Sei Whale
(*Balaenoptera borealis*)

5-Year Review:
Summary and Evaluation

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National Marine Fisheries Service
Office of Protected Resources
Silver Spring, MD
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5-YEAR REVIEW
Sei Whale (*Balaenoptera borealis*)

1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Regional or Headquarters Office
Heather Austin, Office of Protected Resources, 301-427-8422

1.2 Methodology used to complete review

A 5-year review is a periodic analysis of a species' status conducted to ensure that the listing classification of a species currently listed as threatened or endangered on the List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11-17.12) is accurate. The 5-year review is required by section 4(c)(2) of the Endangered Species Act of 1973, as amended (ESA) and was prepared pursuant to the joint National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service's 5-year Review Guidance and Template (NMFS and USFWS 2018). The NMFS Office of Protected Resources (OPR) led the 5-year review with input from NMFS regional offices and science centers. Information was updated from the 5-year review completed in 2012, based on peer-reviewed publications, government and technical reports, conference papers, workshop reports, dissertations and theses. We gathered information through June 2021. The information on the sei whale (*Balaenoptera borealis*) biology and habitat, threats, and conservation efforts was summarized and analyzed based on ESA section 4(a)(1) factors (see Section 2.3) and the recovery criteria identified in the recovery plan (NMFS 2011; Section 2.2.3) to determine whether a reclassification or delisting may be warranted (see Section 3.0).

NMFS initiated a 5-year review of the sei whale and solicited information from the public on January 29, 2018 (83 FR 4032). Three public comment letters, including literature citations were received and incorporated as appropriate in this review.

1.3 Background

1.3.1 FRN Notice citation announcing initiation of this review

83 FR 4032, January 29, 2018

1.3.2 Listing History

<u>Original Listing</u>
FR notice: 35 FR 8491, June 2, 1970 ("grandfathered" in from precursor ESA)
Date listed: 1970
Entity listed: Sei Whale (*Balaenoptera borealis*)
Classification: Endangered

1.3.3 Associated rulemakings: N/A

1.3.4 Review History

Previous Reviews:

S.L. Perry, D.P. DeMaster, and G.K. Silber. 1999. The Great Whales: History and Status of Six Species Listed as Endangered Under the U.S. Endangered Species Act of 1973. Marine Fisheries Review 61:1, pp. 44-51. Department of Commerce.

Conclusion: No change in endangered classification

NMFS. 2012. Sei whale (*Balaenoptera borealis*) 5-year review: summary and evaluation. NMFS Office of Protected Resources, Silver Spring, MD. 21 pages.

Conclusion: No change in endangered classification

1.3.5 Species' Recovery Priority Number at start of 5-year review: 6(C), which indicates that threats are low, recovery potential is low to moderate, and there is the potential for conflict

1.3.6 Recovery Plan or Outline

Name of plan or outline: Final Recovery Plan for the Sei Whale (*Balaenoptera borealis*)
Date issued: Final plan issued December 2011
Dates of previous revisions, if applicable: N/A

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy[1]

2.1.1 Is the species under review a vertebrate?

___**X_Yes**, *go to section 2.1.2*
_____**No**, *go to section 2.2*

[1] To be considered for listing under the ESA, a group of organisms must constitute a "species," which is defined in section 3 of the ESA to include "any subspecies of fish or wildlife or plants, and any distinct population segment [DPS] of any species of vertebrate fish or wildlife which interbreeds when mature". NMFS and USFWS jointly published a policy regarding the recognition of DPSs of vertebrate species under the Endangered Species Act (61 FR 4722, February 7, 1996). "DPS" is not a scientifically defined term; it is a term used in the context of ESA law and policy. Furthermore, when passing the provisions of the ESA that give us authority to list DPSs, Congress indicated that this provision should be used sparingly. We have discretion with regard to listing DPSs and, in order to be consistent with the directive of the Congressional report that followed the introduction of the DPS language in the ESA to identify DPSs sparingly. We will generally not, on our own accord, evaluate listings below the taxonomic species or subspecies level if the best available information indicates that the species or subspecies is in danger of extinction throughout all or a significant portion of its range. We should only identify DPSs if there is an overriding conservation benefit to the species.

2.1.2 Is the species under review listed as a DPS?

_____**Yes**, *give date and go to section 2.1.3.1*
___**X_No**, *go to section 2.1.4*

2.1.3 Was the DPS listed prior to 1996?

_____**Yes**, *go to section 2.1.2*
_____**No**, *go to section 2.2*

2.1.3.1 Prior to this 5-year review, was the DPS classification reviewed to ensure it meets the 1996 policy standards?

_____**Yes**, *provide citation and go to section 2.1.4*
_____**No**, *go to section 2.1.3.2*

2.1.3.2 Does the DPS listing meet the discreteness and significance elements of the 1996 DPS policy?

_____**Yes**, *discuss how it meets the DPS policy, and go to section 2.1.4*
_____**No**, *discuss how it is not consistent with the DPS policy and consider the 5-year review completed. Go to section 2.4., Synthesis.*

2.1.4 Is there relevant new information for this species regarding the application of the DPS policy?

__Yes

__X_No, *go to section 2.2., Recovery Criteria*

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria?

_X__ Yes, *continue to section 2.2.2.*

____ No

2.2.2 Adequacy of recovery criteria.

2.2.2.1 Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat?

_____**Yes**, *go to section 2.2.2.2*
__X__No, *go to section 2.2.3, and note why these criteria do not reflect the best available information. Consider developing recommendations for revising recovery criteria in section 4.0.*

2.2.2.2 Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)?

_____**Yes**, *go to section 2.2.3*
_____**No**, *go to section 2.2.3, and note which factors do not have corresponding criteria. Consider developing recommendations for revising recovery criteria in section 4.0.*

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information.

Downlisting Criteria from the Final Sei Whale Recovery Plan:

1. Given current and projected threats and environmental conditions, the sei whale population in each ocean basin in which it occurs (North Atlantic, North Pacific and Southern Hemisphere) satisfies the risk analysis standard for threatened status (has no more than a 1% chance of extinction in 100 years) and the global population has at least 1,500 mature, reproductive individuals (consisting of at least 250 mature females and at least 250 mature males in each ocean basin). Mature is defined as the number of individuals known, estimated, or inferred to be capable of reproduction. Any factors or circumstances that are thought to substantially contribute to a real risk of extinction that cannot be incorporated into a Population Viability Analysis will be carefully considered before downlisting takes place.

This criterion has partially been met. Although abundance estimates do not include life stages, it is logical to assume that at least a portion of the estimates per ocean basin include mature, reproductive individuals. Thus, while the minimum population threshold has likely been met in the North Atlantic and North Pacific, we cannot draw that same conclusion for the Southern Hemisphere due to the low confidence in the population estimate for this ocean basin. Furthermore, we do not have the data available to conduct a PVA, which is essential to evaluating whether this criterion has been met.

While NMFS acknowledges that the Marine Mammal Protection Act (MMPA) stock structure does not align with the ESA listed entity for sei whales, MMPA stock assessment reports (SARs) contain the best available demographic information for sei whales in U.S. waters. The most recent SARs from 2016, 2017, and 2019 provide the following minimum population estimates for sei whales -- Nova Scotia stock: 3,098 (NMFS 2020); Hawaii stock: 204 (NMFS 2017); Eastern North Pacific stock: 374 (NMFS 2016; NMFS 2018). Currently, there is no accepted abundance estimate for sei whales in the Southern Hemisphere, which is where the heaviest whaling occurred and represents a major portion of the species' range (Reilly *et al.* 2008; Cooke 2018). The best available information indicates that approximately 9,718 sei whales (no CV) were estimated from a combination of surveys from the International Decade of Cetacean Research (IDCR) program and Japanese Scouting Vessel (JSV) data from 1978 to 1988 (International Whaling Commission 1996; NMFS 2012). However, this estimate is considered poor and unreliable because no variance is given and JSV data were not collected according to any kind of statistical design (Reilly *et al.* 2008; Cooke 2018). Based on the history of catches and trends in catch per unit effort (CPUE) data, other estimates range from 9,800 to 12,000 sei whales (no CV) (Mizroch *et al.* 1984; Perry *et al.* 1999; NMFS 2012). However, these estimates are considered poor because CPUE-based abundance estimates are no longer accepted in IWC stock assessments, and the historical back calculation was based on historical catches known to be seriously flawed. Therefore, due to these inherent uncertainties, the Southern Hemisphere lacks reliable abundance information.

There are insufficient data to provide a current and scientifically rigorous estimate of global abundance for sei whales due to limited survey effort (Reilly *et al.* 2008; Cooke 2018). However, a crude estimate of global decline from approximately 250,000 whales before whaling to perhaps 32,000 whales by the 1970s to 1980s is reported (Wiles 2017). Since 2010, sei whale sightings data have been collected in the North Pacific as part of the International Whaling Commission's Pacific Ocean Whale and Ecosystem Research (IWC-POWER) Program, dedicated to North Pacific whale sighting surveys. This program is a collaborative international effort to assess status of large whale populations in North Pacific waters via collection of sightings data to determine abundance and associated trends of large whales (Matsuoka *et al.* 2016; Hakamada *et al.* 2017). In addition, data on sei whale distribution and stock structure have been reported during the second phase of the western North Pacific Japanese Special Permit Program (JARPNII) from 2000 to 2016. Sightings data from these survey programs have helped elucidate distribution and abundance estimates of sei whales in data poor areas of the North Pacific. In addition, observations of sei whales in the Southern Ocean have been noted in recent sighting surveys conducted by the Japanese government via the New Scientific Whale Research Program in the Antarctic Ocean (NEWREP-A) (Isoda *et al.* 2017).

More detailed abundance information by ocean basin is discussed below.

<u>North Atlantic</u>

No estimates of pre-exploitation population size are available and abundance estimates for the entire sei whale population in the North Atlantic remains unknown (Waring *et al.* 2009; NMFS 2012; Prieto *et al.* 2012a). Most of the data on sei whale occurrence result from historical whaling records, thus detailed knowledge of their current abundance and distribution patterns is lacking (Prieto *et al.* 2012a). In recent years, much of the data on distribution and abundance come from either dedicated or opportunistic sighting surveys. In addition, much of the survey information has not been published in peer-reviewed journals, making it difficult to assess and interpret (Prieto *et al.* 2012a).

