanglement in fishing gear, including reports from fishermen and fishery observers.

As mentioned in section H1, there have been very few confirmed cases of blue whale entanglements in fishing gear, however it is suspected that this likely represents only a fraction of the entanglements and more information is needed to determine if this is a significant cause of mortality. To this end, existing data on entanglements in fishing gear should be reviewed, including an evaluation of potential overlaps in distribution between fishing operations and blue whales to understand the types of fisheries and fishing gear that might pose the greatest risk to blue whales.

Reports from fishermen/women and fishery observers may provide valuable information about fishing gear entanglements and the potential harmful consequences for blue whales. .

Please note that there are no specific costs associated with this action, as it is covered by NMFS staff time only (Table 2).

5.4.2 Review photographic databases for evidence of injury to blue whales caused by fishing gear entanglement.

Existing databases, especially those with extensive photographic records of blue whale observations, should be searched for evidence of fishing gear entanglements. Although the records may not be sufficient to quantify blue whale injury or mortality rates from this source, such a review might provide indications about the nature and extent of fishing gear entanglements. This, in turn, will help in developing threat-reduction measures.

Please note that there are no specific costs associated with this action, as it is covered by NMFS staff time only (Table 2).

5.4.3 Conduct studies to determine if fishing gear entanglement is adversely affecting blue whale abundance and recovery.

Evaluate the magnitude of the risk of fishing gear entanglements on blue whale populations to determine the relative impact to recovery.

Please note that there are no specific costs associated with this action, as it is covered by NMFS staff time only (Table 2). Cost savings may be realized from combining this work with actions 2.0 and 3.0.

5.4.4 If found to be detrimental to blue whale abundance and recovery, develop means to reduce entanglements, and enhance the effectiveness of disentanglement of individual blue whales in fishing gear. Determine whether measures to reduce entanglements are effective.

Research on possible modifications to fishing gear that may allow an entangled whale to free itself should be fostered or continued if underway. These studies might include assessing the potential use of biodegradable lines, studying ways to reduce the number and length of vertical lines in the water column, designing breakaway lines for heavy gear, and researching acoustic deterrents.

Costs in the implementation schedule (Table 2) are listed as TBD because the step(s) taken to address risk of fishing gear entanglement will depend on the findings from 5.4.1 and 5.4.2, and a determination of whether fishing gear entanglement is impeding blue whale recovery.

5.5 Climate change

5.5.1 Conduct research and perform analyses to understand whether climate change is adversely affecting blue whale distribution, abundance, or fecundity.

Improved knowledge of the effects of climate change on blue whale feeding ecology and habitat use would be informative for evaluating or predicting shifts in prey abundance or distribution caused by climate change. Similarly, information on the environmental drivers influencing distribution of blue whales and their prey, and the long-term changes in these factors, will aid in understanding the overall impact, if any, to various blue whale populations resulting from climate change. Although the natural absorption of carbon dioxide (CO_2) by the world's oceans helps mitigate the climatic effects of anthropogenic emissions of CO_2, it is believed that the resulting decrease in pH will have negative consequences. While the full ecological consequences of these changes are not known, organisms such as blue whales may suffer adverse effects, either directly as reproductive or physiological effects or indirectly through negative impacts on their food resources.

Research and analyses on blue whale abundance, distribution, and habitat characteristics conducted as part of other identified recovery actions (2.0, 3.0, and 4.0) may be informative for understanding effects of climate change. Any efforts to combine data collection or analysis would reduce costs.

5.5.2 If found to be detrimental to blue whale distribution, abundance, or fecundity, take steps to minimize climate change impacts.

Strategies developed through international efforts to minimize the effects of climate change on blue whales and the ecosystems they inhabit should be pursued. However, costs in the implementation schedule (Table 2) are listed as TBD because the step(s) taken to address climate change impacts will depend on the findings from 5.5.1 and a determination of whether climate change is impeding blue whale recovery.

6.0 Maximize Efforts to Acquire Scientific Information from Dead, Stranded, and Entangled or Entrapped Blue Whales

Assessments of the causes and frequency of mortality (either natural or human-caused) is important to understanding population dynamics and threats that may impede improving the status of blue whale populations. Therefore, cause of death determinations are an important part of recovery and threat reduction actions. Discovery of an animal under circumstances allowing response and, if dead, necropsy in a timely and rigorous manner is a relatively rare event. Accordingly, efforts to detect and investigate blue whale deaths, strandings, and other responses should be as efficient as possible.