While total abundance estimates of the sei whale population in the North Atlantic is unknown, abundance estimates do exist for certain regions and seasons (MacLeod *et al.* 2005; Waring *et al.* 2009; Palka *et al.* 2012; Palka *et al.* 2017; Stone *et al* 2017; and Storrie *et al.* 2018). In the northwestern Atlantic Ocean, Mitchell and Chapman (1977) provided stock estimates for the Nova Scotia stock based on tag-recapture data, and compared these estimates to existing shipboard strip census data during the late 1960s. Tag-recapture estimates for the Nova Scotian stock were between 1,393 and 2,248 sei whales. Strip census data gave counts of a minimum of 870 whales off Nova Scotia and 965 whales for the Labrador Sea stock (Mitchell and Chapman 1977). Roberts *et al.* (2016a; 2016b) produced an average summer estimate of 717 (CV=0.30) sei whales for U.S. Atlantic waters and the Canadian Scotian Shelf using data from 1992-2014 aerial and shipboard cetacean surveys. More recently, an updated study, conducted by Palka *et al.* (2017) as part of a multi-agency funded project, used systematic line-transect data collected by NMFS shipboard and aerial surveys from 2011-2015 to produce seasonal abundance estimates of cetaceans in U.S. Atlantic waters. Average seasonal abundances of sei whales from 2010-2013 ranged from 1,872 (CV=0.42) in the summer to 2,489 (CV=0.49) in the fall, to a spring estimate of 6,292 (CV=1.02) indicating a seasonal migration pattern (Palka *et al.* 2017). Additionally, NMFS considers this spring estimate of 6,292 (CV=1.02) as the best available for the Nova Scotia stock of sei whales, because it was derived from surveys covering the largest proportion of their range (Halifax, Nova Scotia to Florida), during the season when they are the most prevalent in U.S. waters (in spring), using only recent data (2010-2013), and correcting aerial survey data for availability bias (NMFS 2020). However, this estimate must be considered uncertain due to lack of surveys for the entire known range of this stock, uncertainties regarding population structure and whale movements between surveyed and unsurveyed areas, and because of issues in data collection and analysis (NMFS 2020).

Systematic surveys of Canadian Atlantic waters in 2007 and 2016 recorded few sei whales, suggesting a current population of less than 1,000 individuals, and below its size at the end of commercial whaling (COSEWIC 2019; NMFS 2020; Gomez *et al.* 2020). Consequently, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) re-examined the Atlantic population of sei whales in May 2019 and recommended uplisting them to endangered (COSEWIC 2019). Thus, the Atlantic population of sei whales has now been added under Schedule 1 of Canada's Species at Risk Act (SARA). In other studies, systematic line-transect aerial surveys from 2011-2015 off the coast of Massachusetts and Rhode Island, yielded a mean abundance range of 0 to 27 individuals with upper 95% confidence limits ranging up to 202, and peak presence in the spring and summer months (Kraus *et al.* 2016; Stone *et al.* 2017).

In the northeastern Atlantic Ocean, Norwegian surveys conducted in 1987, 1989, and annually from 1995-2009 yielded only two sei whale sightings (Reilly *et al.* 2008; Cooke 2018). A shipboard sighting survey with reasonably complete coverage was conducted in 1989 for restricted areas in Icelandic and Faroese waters[2]. This survey produced an estimate of about 10,300 sei whales (CV=0.27) (Cattanach *et al.* 1993; Prieto *et al.* 2014). A recent shipboard sighting survey, conducted as part of the North Atlantic Sightings Survey (NASS) in June/July 2015 (which covered the area between the Faroe Islands and East Greenland from latitude 52˚N to 72˚N), reported an abundance estimate of 3,767 (CV = 0.54) (Pike *et al.* 2019). In addition, vessel-based surveys off the coast of Scotland yielded an estimated 1,011 sei whales (CI = 497-2058) (MacLeod *et al.* 2005; NMFS 2012).

It is important to note that some of the estimates cited above are for restricted areas of the eastern, central, and western North Atlantic, which cover only parts of the known summering habitat for North Atlantic sei whales, and where data are available, it is uncertain what portion of

[2] The survey area for the Icelandic survey was portioned into three main areas: (1) the East Greenland coast, Irminger Sea north of 60˚N and the West Icelandic coast north towards the ice edge; (2) the southwestern to eastern coast of Iceland between 60˚N and 65˚N (eastern boundary located at 7˚W); (3) the southern area, approximately between 50˚N and 60˚N and the IWC stock boundaries at 18˚W and 42˚W (Sigurjonsson *et al.* 1991). The survey area for the Faroese survey was west and north of the Faroe Islands which included part of the Rockall plateau and part of the area within the East Greenland/Iceland stock boundaries (please refer to Figure 2 in Cattanach *et al.* 1993).

the population was actually surveyed. If separate ecological units do exist, it is possible that in some areas they overlap both spatially and temporally and have been treated as a single unit in abundance estimates (Prieto *et al.* 2012a). In addition, earlier estimates based on tagging from tag-recapture programs (e.g. Mitchell and Chapman 1977) are considered inadequate, since for these programs to be effective, large numbers of whales have to be tagged and recaptured in each sampling period (Prieto *et al.* 2012a).

North Pacific

Crude estimation of sei whale abundance in the North Pacific in 1963 and 1974 was attempted by Tillman (1977) using catch per unit effort (CPUE) statistics, sighting data, and various assessment models resulting in an estimated 42,000 and 8,600 whales, respectively (NMFS 2012; Hakamada *et al.* 2017). However, since 500 to 600 sei whales were annually killed between 1910 to the late 1950s, the stock size in 1963 was presumably already below its carrying capacity (Tillman 1977; NMFS 2012). The catch per unit effort for sei whales in California declined by 75 percent between 1960 and 1970 (Rice 1977), which is consistent with the assumption that the overall population was substantially reduced.

More recently, systematically designed sighting surveys were conducted under JARPNII from 2000 to 2016 to estimate sei whale abundance using line transect sampling (Hakamada *et al.* 2017). Partial abundance estimates of sei whales from a survey in the North Pacific[3] in early summer (May-June) in 2011 and 2012 and in late summer (July-September) in 2008 were 2,988 (no CV) and 5,086 (no CV), respectively (Hakamada *et al.* 2017; International Whaling Commission 2017). Hakamada *et al.* (2017) produced a summer abundance estimate of 29,632 (CV=0.242; 95% CI: 18,576-47,267) sei whales in the central and eastern North Pacific[4] by the line transect method utilizing IWC-POWER sighting data from 2010-2012. This was the first abundance estimate for sei whales in this region based on line transect sampling (Hakamada *et al.* 2017). To this can be added an estimate of 5,086 (CV 0.38) obtained from national surveys west of 170°E[5] in the same months in 2008 (Hakamada and Matsuoka 2016), giving a total of about 35,000 sei whales.

Abundance estimates for the two most recent line transect surveys of California, Oregon, and Washington waters in 2008 and 2014 out to 300 nautical miles are 311 (CV=0.76) and 864 (CV=0.40) sei whales, respectively (Barlow 2016). The best estimate of abundance for California, Oregon, and Washington waters out to 300 nautical miles is the unweighted geometric mean of the 2008 and 2014 estimates, or 519 (CV=0.40) sei whales (Barlow 2016). Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Exclusive Economic Zone was evaluated using Beaufort sea-state-specific trackline detection probabilities for sei whales, which produced an abundance estimate of 391 (CV=0.9) sei whales within the Hawaii stock (Bradford *et al.* 2017). However, an earlier estimate from Barlow (2003) using data

[3] Note the southern, northern, eastern, and western boundaries of the survey area of JARPNII were 35˚N, the boundary of the exclusive economic zone (EEZ) claimed by countries other than Japan, 170 E, and the eastern coastline of Japan, respectively.
[4] Note that the area was north of 40°N, south of the Alaskan coast including both the US and Canadian Exclusive Economic Zone between 170°E and 135°W.
[5] Note that the area was east of the Japanese coast, west of 170°E, north of 35°N, south of Russian and US EEZ.

from a 2002 shipboard line-transect survey of the same area in summer and fall produced an abundance estimate of 77 (CV=1.06) sei whales, indicating a seasonal migration pattern.

Southern Hemisphere

The International Whaling Commission (IWC) divides the Southern Hemisphere into six longitudinally defined baleen whale management areas. Although some degree of separation among IWC Areas I–VI has been noted and sei whales have been observed to make dynamic movements between stock designation areas (Donovan 1991), information is sparse regarding population structure within these management areas (NMFS 2012). A pre-exploitation population estimate of 65,000 (no CV) individuals was provided by Braham (1991) in the Southern Hemisphere; this estimate is additionally supported by findings from Mizroch *et al.* (1984), who estimated a pre-exploitation size of 63,100 (no CV) sei whales (NMFS 2012). Additionally, the IWC reported a population estimate of 9,718 sei whales (no CV) based on results of the 1978 through 1988 JSV and IDCR survey data, which is fraught with uncertainty due to the JSV data not being collected according to any kind of statistical design (IWC 1996; NMFS 2012). Abundance estimates derived from CPUE data, range from 9,800 to 12,000 sei whales (no CV) (Mizroch *et al.* 1984; Perry *et al.* 1999; NMFS 2012). However, these estimates are considered poor and fraught with uncertainty as CPUE-based abundance estimates are no longer accepted in IWC stock assessments, and the historical back calculation was based on historical catches known to be seriously flawed. Therefore, due to these inherent uncertainties, the Southern Hemisphere lacks reliable abundance information. Branch and Butterworth (2001) estimated abundance using the IDCR's Southern Ocean Whale Ecosystem Research (SOWER).

A study from Acevedo *et al.* (2017) reported regular occurrence of sei whales within Chile's Magellan Strait and adjacent waters between 2004 and 2015 using sighting data from various systematic cetacean sighting surveys. While these surveys were not designed to provide an abundance estimate for sei whales in the area, the average group size for the entire study period was 3.8 whales (SD = 2.4; median =3; n = 65) (Acevedo *et al.* 2017).

A recent study conducted by Weir *et al.* (2021) provided a new sei whale abundance estimate along the west coast of the Falkland Islands. Weir *et al.* (2021) reported 716 sei whales (CV= 0.22; 95% CI [448, 1,144]), using a design-based approach and 707 sei whales (CV=0.11; 95%CI [777, 1,032]) using a model-based approach via line transect and nonsystematic survey methodologies. This data indicates that the Falkland Islands inner shelf region may support a globally important seasonal feeding ground for sei whales (Weir *et al.* 2021). Furthermore, a study by Baines *et al.* (2020), used generalized additive models (GAMs) and MaxEnt models to predict the relative densities of sei whales around the Falkland Islands, and found that relative density of sei whales increased with sea surface temperature, and their predicted distribution was widespread across the inner shelf which is consistent with the use of Falklands' waters as a coastal summer feeding ground.

Overall, the absence of dedicated systematic and corresponding abundance estimates for Southern Hemisphere sei whales hinders our understanding of the status of sei whales within this ocean basin since the cessation of whaling.

2. Factors that may limit population growth, *i.e.*, those that are identified in the threats analysis under relative impact to recovery as high or medium or unknown, have been identified and are being or have been addressed to the extent that they allow for continued growth of populations. Specifically, the factors in 4(a)(l) of the ESA are being or have been addressed as follows:

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

- *Effects of reduced prey abundance due to climate change continue to be investigated and action is being taken to address the issue, as necessary.* (Threat discussed in Recovery Plan section G.11)

The effects of reduced prey abundance due to climate change continue to be investigated, but whether actions are necessary to address the issue remains unknown.

In the recovery plan, the threat severity posed by environmental variability to sei whale recovery was ranked as medium due to the oceanographic and atmospheric conditions that have changed over the last several decades. Uncertainty was ranked as high, due to the unknown potential impacts of climate and ecosystem change on sei whale recovery and regime shifts on abundance of prey species. Thus, the relative impact to recovery was ranked as unknown but potentially high (NMFS 2011; NMFS 2012).

Since the last 5-year review, some new information has emerged on the impacts of climate and oceanographic change on prey species. These changes could affect sei whales that are dependent on those affected prey, and could potentially contribute to mortality events for this species.

Climate change has received considerable attention over the past decade, with rising concerns about global warming and recognition of natural climatic oscillations on varying time scales, such as long-term and short-term shifts in the Pacific Decadal Oscillation and El Niño Southern Oscillation, respectively (NMFS 2011). Global warming may likely have detrimental effects on marine mammal populations (Prieto *et al.* 2012a). Climate change may affect cetacean distribution, timing and range of migrations, abundance, mortality, reproductive success, and prey resources (Simmonds and Isaac 2007; Prieto *et al.* 2012a). Breitburg *et al.* (2018) reported that analyses of direct measurement sites around the world show that oxygen-minimum zones have expanded in the open ocean by several million square kilometers and hundreds of coastal sites have low oxygen concentrations which limit the abundance and distribution of animal populations and alter nutrient cycling. This may change food web structures and negatively affect food security for many marine species. The feeding range of the sei whale is wide, and while there may be differences between sei whale stocks and their associated prey species, this large feeding range may make them more resilient to climate change on a global scale, should it affect prey, compared to a species with a narrower range (NMFS 2011).

Arctic and sub-arctic ecosystems are likely to be significantly impacted by increased global temperatures, especially in regard to the extent of sea ice coverage that determines timing and abundance of phytoplankton blooms (NMFS 2011). In addition, ocean acidification effects seem to vary with developmental stages in the Arctic copepod *Calanus glacialis*, with the developmental rate of the Nauplius larvae and the last copepodite stage appearing largely unaffected, whereas earlier copepodite stages exhibit increased metabolic rate due to feeding at high pCO_2 levels and decreased growth (NMFS 2011; Thor *et al.* 2017; Arctic Monitoring Assessment Program 2018). These changes to earlier copepodite stages could have serious implications for *C. glacialis* populations, including prolonged stage development time and reductions in individual body size of developing copepodites, adults, and ultimately the higher trophic level species which feed on them. Even though sei whales prefer the late copepodite stages, changes to earlier copepodite stages could result in decreased body size of late copepodite stages, thus potentially impacting prey availability to sei whales in arctic and sub-arctic ecosystems (Schilling *et al.* 1992, Tamura *et al.* 2009; AMAP 2018).

In regions of the North Atlantic, increases in sea surface temperature have been reported, including the Newfoundland-Labrador, west Greenland, Scottish and Icelandic shelves along with the Faroe Plateau (Belkin 2009; Prieto *et al.* 2012a). This region includes a large proportion of the known sei whale summer habitat. Marine ecosystems have a critical thermal threshold. This means that a small increase in sea surface temperature triggers abrupt ecosystem shifts at multiple trophic levels, which may already be causing a reorganization in marine copepod diversity in the North Atlantic (Beaugrand *et al.* 2002; Beaugrand *et al.* 2008; Prieto *et al.* 2012a). In the northeastern Atlantic, recent studies have shown that copepod distribution is changing - warmer water species are shifting poleward accompanied by an associated decrease in the number of subarctic and arctic species as a result of climatic changes (NMFS 2011; Prieto *et al.* 2012a). More recently, projections of copepod species in the North Atlantic by the end of the century under various climate change scenarios indicate a prevailing poleward shift of copepod species, with a poleward community shift of 8.7 km per decade on average coupled with an area characterized by high species turnover of local colonization and extinction located south of the Oceanic Polar Front where sea surface temperature is projected to increase by the end of the century (Villarino *et al.* 2015). In addition, Western Atlantic coldwater copepods such as *Calanus finmarchicus* have been observed shifting north at 8.1 km per year (Grieve *et al.* 2017). These changes in prey abundance and distribution may have impacts for sei whales, since copepods are their main source of prey in this ocean basin (Prieto *et al.* 2012a). Davis *et al.* (2020) assessed the acoustic presence of sei whales in the temperate North Atlantic Ocean over a decade from data collected from 2004-2014. Data from this study showed higher acoustic presence in the mid-Atlantic regions post 2010, with sei whales more frequently detected in the northern latitudes of the study area after 2010. However, despite this general northward shift, the sei whale was detected less on the Scotian shelf area after 2010, matching documented shifts in prey availability in this region (Davis *et al.* 2020).

In waters off the Azores, Visser *et al.* (2011) observed sei whales arriving in April/May, which coincides with the spring phytoplankton bloom with a residence time of up to 17 days. Individual whales spent most of their time exhibiting foraging and travelling behavior (Visser *et al.* 2011). In addition, the authors note that global warming reduces phytoplankton growth and suppresses spring bloom development in Azorean waters. Thus, climate change could affect sei whale migratory patterns, due to loss of this foraging area in this region of the North Atlantic and reduce opportunities to boost their energy reserves en route to summer feeding grounds. While shifts in migratory timing have not been observed in sei whales in the North Atlantic, they have been documented in fin and humpback whales in a North Atlantic summer feeding ground in the Gulf of St. Lawrence, Canada (Ramp *et al.* 2015). Analyses from this feeding ground indicated that the trend in arrival was strongly correlated to earlier ice break-up and rising sea surface temperature, likely triggering earlier primary production (Ramp *et al.* 2015).

In the Northeast Pacific, harmful algal bloom (HAB) events have been increasing in strength, intensity and extension resulting in mortality events for other cetacean and marine mammal species (Cook *et al.* 2015; Lefebvre *et al.* 2016; Häussermann *et al.* 2017). This indicates a similar process may be occurring in both hemispheres. In addition, Sasaki *et al.* (2012) reported that seasonal shifts in sei whale habitat in the western North Pacific is linked with changing oceanographic conditions due to climate change.

In the Southern Hemisphere, increased frequency of extreme El Niño events due in part to climate change and increased sea surface temperature, has contributed to the heightening of favorable conditions for HAB events, making toxins a growing concern for marine species and their prey (Cai *et al.* 2014; Hernandez *et al.* 2016; Häussermann *et al.* 2017). Paralytic shellfish poisoning (PSP) toxin is known to accumulate in the pelagic stage of the squat lobster *Munida gregaria* (MacKenzie and Harwood 2014), which is an important prey of sei whales (Häussermann *et al.* 2017). *M. gregaria* abundance is reported to fluctuate drastically and reach extremely high concentrations along the Southern Chilean coast. In March 2015, the largest reported mass mortality event of baleen whales (primarily sei) occurred in a gulf of Southern Chile (Häussermann *et al.* 2017). Häussermann *et al.* (2017) indicated that the 'synchronous death of at least 343, primarily sei whales can be attributed to HABs during a building El Niño' event. All sei whale individuals died near the shore and paralytic shellfish poisoning (PSP) was determined the most probable cause of death[6], since the presence of paralytic shellfish toxin was detected in both whale carcasses and mytilids from the area and evidence for other causes of death was lacking. The combination of older and newer remains of sei whales in the same area indicate that mass mortality events have occurred more than once in recent years. If the frequency and magnitude of mass mortality events increase due to climate change, this would have a direct and significant impact on the local sei whale population and their prey and could threaten the recovery of the sei whale in this portion of the Southern Hemisphere (Häussermann *et al.* 2017).

Overall, the potential impacts of climate and oceanographic change on sei whales pertain to habitat, food availability, and potentially mass mortality events. Sei whale migration, feeding, breeding locations and prey availability may be influenced by ocean currents or water temperature, and any changes in these oceanographic features could change the distribution and location of preferred habitat, prey assemblage(s) and foraging areas (NMFS 2011). These changes may have special implications for sei whales. However, it is difficult to predict the impacts (if any) to sei whales resulting from these aforementioned changes. Sei whales are often observed in the same foraging area for many years and then disappear for prolonged periods of

[6] It is important to note that other possible causes for the synchronous death of hundreds of sei whales (i.e. lethal or highly contagious unknown virus or infection, noise-related mechanism at sea, or biotoxin intake) cannot be completely ruled out as individuals could not be tested for viruses or bacteria, due to the advanced state of decomposition (Häussermann *et al.* 2017).

time, only to reappear years later (Jonsgård and Darling 1977; Schilling *et al.* 1992). Therefore, it is unknown whether climate change will lead to more or less suitable habitat for sei whales.

Due to the inherent uncertainties outlined above and recent research findings, it remains unclear whether reduced prey abundance due to climate change is a threat to sei whales. Further research is needed to identify if and how climate change impacts sei whale prey and mass mortality events.

- *Effects of anthropogenic noise continue to be investigated and actions taken to minimize potential effects, as necessary* (Threat discussed in Recovery Plan section G.2).

Effects of anthropogenic noise continue to be investigated, but whether actions are necessary to address potential effects remains unknown.

The relative impact of anthropogenic noise to the recovery of sei whales is ranked in the recovery plan as unknown due to an unknown severity and a high level of uncertainty. As human activities increase in the ocean, so does the potential for noise (NMFS 2011). Marine acoustic pollution has become an issue of concern over recent decades. Measurements from the North Atlantic indicate that average noise at 50 Hz has increased approximately 5.5 dB per decade from 1950 to 1970 (Ross 2005) and about 0.6 dB per decade from 1966 to 2013 (Širovic *et al.* 2016). Similarly, noise in the North Pacific has been increasing at an average rate of 2.5–3 dB per decade at 30–50Hz since the 1960s (Andrew *et al.* 2002; McDonald *et al.* 2006; Chapman and Price 2011). This rise has been mainly due to shipping and in addition to seismic surveys has become one of the main sources for marine ambient noise below ~1 kHz (Andrew *et al.* 2002; McDonald *et al.* 2006; Hildebrand 2009; Klinck *et al.* 2012; Nieukirk *et al.* 2012).

It is well known that anthropogenic sound from a variety of human activities (e.g. seismic surveys, pile driving, use of explosives, high intensity sonar operations, aircraft and ship noise, etc.) can cause detrimental effects to marine mammals. These effects can cause behavioral changes, mask communication sounds, exclude marine mammals from their habitat, and induce auditory injury or death (Southall *et al.* 2007; Pirotta *et al.* 2014; Verfuss *et al.* 2018). However, the effects of anthropogenic noise are difficult to ascertain specifically for sei whales and research on this topic is ongoing. The possible impacts of various sources of anthropogenic noise, outlined and described below, have not been well studied on sei whales (if at all), although some conclusions from certain studies on baleen whales could be generalized for sei whales (NMFS 2012).