6.1 Make every effort to necropsy stranded blue whales located in U.S. waters to determine cause of death.

The detection and reporting of blue whales, whether stranded or floating at sea, need to be encouraged. Marine Mammal Stranding Network coordinators should continue working with representatives of local, state, and federal agencies, private organizations, academic institutions, and regional and local stranding networks, to ensure use of accepted reporting procedures, implement standardized necropsy protocol, and facilitate information exchange. In addition, the ONMS-WCR, NMFS West Coast Regional Office, and NMFS Science Centers will continue to support necropsies of all stranded whales. In areas where protocols do not exist, they should be developed. As part of this effort, responsibilities of all relevant agencies, organizations, and individuals should be clearly defined.

Blue whales may die at sea, but may not be detected or reported. Mariners, Navy, and Coast Guard personnel; commercial and recreational boaters; and fishermen might observe carcasses at sea, but may not recognize the importance of their observation. All federal and state personnel, boaters, and fishermen should be educated about the importance of reporting carcasses so worthwhile information might be collected.

Each blue whale carcass represents an opportunity for scientific investigation of the cause of death, as well as addressing other questions related to the biology of the species. Delays in attempts to secure or examine a carcass can result in the loss of valuable data, or even of the carcass itself. Stranding Network coordinators should work with appropriate agencies, organizations, and individuals to ensure that, when a blue whale carcass is reported and secured: (i) a necropsy is performed as rapidly and as thoroughly as possible by qualified individuals to gather information regarding the cause of death; (ii) samples are taken and properly preserved for studies of genetics, toxicology, and pathology; and (iii) funding is available to notify and transport appropriate experts to planned necropsy sites rapidly and to distribute tissue samples to appropriate locations for analysis or storage. In addition, coordinators should work with stranding networks and the scientific community to develop and maintain lists of tissue samples requested by qualified individuals and agencies, and ensure that these samples are routinely collected from each carcass and stored in designated locations or distributed to appropriate researchers.

Strandings of blue whales are relatively rare. Costs in the implementation schedule (Table 2) include necropsy and stranding response for blue whales in the U.S. EEZ. Costs for necropsy and response throughout the blue whales' range may be significantly greater.

6.2 Review, analyze, and summarize data on dead blue whales and causes of death.

Current and complete data from stranding events is essential to developing protective measures. These data are likely to be useful in determining the magnitude of potential threats such as vessel strikes, entanglements, and impacts of climate change.

Please note that there are no specific costs associated with this action, as it is covered by NMFS staff time only (Table 2).

6.3 Establish reliable sources of funding for necropsy (including sites to conduct the necropsy), tissue collection, and analysis efforts.

Collection of information from blue whale carcasses is essential to recovery efforts. Therefore, identifying and committing predictable sources of funding for completing necropsy, tissue collection, and analysis efforts is also critical.

Please note that there are no specific costs associated with this action, as it is covered by NMFS staff time only (Table 2).

V. IMPLEMENTATION SCHEDULE

The implementation schedule that follows is used to estimate costs to direct and monitor implementation and completion of recovery actions set forth in this Revised Recovery Plan. It is a guide for meeting recovery goals outlined in this Revised Recovery Plan. The implementation schedule indicates the action numbers, action descriptions, action priorities, duration of the action, the parties potentially involved in the actions, and estimated costs. While parties with authority, responsibility, or expressed interest to implement a specific recovery action are identified in the implementation schedule, this does not require any identified party to implement the action(s) or to secure funding for implementing the action(s).

Priorities in column 3 of the implementation schedule are assigned as follows:

> Priority 1 – These are the recovery actions that must be taken to remove, reduce, or mitigate major threats and *prevent extinction* and often require urgent implementation. Priority 1 actions may include research actions needed to fill knowledge gaps and identify management actions necessary to prevent extinction.
>
> Priority 2 – These are recovery actions to remove, reduce, or mitigate major threats and prevent continued population decline or research needed to fill knowledge gaps, but their implementation is less urgent than Priority 1 actions.
>
> Priority 3 – These are all recovery actions that should be taken to remove, reduce, or mitigate any remaining, non-major threats and ensure the species can maintain an increasing or stable population to achieve delisting criteria, including research needed to fill knowledge gaps and monitoring to demonstrate achievement of demographic criteria.