<u>Ship Noise</u>
The severity of the threat of ship noise remains unknown with a high degree of uncertainty due to the potential for increased vessel noise in the future. Additionally, knowledge gaps still remain on impacts of ship noise to sei whale physiology and behavior. Therefore, the impact of ship noise on sei whale recovery remains unknown.

Sound emitted from large vessels is the principal source of noise in the ocean today, primarily due sound from cargo vessels. Ship propulsion and electricity generation from engines, compressors, and pumps essential for ship operations contribute to noise emissions into the marine environment (NMFS 2011). Prop-driven vessels also generate noise through cavitations, which account for approximately 85 percent or more of the noise emitted by large shipping vessels (Hildebrand 2004; NMFS 2011). Marine ambient noise levels at frequencies below 500 Hz have increased by 20 dB compared to pre-industrial levels (Wright 2008; Hildebrand 2009; Wiles 2017). Additionally, studies indicate that over the past few decades the contribution of shipping activities to ambient noise has increased by 12 dB (Hildebrand 2009).

Direct mortality caused by anthropogenic noise is described as a potentially higher risk in deep diving cetaceans and echolocating odontocetes and a potentially lower risk to their mysticete counterparts (Prieto *et al.* 2012a; Yamato *et al.* 2016). Masking (i.e. acoustic interference), can have serious effects on cetaceans by hampering individual and conspecific communication, finding mating partners, locating prey, and navigational skills, thus negatively affecting reproductive success and ultimately survival (Clark *et al.* 2009; Ahonen *et al.* 2017). In a study of sei whale migratory habitat off the Azores, Romagosa *et al.* (2017 and 2020a) postulated that detection ranges of blue (*Balaenoptera musculus*), fin, (*Balaenoptera physalus*), and sei whales vocalizing frequencies could be impacted by the noise emitted by passing ships within the region, which is concerning given their dependence on long-range communication (Payne and Webb 1971). Additionally, Romagosa *et al.* (2020a) found that shipping noise increased from April through September (maximum of 29% in August) and coincided with the acoustic presence of sei whales for 3 months (April through June). Thus, this overlap increases the risks of acoustic masking, potentially affecting sei whales' ability to communicate (Romagosa *et al.* 2020a).

The acoustic repertoire of sei whales is poorly described and possible impacts of various sources of anthropogenic noise on sei whales have not been well studied and remain unknown (Prieto *et al.* 2012a). Recent shore, aerial, and boat surveys within Berkeley Sound, Falkland Islands, showed no spatial overlap of sei whales and anchored vessels in inner Port William (during 2017), however transiting vessels to/from Port William regularly pass through coastal waters commonly used by sei whales (Weir 2017). However, more research needs to be done to determine a correlation (if any) of sei whale occurrence and any potential responses to vessel-occupied waters. Clark *et al.* (2009) found that mysticetes showed diminished call rates in the presence of passing vessels, and ship noise may be linked to rising levels of the stress hormone cortisol in North Atlantic right whales (NMFS 2011; Rolland *et al.* 2012). Furthermore, vessel noise in habitats near shipping lanes significantly decreases the communication space of multiple baleen whale species (Cholewiak *et al.* 2018a). If sei whale density in a given area is low, any diminished calling activity or communication area might make it more difficult to locate potential mating partners and reduce ability for social interaction (NMFS 2011). Since past research on the sei whale has been hindered due to its oceanic nature, the effect of ship noise on sei whales requires further research to evaluate the impact (if any) on its behavior and ecology.

Based on those stated uncertainties and results of recent research, it remains unknown whether ship noise may be a threat. Further research is needed to determine impacts, if any, resulting from ship noise.

<u>Oil and Gas Activities</u>
A number of activities associated with oil and gas exploration and development result in the introduction of sound into the ocean environment (NMFS 2011). The severity of the threat of oil and gas activities remains unknown with a high degree of uncertainty due to the potential for

increased future oil and gas activities coupled with knowledge gaps that still remain on direct impacts to sei whale physiology and behavior. Therefore, the relative impact to sei whale recovery associated with oil and gas activities is unknown.

Oil and gas activities involve a variety of devices and technologies that introduce energy into the water for purposes of geophysical research, bottom profiling, depth determination, and resource extraction. Loud sounds emitted from air guns associated with seismic surveys to locate undersea oil reserves may adversely affect marine mammals. The United States requires mitigation and monitoring protocols, such as ramp-up procedures and biological monitors who check safety zones. Surveys can thus be halted if protected species (such as sei whales) enter these specified safety zones. As of 2014, there were approximately 179 seismic survey vessels worldwide (Kliewer 2014). Seismic airgun signals can travel extensive distances; Nieukirk *et al.* (2004) detected airgun sounds at the mid-Atlantic ridge at distances of up to 4000 km from survey vessels, and in the equatorial Atlantic, airgun acoustic signals were detected at one recording site every day, and nearly every hour, from August 2009 through December 2010 (Haver *et al.* 2017). Oil and gas drilling produces low-frequency sounds with strong tonal components in frequency ranges in which large baleen whales communicate (NMFS 2011). In particular, the sounds produced by airguns overlap with the primary frequency range of sei whale acoustic signals. Baleen whales are known to detect the low-frequency sound pulses emitted from air guns used during seismic surveys and have been observed to change behavior near these vessels (McCauley *et al.* 2000; Stone 2003). Seismic operations have also been linked to extended area avoidance in fin whales (Castellote *et al.* 2012), decreases in song production in humpback whales (Cerchio *et al.* 2014), and changes in dive behavior in bowhead whales (Robertson *et al.* 2013). Bowhead whales also reduce their respiration rates and alter time at the water's surface and adjust their calling rates when in the vicinity of seismic blasts (Ahonen *et al.* 2017). Furthermore, McCauley *et al.* (2017) reported that exposure to air gun signals resulted in the mortality of copepods and krill larvae, and decreased overall zooplankton abundance. However, whether sei whales respond in a similar manner to their mysticete counterparts remains unknown.

Dunlop *et al.* (2016, 2017, and 2018) observed general avoidance patterns of humpback whales to an air gun array. During a study of behavioral responses of migrating humpback whales to air gun noise, Dunlop *et al.* (2018) found that groups of whales were more likely to show an avoidance response when the received sound exposure level was greater than 130 dB and within 4 km of the source, whereas a small number of whales did not show an avoidance response at the highest received levels. Therefore, an estimate of the maximum response threshold for these humpback whales was not feasible (Dunlop *et al.* 2018). In addition, Ahonen *et al.* (2017) found that bowhead whales reduce their respiration rates, alter time at the water's surface, and adjust their calling rates when in the vicinity of seismic blasts. However, whether sei whales respond in a similar manner to their mysticete counterparts remains unknown.

While oil and gas activities have been shown to affect baleen whale behavior in a number of species, there have been minimal studies for sei whales, which reflects the paucity of overall field research on this species rather than an observed lack of impacts. Additionally, these activities could potentially adversely affect sei whales, since low-frequency sonar transmissions overlap the frequency ranges of sei whale vocalizations, thereby masking communications between individuals, and negatively affecting social ecology and interactions of sei whale groups (NMFS 2011). However, the extent to which oil and gas exploration activities are a threat to sei whales remains unknown, and further research is needed to determine impacts from these activities.

Noise from Aircraft and Unmanned Aerial Systems (UAS)

In addition to the low-frequency pulses emitted during oil and gas exploration activities, underwater noise can also be introduced by low-flying aircraft as part of surveillance and survey activities (NFMS 2011). Baleen whales have been documented exhibiting short-term reactions (e.g. short surfacing times, immediate dives or turns, changes in behavior) to twin otter aircraft and helicopters flying at low altitudes (≤150 m for helicopter and ≤182 m for the plane) and close lateral distances of ≤ 250 m (Patenaude *et al.* 2002). The impacts of aircraft sound on cetaceans or other marine mammals while they are in the water is influenced by the animal's depth, the aircraft's altitude, aspect, and strength of the noise coming from the aircraft (NMFS 2011). The potential for disturbance to sei whales is likely higher at lower flight altitude (NMFS 2011; Smith *et al.* 2016). However, since sound is easily dispersed through the air, the effect on individual whales over their life span would be minimal. In addition, the use of UAS or 'drones' has been increasing. Although it is generally considered that drones cause less disturbance to marine mammals than other survey platforms (like ships and aircraft), some disturbance is likely (Fiori *et al.* 2017).

While noise from aircraft and UAS activities have been shown to affect marine mammals, there have been minimal studies for sei whales, which reflects the paucity of overall field research on this species rather than an observed lack of impacts. Thus, the extent to which noise from aircraft and UAS activities are a threat to sei whales remains unknown, and further research is needed to determine impacts from these activities.

Offshore Energy Development

Energy demand is increasing worldwide from a variety of sources, and a significant portion of that energy is found in the marine environment via oil and gas reserves. Once suitable reserves are found, the next stage is development and installation of drilling platforms or structures and transport systems, such as pipelines. The development of offshore energy resources, however, can impact the marine environment and the associated marine fauna. Such impacts range from impact pile driving (which is a source of low-frequency sound) and blasting to increased vessel and/or aircraft activity (NMFS 2011). Since sei whales are primarily oceanic, and offshore energy development projects are a coastal enterprise, the severity of this threat is low with a medium degree of uncertainty due to the potential for increased offshore energy development activities coupled with knowledge gaps that still remain regarding impacts to sei whale ecology, physiology, and behavior. Therefore, the relative impact to sei whale recovery associated with offshore energy development is ranked as low.

Stone *et al.* (2017) regularly observed sei whales in two wind energy areas offshore of Rhode Island and Massachusetts between October 2011 and June 2015, where previously they had been considered infrequent visitors to the area (Kenney and Vigness-Raposa 2010). Stone *et al.* (2017) suggested that this area could potentially be a seasonal foraging area for sei whales, and future wind (or other industrial) energy development could affect their distribution and behavior. In addition, offshore energy development could potentially degrade sei whale habitat or displace them from common foraging or breeding areas. However, further research is required to determine what impacts, if any, wind and/or offshore energy development have on sei whales.

Based on those stated uncertainties and results of recent research, it remains unknown whether offshore energy development is a threat. Further research is needed to determine impacts, if any, resulting from offshore energy development.

<u>Military Sonar and Explosives</u>
The large spatial scale, frequency, duration, and diverse nature of military training activities in areas where sei whales occur suggest that these activities have the potential to adversely affect sei whales (NMFS 2012). The severity of the threat of military sonar and explosives on sei whales remains unknown with a high degree of uncertainty due to the potential for increased future military sonar and detonations coupled with knowledge gaps that still remain regarding impacts to sei whale physiology, ecology and/or behavior. Therefore, the relative impact to sei whale recovery associated with military sonar and explosives is unknown.

The effect(s) of military activities and sonar on sei whales remains uncertain, since no direct evidence is available to evaluate impacts on sei whale physiology, ecology, and/or behavior. However, the large scale and diverse nature of military activities throughout the North Atlantic, North Pacific and Southern Ocean creates potential situations where disturbance, injury, or mortalities could potentially occur (NMFS 2012). Military training activities by the U.S. Navy regularly occur in the Atlantic (including the Gulf of Mexico and Mediterranean Sea), Indian, and Pacific Oceans. Activities range from anti-submarine warfare, surface warfare, anti-surface, mine warfare exercises, missile exercises, sinking exercises, and aerial combat exercises. In addition, the U.S. Navy conducts ship shock trials, which involve detonations of high explosive charges. The U.S. Navy also utilizes low-, mid-, and high frequency active sonar systems, including one that operates in the western and central Pacific Ocean, where sei whales are known to migrate to/from feeding grounds (NMFS 2011; NMFS 2012).

Due to the large scale and diverse nature of military activities throughout the North Atlantic, North Pacific, and Southern Ocean basins means there is potential for disturbing, injuring, or killing cetaceans, including sei whales (NMFS 2011). For example, the waters off western Scotland are an important cetacean habitat for a number of mysticetes, including a known cetacean breeding ground for a variety of species (Parsons *et al.* 2000). However, this region is also a major area for a number of military activities including submarine exercises, torpedo testing, firing ranges and training exercises (Parsons *et al.* 2000). Sei whales are known to occur off the northwest coast of Scotland (Hebrides region) and communicate using pulse frequencies that overlap with the low frequency active sonar used for military training exercises in coastal and deeper waters. However, no studies exist that measure sighting rates or assess direct impacts to sei whales. An analysis of minke whale (*Balaenoptera acutorostrata*) sightings data showed a marked decrease in cetacean sightings for the duration of these military training exercises, and a subsequent analysis showed that the observed decrease was statistically significant (ANOVA on log transformed data; $F=4.6$; $p<0.005$) (Parsons *et al.* 2000). This suggests that military training exercises and active sonar could potentially adversely affect sei whales, since low-frequency sonar transmissions overlap the frequency ranges of sei whale vocalizations, thereby masking communications between individuals, and negatively affecting social ecology and interactions of sei whale groups (NMFS 2011).

In addition, overlap between sei whale hearing and low- to mid-frequency sonar could result in hearing loss, sensitivity, or behavioral disturbance to avoid or evade sonar transmissions. Goldbogen *et al.* (2013) used controlled experiments with simulated military sonar and mid-frequency sounds to evaluate behavioral responses of tagged blue whales, which ranged from cessation of deep feeding and increased swimming speed away from the sound source. Additionally, controlled exposure experiments conducted by Southall *et al.* (2014) and McCauley *et al.* (2000) on other baleen whales resulted in clear behavioral reactions. These reactions ranged from small changes in dive behavior (blue whales) to general avoidance (female humpback whales). However, whether sei whales respond in a similar manner to their mysticete counterparts remains unknown. Sei whale vocalizations are the least studied of all the rorquals (i.e. a family of baleen whales with expandable throat pleats). However, other studies on the effects of Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar on other mysticetes (foraging blue and fin whales in California, migrating gray whales off California, and singing humpback whales in Hawaii) did not detect biologically significant responses (U.S. Department of the Navy 2012; NMFS 2012).

Underwater detonations from military operations and training exercises range from large explosives such as those associated with ship sinking exercises or ship shock trials, to missile exercises, gunnery exercises, mine warfare, disposal of unexploded ordnance, and grenades (NMFS 2011). Whales that are in the immediate vicinity to these military activities could be killed, seriously injured, or suffer ear injuries (e.g. tympanic membrane rupture, fractured tympanic bullae) (Yamato *et al.* 2016). While those individuals farther away could still experience physiological stress responses or behavioral disturbance the severity depends on their distance from the detonation (NMFS 2011). Yamato *et al.* (2016) found that filter-feeding mysticetes were more resilient to traumatic ear injury compared to their echolocating-odontocete counterparts. Yamato *et al.* (2016) examined 11 specimens of fractured and healed cetacean tympanic bullae. These cetacean tympanic bullae (which included 1 sei whale) displayed healed fractures, all in species for which the condition was previously unknown. Toothed whale specimens showed less remodeled fractures compared to their mysticete counterparts, indicating that baleen whales are more capable of overcoming traumatic ear injury, whereas ear injuries may be more lethal to echolocating-odontocetes (Yamato *et al.* 2016). Even if sei whales are physiologically more resilient to military detonations and sonar, the effect of active sonar and military detonations on sei whales has not been well studied and remains uncertain.

Based on those stated uncertainties and results of recent research, the effect of active sonar and military explosives on sei whales remains uncertain. The possible sources and impacts of military sonar and explosives require further study.

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

- *Management measures are in place that ensure that any hunting (commercial, subsistence, and scientific) is at a sustainable level.* (Threat discussed in Recovery Plan section G.9)

This criterion has been met, as long as the IWC and the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) ensure management measures are maintained. The IWC's moratorium on the commercial hunting of sei whales in most of their range has been in force for more than three decades, and it has almost certainly had a positive effect on the species' recovery. Whales are listed in CITES and although some Parties have taken a reservation on them, CITES resolution 11.4 (Ref CoP12) "recommends that the Parties agree not to issue any import or export permit, or certificate for introduction from the sea, under this Convention for primarily commercial purposes for any specimen of a species or stock protected from commercial whaling by the International Convention for the Regulation of Whaling" (ICRW). Thus, CITES and ICRW are to be applied in a mutually supportive manner to protect certain whale stocks and species. The threat of direct harvest of sei whales, from either scientific whaling or commercial whaling, occurs at a medium severity and there is a medium level of uncertainty. Thus, the relative impact to recovery of sei whales due to direct harvest is ranked as medium in the recovery plan.

Direct harvest, although rare today, was the main cause of initial depletion of sei whales and other large cetaceans. Global population of sei whales declined from approximately 250,000 individuals prior to commercial whaling to perhaps 32,000 individuals by the 1970s to 1980s (Thomas *et al.* 2016; Wiles 2017). In the North Atlantic, direct harvest of sei whales started in the late 1800s off the coast of Norway and continued in that region until the 1950s, and off the coast of Iceland after the 1950s up until 1989, with peak catch from 1960 to 1970 (Reilly *et al.* 2008; Thomas *et al.* 2016; Wiles 2017). In one year (1885), more than 700 sei whales were killed off Norway, and small numbers were taken off Spain and Portugal starting in the 1920s (though some individuals were misidentified as fin whales in the catch statistics) (NMFS 2011). Sei whales were hunted from land stations ranging from northeast Canadian waters (Nova Scotia, Newfoundland), Iceland, and East Greenland, to the European coast (Shetlands, Hebrides, Faroes, Ireland and Spain), the Iberian Peninsula and northern Morocco (Prieto *et al.* 2012a; Thomas *et al.* 2016). In Iceland, a total of 2,574 sei whales were taken between 1948 and 1985, and a total of 825 sei whales were taken on the Scotian Shelf between 1966 and 1972 (Sigurjónsson 1988; NMFS 2011).

In the North Pacific, sei whales were hunted in northern Japanese waters by 1910 and off the California coast in the 1920s; pre-whaling numbers in this region ranged from 42,000 to 62,000 individuals, and fell to approximately 8,600 individuals when whaling ended (Prieto *et al.* 2012a; Thomas *et al.* 2016; Wiles 2017). Large numbers of sei whales (~2,000 individuals) were harvested off of Vancouver Island and along the British Columbian coast from 1908 to 1967, with more than half harvested between 1962 and 1966 (NMFS 2011; Wiles 2017). The total reported kill of sei whales in the North Pacific by commercial whalers was 61,500 between 1947 and 1987 (NMFS 2011).

Following depletion of blue, fin, and humpback whale stocks, sei whales were heavily exploited by modern whalers in the Southern Hemisphere from the mid-1960s to early 1970s (Reilly *et al.* 2008; IWC table showing total catch by whale species since 1985). Sei whales were harvested in excess of 1,000 per season during pelagic operations in the Southern Hemisphere beginning with the 1959/1960 season, reaching a peak with the 1964/1965 season where 17,721 individuals were killed (Prieto *et al.* 2012b; Thomas *et al.* 2016). Globally, populations of sei whales were severely depleted by the mid-1970s. Overall, exploitation in the North Atlantic occurred over a longer period and was less intensive (Reilly *et al.* 2008; Cooke 2018). Commercial exploitation ceased in the North Pacific in 1975, in the Southern Hemisphere in 1979 and in the North Atlantic in 1989 (Reilly *et al.* 2008; NMFS 2011; Thomas *et al.* 2016; Cooke 2018). Although there is currently no commercial whaling for sei whales by IWC member nations that are a party to the moratorium, hunting of sei whales occurred under a provision in the ICRW for special permit whaling for scientific purposes (IWC table showing total catch by whale species since 1985). Iceland and Norway do not adhere to the moratorium since both countries filed objections or reservations to it[7]. While neither Iceland nor Norway have hunted sei whales for commercial purposes under their exceptions to the moratorium, Iceland conducted scientific whaling for sei whales in 1986 – 1988. Hunting of sei whales in Greenland has occurred in accordance with the IWC's aboriginal subsistence whaling quota (Prieto *et al.* 2012b; IWC table showing total catch by whale species since 1985). Japan has continued to hunt sei whales under a scientific permit as part of the Japanese Whale Research Program under Special Permit in the North Pacific (JARPN II) program (Baker *et al.* 2010; NMFS 2011). If Iceland and Norway were to conduct commercial whaling on sei whales, Iceland and Norway would set their own catch limits, and have to submit information on their catches and associated scientific data to the IWC. In addition, Iceland has consistently expressed an interest in developing its whaling industry, which targets fin and minke whales, and could target sei whales (Sigurjónsson 1988; NMFS 2011). From 2004 through 2013, about 100 sei whales were taken annually from the western North Pacific as part of Japan's JARPN II program. Beginning in 2014, Japan reduced the annual take of sei whales from 100 to 90 individuals (Thomas *et al.* 2016). However, beginning in 2017, Japan increased its annual take to 134 whales under its New Scientific Whale Research Program in the western North Pacific (NEWREP-NP) (IWC table showing total catch by whale species since 1985; Government of Japan 2017). Whaling for sei whales by Japan is likely to continue, albeit for commercial purposes rather than for scientific purposes, at levels considered sustainable by the IWC Scientific Committee. On December 26, 2018, Japan announced that it will withdraw from the ICRW effective June 30, 2019 and resume commercial whaling in its exclusive economic zone. Japan's withdrawal from the ICRW ends its scientific whaling program. Japan's commercial whaling is likely to include the harvest of sei whales, as did its scientific whaling program. The purpose of Japan's hunt for sei whales will change from scientific purposes to commercial purposes, and the location of the hunt will change from the high seas to Japan's exclusive economic zone. While Japan's resumption of commercial whaling in its exclusive economic zone will be outside of IWC oversight, Japan has indicated that it will abide by IWC Scientific Committee advice with regard to setting sustainable catch limits.