This implementation schedule accords priorities to individual actions to specify their importance in the recovery effort. It should be noted that even the highest-priority actions within a plan are not given a Priority 1 ranking unless they are actions necessary to prevent extinction or to identify those actions necessary to prevent extinction.

As discussed in Section I.H above, while there are no known current operative threats to the species, there are numerous potential threats. These include potential threats that are known to be affecting one or more subspecies or populations, but more research is needed to understand the extent to which the stressor occurs or affects the globally listed entity. As such, many of the recovery actions addressing potential threats to blue whale are listed as Priority 1 if research and/or other monitoring efforts identify that the potential threats are indeed operative threats to blue whale recovery. We cannot know the outcome of the research or monitoring efforts before they occur. If research does not support identification of these potential threats as operative threats, then the recovery actions addressing them should be considered lower priority. In addition, the research actions will also contribute to monitoring of stressors to confirm that they remain at insignificant levels that do not limit recovery.

For each of the six major recovery actions, Table 2 provides cost sub-totals in ***bold italics***. Recovery actions are linked, in that the ability to complete one may depend on outcomes from a previous study. However, the costs of recovery actions are estimated individually. Additionally, many of the recovery actions are similar to those identified in other NMFS large whale recovery plans (see https://www.fisheries.noaa.gov/resources/documents) and might be expected to provide information on or benefit other large whales in the area. However, the costs of recovery actions are estimated as if efforts are specific to blue whales. Therefore, in some cases the identified costs of actions that benefit multiple species may be overestimates.

Costs are estimated in accordance with the number of years necessary to complete the action once implementation has begun. Some costs are listed over discrete periods of time (*e.g.*, 5 years), while others are listed as ongoing. "Ongoing" means that the action should be conducted regularly or opportunistically for the foreseeable future, until the knowledge gap has been filled, or until the threat has been reduced to the point where it is no longer a concern.

It is not possible to predict the time and total cost to recovery with the current information available because of the uncertainty of which potential threats are actually operative threats, as explained previously. Thus, an estimate of the time required and the cost to carry out those actions needed to achieve the plan's goal and to achieve intermediate steps (beyond 5 years) is not practicable. Conducting research necessary to support conclusions regarding the impact of potential threats to blue whale populations, and developing, implementing, and evaluating the effectiveness of management measures to reduce threats or potential threats may take decades. The minimum data needed to satisfy criterion 1 for downlisting or delisting are population structure studies and abundance surveys, which will also take decades, given the species' global distribution and requirement to evaluate the trend in abundance over a 30 year period. In the future, as more information is obtained, it may be possible to develop estimates for the entire time to recovery and its expense.

Table 2. Implementation Schedule by Fiscal Year

Action Number	Action Description	Priority	Action Duration (years)	Agencies/ Organizations Potentially Involved	Cost Estimates by FY (thousands of dollars)						
					FY1	FY2	FY3	FY4	FY5	FY6+[8]	Total[9]
1.0	***Coordinate Federal and International Measures to Maintain International Regulation of Whaling for Blue Whales***	1	Ongoing	NMFS, IWC, International Partners, U.S. Department of State	*	*	*	*	*	*	*
TOTAL 1					*****	*****	*****	*****	*****	*****	*****
2.0	***Determine Blue Whale Taxonomy, Population Structure, Occurrence, Distribution, and Range.***										
2.1	*Conduct studies to investigate population discreteness and population structure of blue whales*	2	Ongoing (15+)	NMFS, IWC, International Partners	250	250	250	250	250	250+	1,500+
2.2	*Conduct studies to assess blue whale occurrence, daily and seasonal movements, and inter-area exchange*	2	Ongoing (15+)	NMFS, IWC, Navy, International Partners, Non-Governmental Partners	150	150	150	150	150	150+	900+
2.3	*Support the development of models to yield robust predictions of blue whale distribution.*	2	4-5	NMFS, IWC, Non-Governmental Partners	*	*	*	*	*	*	*
TOTAL 2					400	400	400	400	400	400+	2,400+

[8] For actions with a discrete duration exceeding five fiscal years, the FY6+ column includes total costs anticipated after FY1-5. For ongoing actions (see definition of "ongoing" above), costs beyond FY5 are listed as a single year's cost with the symbol "+" to indicate additional, ongoing annual costs.
[9] For actions with a discrete duration, the total is the sum of anticipated costs across the action's duration. For ongoing actions, the total is the sum of the first six fiscal years (FY1-6) with the symbol "+" to indicate additional, ongoing annual costs.