Well-documented pirate whaling has occurred in the northeastern Atlantic as recently as 1979 (NMFS 2011), and attempted illegal trade in baleen whale meat has been documented throughout the 1990s (Baker and Palumbi 1994). In addition, Baker *et al.* (2004) found sei whale products for sale from the Southern Hemisphere which may have originated from illegal, unreported or undocumented sources. Since the mid-1970s, there has been some demand in world markets (most of it centered in Japan) for baleen whale meat (NMFS 2011). Genetic evidence of illegal

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[7] 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).

international trade of whale meat (including the sei whale) has been provided by Baker *et al.* (2010), who linked whale meat products purchased at restaurants in Los Angeles, USA and Seoul, South Korea.

Sei whales are listed in Appendix I of CITES (Lyman and Jamin 2018). Since 2002, Japan has hunted sei whales on the high seas as part of its special permit whaling program under Article VIII of the ICRW (Lyman and Jamin 2018). Because sei whale specimens are taken in the marine environment beyond the jurisdiction of any State, Japan must issue 'introduction from the sea' (IFS) certificates pursuant to Article III of CITES, which prohibits introductions from the sea of specimens that will be used for 'primarily commercial purposes'. However, in 2018, CITES Parties determined that although Japan was engaged in lethal take of sei whales under the pretext of hunting for scientific research, the vast majority ended up being sold commercially in both wholesale and retail marketplaces (CITES 2018a; CITES 2018b; Lyman and Jamin 2018). The introduction from the sea of sei whale meat and other edible products for commercial purposes was the subject of an Article III compliance procedure, and Japan was found noncompliant by CITES (CITES 2018a; CITES 2018b). Consequently, CITES directed Japan to halt activities that were non-compliant with the CITES provisions governing the commercial trade of an endangered whale species. In turn, Japan agreed to formulate remedial actions and delay departure of their research whaling vessels until after the 71st meeting of the CITES Standing Committee (SC). However, Japan may no longer be out of compliance with CITES requirements as whaling of sei whales on the high seas will cease due to their withdrawal from the ICRW.

The IWC was established under the ICRW whose purpose is to 'provide for the proper conservation of whale stocks and thus make possible the orderly development of the whaling industry' (Stevens 2017). Sei whales have been protected from commercial whaling since the IWC moratorium took effect in 1986. While it is likely that this moratorium will continue into the future, Japan will likely harvest sei whales for commercial purposes, rather than for scientific purposes at levels considered sustainable by the IWC Scientific Committee. Despite this harvest, sei whales are currently legally protected through most of their range.

Regarding recreational and educational uses, sei whales have been sighted and viewed more frequently by whale watching vessels in the northeast United States (NMFS 2011), though impacts of these activities remains unknown.

Factor C: Disease or Predation.
The sei whale recovery plan did not include criteria for this factor. See Section 2.3.2: Five Factor Analysis for new information.

Factor D: The inadequacy of existing regulatory mechanisms.

- *Hunting is addressed under Factor B.*

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

- *Ship collisions continue to be investigated and actions taken to minimize potential effects, as necessary.* (Threat discussed in Recovery Plan section G. 3)

The sei whale recovery plan (NMFS 2011) ranked the relative impact of ship collisions to the recovery of sei whales as unknown but potentially low due to a high level of uncertainty and low severity. Overall, effects of ship collisions continue to be investigated, but whether actions are necessary to address the issue remains unknown.

Increased demand for global trade coupled with increased military activities is driving ship traffic growth in the world's oceans, with a global fourfold increase between 1992 and 2012 (Tournadre 2014). As the world's ship traffic increases, so does the potential for increased ship collisions with large whales, especially as whale populations recover from exploitation and grow in size. Laist *et al.* (2001) estimated that between 13% and 20% of the stranding of large whales in the United States, South America, France, and Italy were attributed to ship strikes; and sei whale mortality due to collisions with ships has been documented (Glass *et al.* 2010; Van der Hoop *et al.* 2013).

Overall, there are relatively few documented accounts of vessel strikes with sei whales, and it is suspected that strikes on this species are underreported because the whales do not strand, or if they do, they do not always exhibit obvious signs of trauma (Van Waerebeek *et al.* 2007; NMFS 2017). For example, Rockwood *et al.* (2017) recently reported that mortality estimates of ship struck large whales (blue, fin and humpback whales) were far higher than current minimum estimates off the U.S. west coast. Laist *et al.* (2001) reported two vessel strikes of sei whales in the United States, one each off of Massachusetts and Maryland both involving animals brought into port on the bows of ships. An additional record was noted by Jensen and Silber (2004), and in 1998 Félix and Van Waerebeek (2005) reported a dead juvenile sei whale brought into Dakar, Senegal, draped over the bow of a container ship. Glass *et al.* (2010) reported three ship strikes in the northwest Atlantic between 2004 and 2008, two of which resulted in whale mortality, and one sei whale was struck in 1994 in Hauraki Gulf, New Zealand (NMFS 2012). Van der Hoop *et al.* (2013) noted that approximately 9 sei whales died from vessel strikes according to an analysis of large-whale stranding, mortality, and necropsy reports from 1970 through 2009 in the North Atlantic. In addition, four records of sei whale mortality from vessel collisions along the U.S. Atlantic coast were reported between 2013 through 2017, which resulted in an annual rate of serious injury and mortality of 0.8 for Nova Scotian sei whales from vessel collisions (NMFS 2020). One ship strike death was reported in the eastern North Pacific Ocean (off Washington) in 2003 (NMFS 2017a). From 2008 through 2014, over 800 incidents of human caused serious injury and mortality involving 19 cetacean species were reported in the Atlantic by marine mammal response networks in Canada. One sei whale was confirmed dead by vessel strike in the Quebec region (Themelis *et al.* 2016 DFO). A sei whale was reported struck by a ship in a port in New Zealand (Pirotta *et al.* 2019). Weir (2017) mentioned some anecdotal reports of ships making physical contact with a sei whale within Berkeley Sound, Falkland Islands and a second near-miss collision in Falkland Sound, which confirms the increased potential of sei whale ship strikes, especially in high ship-traffic areas of ports and harbors.

To reduce the threat of ship strikes to North Atlantic right whales, NMFS has taken action by establishing ship speed restrictions, mandatory ship reporting systems, recommended routes, and a sighting advisory system in specified areas of U.S. Atlantic waters. In 2008, NMFS implemented a five-year regulation that required large ships to restrict speeds to 10 knots in

North Atlantic right whale seasonal management areas. This rule was extended indefinitely in 2013. While it was designed to specifically protect North Atlantic right whales, this rule is expected to reduce ship strikes to other marine mammals, including sei whales (NMFS 2008). In 2013, shipping routes into Los Angeles/Long Beach and San Francisco areas, the two major ports in California, were modified to protect large whales, including sei whales (NOAA Fisheries recommendations on how to reduce the risk of ships striking large whales). At an international scale, the IWC has identified the need to produce a Strategic Plan to mitigate the impacts of ship strikes on cetaceans and aims, by 2020, to develop approaches and solutions to “achieve a permanent reduction in ship strikes” (Description of IWC strategies to reduce the risk of ship collisions with large whales). While the IWC’s Strategic Plan does not focus specifically on sei whales, the resulting outcome(s) and/or action(s) could only help mitigate ship strikes as a threat to sei whales.

Overall, the possible impacts of ship strikes on recovery of the sei whale is poorly understood, but may be significant due to increased global ship traffic. However, while ship strike prevention regulations do exist for other cetaceans, none specific to sei whales have been implemented. Because many ship strikes likely go unreported or undetected for various reasons, any estimates of serious injury or mortality should be considered as minimum estimates.

Based on those stated uncertainties and results from recent studies, it remains unknown whether collisions with vessels are a threat to the sei whale population. Further research is needed to determine impacts, if any, resulting from ship strikes.

- *Entanglement with gear associated with the offshore gillnet fishery continues to be investigated and actions taken to minimize potential effects, as necessary* (Threat discussed in Recovery Plan section G.1)

Effects of gear entanglement associated with the offshore gillnet fishery continue to be investigated, but whether actions are necessary to address potential effects remains unknown. The sei whale recovery plan (NMFS 2011) identified the threat of gear entanglement associated with the offshore gillnet fishery as low severity, with a medium level of uncertainty, and the relative impact to recovery of sei whales as unknown but potentially low.

The level of threat that gear entanglement poses to large whale populations is poorly understood, but continues to be a growing concern (Prieto *et al.* 2012a; Reeves *et al.* 2013). For many species of large whales occupying coastal habitats in heavily fished regions, gear entanglement is a major source of injury and mortality (Prieto *et al.* 2012a; Wiles 2017). More gear entanglements are known to occur in coastal and continental shelf waters compared to offshore waters (Saez *et al.* 2013), which sei whales have been known to seasonally occupy. Additionally, entanglement occurrence may be a consequence of increased reporting and/or fishing effort in these areas. Large whales can become entrapped in active drifting (i.e. gillnets) stationary fishing gear, or in discarded netting (Reeves *et al.* 2013; Wiles 2017). In addition, large whales can break through and carry away fishing gear, which results in gear being dragged for prolonged periods of time (for months or even years) (Weir 2017). Mortality, injury, or eventual starvation can result due to chronic physical trauma, inhibited movement, or infections if whales are not disentangled or are unable to free themselves from fishing gear (Wiles 2017; Weir 2017). In addition, probabilities of entanglement has increased over the past few decades and is a source of mortality for some protected whale populations, with fishing gear entanglements being the leading cause of death in large whales necropsied in the United States and Canada (Cassoff *et al.* 2011; Van der Hoop *et al.* 2013).