Action Number	Action Description	Priority	Action Duration (years)	Agencies/ Organizations Potentially Involved	Cost Estimates by FY (thousands of dollars)						
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	**FY6+[8]**	**Total[9]**
3.0	***Estimate Population Size and Monitor Trends in Abundance***										
3.1	*Establish collaborative agreements with relevant national governmental bodies and scientific institutions to develop plans for estimating abundance and monitoring trends in abundance.*	2	3-5	NMFS, IWC, International Partners, U.S. Department of State	*	*	*	*	*	*	*
3.2	*Conduct surveys to estimate blue whale abundance and monitor trends in abundance worldwide.*	2	Ongoing (15+)	NMFS, International Partners, Non-Governmental Partners	700	700	700	700	700	700+	4,200+
3.3	*To the extent possible, work with appropriate government agencies in other countries to develop and maintain blue whale photo-identification programs, and educate and involve the public about contributing information about live, dead, entangled, or ship-struck whales, to continue to support or establish international databases*	2-3	Ongoing	NMFS, International Partners, Non-Governmental Partners	80	80	80	80	80	80+	480+
TOTAL 3					780	780	780	780	780	780+	4,680+
4.0	***Identify, Characterize, Protect, and Monitor Habitat Important to Blue Whale Populations***										
4.1	*Characterize blue whale habitat.*	2	5	NMFS, International Partners, Non-Governmental Partners	400	400	400	400	400	TBD	2,000
4.2	*Monitor important habitat features and blue whale use patterns to assess potentially detrimental shifts in habitat features that might reflect disturbance or degradation of habitat.*	2	Ongoing	NMFS, International Partners, Non-Governmental Partners	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Action Number	Action Description	Priority	Action Duration (years)	Agencies/ Organizations Potentially Involved	Cost Estimates by FY (thousands of dollars)						
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	**FY6+**[8]	**Total**[9]
4.3	*Promote measures to identify and protect important habitat throughout the species' range.*	2	Ongoing	NMFS, International Partners	*	*	*	*	*	*	*
TOTAL 4					400	400	400	400	400	TBD	2,000+
5.0	***Investigate Human-Caused Potential Threats and, Should They Be Determined to Be Limiting Blue Whale Recovery, Take Steps to Minimize Their Occurrence and Severity***										
5.1	*Anthropogenic noise*										
5.1.1	*Conduct studies to determine whether anthropogenic noise is adversely affecting blue whale distribution, behavior, or vital rates*	2	5-10 years	NMFS, U.S. Navy, Bureau of Ocean Energy and Management (BOEM); International Partners, Non-Governmental Partners	300	300	300	*	*	*	900
5.1.2	*Take steps to minimize anthropogenic noises that are found to be detrimental to blue whale*	1	Ongoing	NMFS, U.S. Navy, BOEM	TBD	TBD	TBD	TBD	TBD	TBD	TBD
5.2	*Vessel collisions*										
5.2.1	*Maintain database of known ship strikes of blue whales.*	2	Ongoing	NMFS, IWC	*	*	*	*	*	*	*
5.2.2	*Review photographic databases for evidence of injuries to blue whales from ship strikes to better characterize these events.*	2	Ongoing	NMFS	*	*	*	*	*	*	*
5.2.3	*Conduct studies to identify areas of high risk for blue whale ship strikes and monitor high risk areas in order to evaluate the effect on blue whales.*	2	2	NMFS, USCG	30	30	*	*	*	*	60
5.2.4	*Conduct studies to determine whether collisions with ships are adversely affecting blue whale abundance and recovery.*	2	Ongoing	NMFS	*	*	*	*	*	*	*