Overall, documented cases of sei whale entanglement are rare, and serious injury and mortality from entanglement in fishing gear in the northwest Atlantic have been reported at a much lower rate compared to their mysticete counterparts (Glass *et al.* 2010; Prieto *et al.* 2012a). In the Northwest Atlantic, there is one record of entanglement reported in 2017 off the coast of North Carolina (at the Cape Lookout Bight) of an emaciated sei whale carrying a large mass of heavily fouled gear consisting of line and buoys over its back (Henry *et al.* 2017; NMFS 2020; Henry *et al.* 2020). This resulted in an annual serious injury and mortality rate of 0.2 for Nova Scotian sei whales from fishery interactions (NMFS 2020). Additionally, warming trends in the Gulf of Maine and waters around Cape Cod is resulting in movement of trap pot fisheries further off shore which is increasing the risk of entanglement for sei whales (Hayes *et al.*2018). In the central North Pacific, a subadult sei whale was documented in March 2011 off the coast of Maui, Hawaii entangled in wraps of heavy line around its tailstock and trailing about 30 feet of line including a large bundle (Bradford and Lyman 2015; NMFS 2017). In the eastern North Pacific, the California swordfish drift gillnet fishery is the only fishery that has been identified in U.S. waters as likely to take sei whales, but no fishery mortality or serious injuries have been observed from > 8,600 monitored fishing sets from 1990-2014 (Carretta *et al.* 2017). However, it is important to note that large whale gillnet mortality may be underreported and/or unobserved since large whales can swim away with portions of the net attached. Whales carrying gear may die later, become debilitated or seriously injured, or have normal functions impaired, but with no evidence of the incident recorded (NMFS 2012). Crude estimates indicate approximately 73 rorquals were killed per year in the southern California offshore drift gillnet fishery during the 1980s, some of which may have been sei whales (NMFS 2012). Recently, in the Southern Hemisphere, the first mortality of a sei whale from entanglement was reported in the Aysén region of Chile (Espinosa-Miranda *et al.* 2020). The sei whale died after being entangled in a salmon farm net in Puerto Aysén, at the southern tip of Chile.

Data on entanglement and entrapment in non-U.S. waters is largely anecdotal and not reported systematically because observer coverage may not exist or fisheries are only partially observed. Weir (2017) recently reported a photograph taken in March 2011 of a sei whale in Berkeley Sound, Falkland Islands entangled in rope likely attributed to fishing gear. In Atlantic Canadian waters, Themelis *et al.* (2016) reported two cases of sei whale mortality due to fishing gear from 2008-2014.

Currently, a number of whale disentanglement initiatives exist worldwide to attempt to reduce the threat of fisheries entanglement on cetaceans. In 2011, the IWC launched a Global Whale Entanglement Response Network to help build an effective response network, with the goal of preventing entanglements from happening. The IWC holds specialist workshops around the world to help educate scientists, government representatives, and conservationists on entanglement issues, importance of data gathering, and releasing whales safely at sea (Description of IWC's Global Whale Entanglement Response). At a more local scale, the United States has taken action under the Marine Mammal Protection Act (MMPA) by developing and implementing Marine Mammal Take Reduction Plans to help recover and prevent extirpation of strategic marine mammal stocks. The goal of each plan is to reduce incidental mortality and serious injury of marine mammals from commercial fishing activities (including entanglement) (Description of NOAA Fisheries Marine Mammal Take Reduction Plans and Teams). In addition, NMFS has led efforts to mitigate the effects of whale entanglement via collaboration with stakeholders along with communication and outreach efforts directed at the commercial and recreational fishing communities. This included implementing recommended gear changes, modifying best practices, and enhancing reporting requirements of entangled whales. While both of these initiatives do not specifically focus on sei whales, the resulting outcome(s) and/or action(s) could help mitigate gear entanglement associated with the offshore gillnet fishery as a threat to the sei whale population. More recently, with the increasing entanglement threats to North Atlantic right whales (Hayes *et al.* 2018), a great deal of focus has been put on advancing fishing technology to minimize the amount of vertical line in the water column with the pursuit of buoy-less technologies (Moore and Browman 2019).

Based on those stated uncertainties and results from recent research, it remains unknown whether gear entanglement from the offshore gillnet fishery is a threat to sei whales. Further research is needed to determine associated impacts resulting from gear entanglement.

2.3 Updated Information and Current Species Status

In this section, we present new information since the sei whale recovery plan (NMFS 2011) and the last 5-year review completed in 2012. For new information related to the recovery criteria, see Section 2.2.3.

2.3.1 Biology and Habitat

2.3.1.1 New information on the species' biology and life history:

Feeding Behavior and Prey Selection

Information on the biology of sei whale is sparse compared to most other rorquals (Prieto *et al.* 2012a; Wiles 2017). The sei whale is typically observed alone or in small groups of two to five animals, although larger aggregations of as many as 100 individuals can occur at feeding grounds (Wiles 2017; Weir 2017). Overall, sei whales are known for their erratic appearance in certain feeding grounds, exhibiting a large abundance in some years and absent (sometimes for years or even decades) in others (Reilly *et al.* 2008; Prieto *et al.* 2012a). Sei whales are opportunistic feeders and their diet is diverse; prey preference depends on location and season, selecting prey that occur in aggregations in surface waters (NMFS 2011; Prieto *et al.* 2012a; Wiles 2017). Although they feed primarily on copepods, small schooling fish, euphausiids, decapods, and squid have been documented as sei whale prey (Wiles 2017). These prey preferences have been shown not only by stomach content analyses, but also by direct observations of feeding behavior, by inference, and examination of feces (NMFS 2011). Sei whales filter prey through their baleen, and have the unique ability to capture prey via engulfment (like other rorquals), or via skimming on lower prey concentrations (Prieto *et al.* 2012a). This ability to switch feeding modes is attributed to anatomical adaptations of the internal baleen fringe (which is finer compared to other rorquals) and the mouth cross-section, which has features similar to right whales (Prieto *et al.* 2012a; Wiles 2017).

Recently, in the South Atlantic, Segre *et al.* (2021) studied how sei whales are able to switch between feeding behaviors with the goal of better understanding the rapid evolution and flexibility of filter-feeding strategies. Segre *et al.* (2021) deployed multi-sensor biologging tags on two sei whales foraging within the Berkeley Sound, off the coast of the Falkland Islands, and measured the kinematics of feeding behaviors. The authors found that when foraging at the surface, sei whales used a unique combination of surface lunges and skim-feeding behaviors. The surface lunges were slow and repetitive, and were unlike lunges performed by other rorqual species. The skim-feeding events featured a different filtration mechanism from the lunges and were kinematically different from the continuous filter feeding used by balaenids. While foraging below the surface, sei whales used faster and more variable lunges. These morphological characteristics which allow sei whales to effectively perform different feeding behaviors suggest that they rapidly evolved their versatile form to compete with larger and more efficient rorqual species (Segre *et al.* 2021).

In the North Atlantic, sei whales have regularly been observed skim-feeding (Dr. Danielle Cholewiak, NEFSC, personal communication, March 11, 2019). . During a survey of macroscopic and microscopic wear patterns in the baleen of eight whale species, Werth *et al.* (2016) found that sei whale baleen exhibited the most plate scratching (100% of all sei whale plates had scratches), which was similar to wear patterns of other balaenid baleen specimens who are known to skim-feed. This indicates that the sei whale uses similar skim foraging methods as their balaenid counterparts (Werth *et al.* 2016).

In the North Pacific, sei whales are considered to feed at somewhat higher trophic levels than in the Southern Ocean and exhibit a diverse diet (NMFS 2011). Watanabe *et al.* (2012) found that sei whales during summer in the subarctic and transition regions of the western North Pacific showed a prey preference for the Japanese anchovy *Engraulis japonica*, which correspond well to the northernmost region of the transition zone. A new study on sei whale foraging and diving behavior conducted by Ishii *et al.* (2017) indicated that sei whales change their diving depth and dive patterns in response to diel vertical migration or their prey. In addition, Ishii *et al.* (2017) suggested that sei whales may change their diving depth in response to changes in 'the distribution depth of their prey in order to maximize their feeding efficiency'. However, due to the small sample size (two individuals) in this study, general conclusions regarding sei whale diving behavior cannot be made at this time. In the North Atlantic, Prieto *et al.* (2012a) described sei whale feeding behavior as stenophagous, feeding almost exclusively on calanoid copepods and euphausiids, which brings into question the resilience of this species to perturbations in prey assemblages within this ocean basin. Additionally, sei whales are usually associated with oceanic frontal systems within their feeding grounds, and are commonly found along continental slopes or in basins situated between banks, where conditions enhance prey abundance (Prieto *et al.* 2012a; Murase *et al.* 2014).

Acoustics
Acoustic behavior and characteristics of sei whales is poorly understood and only a few accounts exist (Prieto *et al.* 2012a). Calls attributed to sei whales are low frequency, generally between 38 and 100 Hz, but there are some reports of higher frequency calls (3.5 kHz) (McDonald *et al.* 2005; Baumgartner and Fratantoni 2008). Variation in reported call parameters has been observed, but may be due to different geographic areas or populations (Prieto *et al.* 2012a). In addition, Baumgartner and Fratantoni (2008), observed higher vocalization rates of sei whales during the day when a key copepod prey species (*Calanus finmarchicus*) was found at depth, postulating that calls were the result of social interaction and increased when feeding activity decreased. Recently, Calderan *et al.* (2014) documented the first low-frequency (<100 Hz) recordings of sei whale calls observed in the Southern Ocean. In addition, Romagosa *et al.* (2015) added to this acoustic data by documenting the first record of sei whale calls from two individuals off the coast of the Azores during their migration to northern latitudes in spring and early summer. The authors noted their data could potentially support the findings of Baumgartner and Fratantoni (2008), which showed increased vocalizations with decreased feeding activity as the pair was recorded during the day and did not appear to be feeding (Romagosa *et al.* 2015). In addition, these calls were similar to sei whale calls reported off New England, Hawaii, and Florida.

Physiology and Organismal Biology
Apprill *et al.* (2020) examined the microbiota of 75 epidermal samples opportunistically collected from nine species within four marine mammal families including Balaenopteridae (sei whales). The study found that skin microbiotas were significantly different among host species, and microbial community distance was directly correlated with mitochondrial-based host genetic divergence. These data suggest that a phylosymbiotic relationship may exist between microbiota and their sei whale hosts, potentially providing specific health and immune-related functions that contribute to the success of sei whales in diverse ocean ecosystems (Apprill *et al.* 2020).

2.3.1.2 Abundance, population trends (see Section 2.2.3 Downlisting Criteria 1), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends
Information on sei whale demography is sparse at best. Taylor *et al.* (2007) estimated the generation time to be 23.3 years, with age at sexual maturity between 8-10 years (Lockyer 1984; Horwood 1987; NMFS 2011). Sei whale life span is about 60 years (Wiles 2017). A more recent study on earplug-based age determination of western North Pacific sei whales sampled by JARPNII/NEWREP-NP surveys between 2002 and 2018, found that age at

sexual maturity for males and females were 6.7 (SE=0.29) and 6.9 (SE=0.27) years, respectively (Bando *et al.* 2020).