Action Number	Action Description	Priority	Action Duration (years)	Agencies/ Organizations Potentially Involved	Cost Estimates by FY (thousands of dollars)						
					FY1	FY2	FY3	FY4	FY5	FY6+[8]	Total[9]
5.2.5	*If ship strikes are determined to be detrimental to blue whale abundance and recovery, work with mariners, the shipping industry, and appropriate state, federal, and international agencies to develop and implement measures to reduce the threat of ship strikes, and report strikes, should they occur. Maintain the traffic separation schemes off the U.S. West Coast, and evaluate and adjust, as appropriate.*	1	Ongoing	NMFS, USCG, International Maritime Organization, International Partners	TBD	TBD	TBD	TBD	TBD	TBD	TBD
5.3	*Marine debris*										
5.3.1	*Identify if blue whale habitat and significant deposits of marine debris coincide and evaluate the effect on blue whales.*	2	Ongoing	NMFS, IWC, International Partners	100	100	100	100	100	100+	600+
5.3.2	*Conduct studies to determine whether marine debris is adversely affecting blue whale abundance and recovery.*	2	Ongoing	NMFS	*	*	*	*	*	*	*
5.3.3	*If found to be detrimental to blue whale abudance and recovery, develop and implement means to reduce marine debris, incuding lost fishing gear, and improve the reporting of lost gear.*	1	TBD	NMFS, International Partners	TBD	TBD	TBD	TBD	TBD	TBD	TBD
5.4	*Fishing gear entanglement*										
5.4.1	*Review data on blue whale entanglement in fishing gear, including reports from fishermen and fishery observers..*	2	Ongoing	NMFS	*	*	*	*	*	*	*

Action Number	Action Description	Priority	Action Duration (years)	Agencies/ Organizations Potentially Involved	Cost Estimates by FY (thousands of dollars)						
					FY1	FY2	FY3	FY4	FY5	FY6+[8]	Total[9]
5.4.2	*Review photographic databases for evidence of injury to blue whales caused by fishing gear entanglement.*	2	Ongoing	NMFS	*	*	*	*	*	*	*
5.4.3	*Conduct studies to determine if fishing gear entanglement is adversely affecting blue whale abundance and recovery*	2	Ongoing	NMFS	*	*	*	*	*	*	*
5.4.4	*If found to be detrimental to blue whale abundance and recovery, develop means to reduce entanglements, and enhance the effectiveness of disentanglement of individual blue whales in fishing gear. Determine whether measures to reduce entanglements are effective.*	1	TBD	NMFS, International Partners, Non-Governmental Partners	TBD	TBD	TBD	TBD	TBD	TBD	TBD
5.5	*Climate change*										
5.5.1	*Conduct research and perform analyses to understand whether climate change is adversely affecting blue whale distribution, abundance, or fecundity*	2	Ongoing	NMFS, IWC, NOAA's National Ocean Service (NOS), NOAA Office of Oceanic and Atmospheric Research	150	150	150	150	150	150+	900+
5.5.2	*If found to be detrimental to blue whale distribution, abundance or fecundity, take steps to minimize climate change impacts.*	1	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
TOTAL 5					***580 and TBD***	***580 and TBD***	***550 and TBD***	***250 and TBD***	***250 and TBD***	***250+ and TBD***	***2,460+ and TBD***
6.0	***Maximize Efforts to Acquire Scientific Information from Dead, Stranded, and Entangled or Entrapped Blue Whales***										

Action Number	Action Description	Priority	Action Duration (years)	Agencies/ Organizations Potentially Involved	Cost Estimates by FY (thousands of dollars)						
					FY1	FY2	FY3	FY4	FY5	FY6+[8]	Total[9]
6.1	*Make every effort to necropsy stranded blue whales located in U.S. waters to determine cause of death.*	2	Ongoing	NMFS, USCG, States, Stranding networks, other partners	30	30	30	30	30	30+	180+
6.2	*Review, analyze, and summarize data on dead blue whales and causes of death.*	3	Ongoing	NMFS, States, NOS	*	*	*	*	*	*	*
6.3	*Establish reliable sources of funding for necropsy (including sites to conduct the necropsy), tissue collection, and analysis efforts.*	3	Ongoing	NMFS	*	*	*	*	*	*	*
TOTAL 6					***30***	***30***	***30***	***30***	***30***	***30+***	***180+***

*No cost associated; NMFS staff time only

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