The IWC Scientific Committee has used a natural mortality of 0.06, with age at first reproduction declining with stock depletion from 12-13 years to 10-11 years, and an annual pregnancy rate increasing with stock depletion from 0.27 to 0.37-0.39, which may be due to changes in ocean carrying capacity caused by whaling (IWC 1980; Reilly *et al.* 2008; Wiles 2017). Horwood and Millward (1987) also concluded that maximum rate of increase for sei whale populations is less than 3% per year. The sei whale gestation is approximately 10.5 months, with one calf born every 2-3 years (Kitayama *et al.* 2015; Wiles 2017). Mean fetal length at birth is approximately 4.5m (Kitayama *et al.* 2015). Newer data on life history parameters have been collected in the northwestern Pacific during 2004-2015 and are awaiting analysis (IWC 2017). Sei whale calves are most likely nursed for six to nine months, so weaning most likely occurs on the feeding grounds in summer or autumn (NMFS 2011).

Calculations of body length and evidence of seasonal spermatogenesis cycles have been shown to vary due to differences in calculation and sampling methodologies. For North Atlantic sei whales Lockyer (1984) pooled information on baleen whale reproductive parameters and estimated the mean age at sexual maturity was 8 years and mean length was 12.9m for male sei whales; for female sei whales, mean age at sexual maturity was 8 years and mean length was 13.3m.

Based on an examination of over 1,000 individual sei whales captured off the coast of South Africa, Best and Lockyer (2002) calculated a mean age of sexual maturity of 8.2 years and 8.6 years for Southern Hemisphere females and males, respectively (with first onset of sexual maturity occurring in some individuals in the third year) (NMFS 2011). Evidence for seasonal cycles in spermatogenesis is ambiguous for sei whales. Data gathered from the northwest Atlantic suggests a seasonal cycle with activity in late summer, which was supported by samples from Icelandic whaling (Prieto *et al.* 2012a). However, results from the Southern Hemisphere did not find seasonal cycles in spermatogenesis (Prieto *et al.* 2012a), which could reflect physiological differences between the North Atlantic and Southern Hemisphere populations. Results from various studies indicate that estimates of conception dates vary by ocean basin (Prieto *et al.* 2012a). Calculated estimates of ovulation rates vary, however, and it is generally agreed that female sei whales undergo a 2-3 year cycle (Prieto *et al.* 2012a). Conception occurs over a range of months, peaking in June and July in the Southern Hemisphere, in November and December in the North Pacific, and in December and January in the North Atlantic (Horwood 1987; Prieto *et al.* 2012a).

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

The sei whale exhibits moderate to high genetic diversity at microsatellite and mtDNA loci. Pastene *et al.* (2016) analyzed 1,554 pelagic North Pacific sei whales at 487 base pairs of the mtDNA control region and 17 microsatellite loci. Huijser *et al.* (2018) analyzed a subset of the samples from the North Pacific Ocean (n = 489) and an additional 87 samples from the North Atlantic Ocean. Both studies found that there is high haplotype diversity in the North Pacific population and moderate haplotype diversity in the North Atlantic population, indicating greater diversity in the Pacific Ocean. This however, may be attributed to a greater sample size, greater population size, or longer evolutionary history. Regardless, these studies indicate that the sei whale has moderate to high genetic diversity, providing the raw genetic material required to adapt to changes in its environment, and thus some resilience to such perturbations.

The sei whale also demonstrates genetic discontinuity and significant spatial structure within its global range. Baker *et al.* (2004) compared mitochondrial deoxyribonucleic acid (i.e., mtDNA) control region and cytochrome b sequences of sei whales sampled in the North Atlantic Ocean (n = 4), North Pacific Ocean (n = 40), and Southern Hemisphere (n = 11). They found strong bootstrap support (i.e. 95 percent) separating the North Atlantic haplotypes (i.e. unique mtDNA sequences) from all others; however, there was less than 50 percent bootstrap support for separation between Southern Hemisphere and North Pacific haplotypes at both genetic markers (Baker *et al.* 2004). Huijser *et al.* (2018) also compared mtDNA control region sequences of samples collected from the North Atlantic Ocean (n = 84), North Pacific Ocean (n = 488), and Southern Hemisphere (n = 1). They found strong bootstrap support (i.e. 90 percent) for two clades: one including six haplotypes from the North Atlantic Ocean and another comprising one North Atlantic haplotype (from samples collected in the Azores), the Southern Hemisphere haplotype, and all North Pacific haplotypes. The authors concluded that there is low bootstrap support for the separation of the Azores haplotype from the remainder of that clade (75 percent; Huijser *et al.* 2018). Performing additional mtDNA analyses and analyzing samples at seven or more microsatellite loci, Huijser *et al.* (2018) found strong genetic differentiation between samples collected in the North Pacific and North Atlantic Oceans. Their microsatellite analyses revealed two (i.e. K = 2 using the software, Structure), highly differentiated ($\Phi ST = 0.72$; $P < 0.05$) populations. Their mtDNA analyses also indicated strong genetic structure ($\Phi ST = 0.72$; $P < 0.001$) between North Pacific and North Atlantic populations, corresponding to a divergence time of approximately 163,000 years, with a 95 percent confidence interval of 57,000 to 386,000 years (Huijser *et al.* 2018). Huijser *et al.* (2018) did not find statistically significant differences among three locations within the North Atlantic Ocean (including the Azores) at the mtDNA control region nor between the microsatellite loci, however, the 95 percent confidence intervals varied widely (ΦST = 0.00 to 0.14; Huijser *et al.* 2018), revealing some uncertainty in the microsatellite results, and the authors acknowledged that they could not rule out potential population structure within the ocean basin. The authors also noted that samples were not available from all potential stocks, limiting their ability to test for population structure within the North Atlantic Ocean.

The same is true for the North Pacific Ocean. Genetic analyses indicated that there is no population structure within the pelagic North Pacific Ocean; however, samples were not available from the other four putative stocks (Pastene *et al.* 2016). From these data, it is clear that there is genetic discontinuity within the species. The bi-parentally inherited microsatellite loci indicate genetic discontinuity between the North Atlantic and North Pacific Oceans. Most analyses of maternally-inherited mtDNA also support genetic discontinuity; however, while six North Atlantic haplotypes cluster together and are highly divergent from all others, one North Atlantic haplotype sampled from the Azores does not fit neatly into this clade. It is unclear whether this haplotype represents recent immigration or the existence of a rare, ancestral North Atlantic lineage (Huijser *et al.* 2018). Furthermore, it is unclear whether there is genetic discontinuity between North Pacific Ocean and Southern Hemisphere sei whales.

Taguchi *et al.* (2021) conducted the first population genetic study of sei whales worldwide using microsatellite DNA (msDNA). Findings from this study demonstrated the hierarchical genetic structuring of sei whales globally for the first time, with high genetic diversity found in the Southern Hemisphere and North Pacific, in which whales in the Southern Hemisphere were genetically closer to North Pacific sei whales than North Atlantic sei whales (Taguchi *et al.* 2021). The haplotype frequency of sei whales was found to be significantly different among the three oceanic regions, and suggests genetic differentiation of this species between the North Atlantic, North Pacific, and Southern Hemisphere (Taguchi *et al.* 2021). This observation is consistent with the pattern of genetic differentiation of sei whales between the North Pacific and North Atlantic presented by Huijser *et al.* (2018).

Taking all the present and previous findings together from the aforementioned studies, sei whales appear to be significantly differentiated among oceanic regions hierarchically, and sei whales in the Southern Hemisphere are more closely related to sei whales in the North Pacific than sei whales in the North Atlantic. Taguchi *et al.* (2021) also suggest that the pattern of genetic structuring in sei whales could be attributed to an historical event (i.e. recent occasional gene flow between Northern and Southern hemispheres and/or incomplete lineage sorting). However, extended genetic analyses using larger sample sizes across the oceans and more genetic loci have to be conducted in this species to investigate finer genetic structure and demographic estimates (e.g., migration rate and effective population size).

Higher taxonomic diversity amongst balaenopterids (including the sei whale) was suggested to be linked to heterochrony (Tsai *et al.* 2014). During ontogeny, sei whale skull morphology changed substantially, which implies significant ontogenetic change in head posture, size, and/or function of feeding muscles.

Overall, Tsai *et al.* (2014), found that balaenopterid ontogeny seemed less constrained in regards to morphological change, and suggested that heterochrony may lead to high diversity in balaenopterids.

2.3.1.4 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):

Distribution

The sei whale is a cosmopolitan species, occurring worldwide across all major ocean basins. They are mainly distributed offshore, occurring from both polar to tropical waters. This species is found in the North Pacific, North Atlantic, and Southern Hemisphere; it also occasionally visits the Mediterranean, with sightings and strandings reported from Spain, Gibraltar, France and possibly Tunisia (Prieto *et al.* 2012a). Sei whale densities appear highest in mid-latitude temperate regions in water temperatures of 8°C to 18°C (Reilly *et al.* 2008). The sei whale is primarily pelagic in nature, commonly found in deep ocean basins or along the continental slope (Prieto *et al.* 2012a). However, sei whales are noted for their erratic appearance in certain regions, specifically feeding grounds, as they often appear within the same feeding ground for a number of years and then disappear for extended periods of time (years to even decades) (Elwen and Relton 2016).

Like other large baleen whales, the sei whale is thought to undergo seasonal migrations between tropical and subtropical latitudes in winter (where mating and calving occur) and temperate and subpolar latitudes in summer (where feeding areas are present). However, the winter breeding areas are still unknown for this species. Feeding areas can vary substantially among years and seasons depending on changing ocean conditions and prey availability (Prieto *et al.* 2012b; Wiles 2017). A study by Prieto *et al.* (2014) utilized satellite tracking to show movements of tagged whales from the Azores to the Labrador Sea, evidence of a migratory corridor between these two areas. This study also identified a link between the Azores and possible wintering grounds off northwest Africa, as one animal tagged in the fall in the Azores migrated southeast towards the Canary Islands (Prieto *et al.* 2014). A more recent study by Romagosa *et al.* (2020b) used a 5-year acoustic data set collected by autonomous recorders in the Azores and found that sei whales showed a bimodal distribution of acoustic presence in spring and autumn, corresponding to their expected migration patterns. Diel differences in sei whale calling varied with season and location within the Azores, highlighting the importance of this region as a migratory and wintering habitat for sei whales. As mentioned earlier (refer to Section 2.2.3 Downlisting Criteria 1), most data in recent years on sei whale distribution come from either dedicated or opportunistic sighting surveys. In addition, much of the survey information has not been published in peer-reviewed journals making it hard to evaluate (Prieto *et al.* 2012a).

More detailed distribution information from either dedicated or opportunistic sighting surveys is discussed below for each ocean basin.

North Atlantic

While previous studies noted that sei whales seldom venture into colder waters of the polar seas, sighting data from a study conducted by Storrie *et al.* (2018) within North Atlantic Arctic waters around the Svalbard Archipelago reported sei whale sightings at the northern tip of Spitsbergen (79.87° N, 14.88°E). This is the most northerly recorded sighting for this species, suggesting a possible range expansion could be taking place in the North Atlantic (Storrie *et al.* 2018). In addition, the Norwegian Polar Institute's Marine Mammal Stranding Database reported a total of 79 sei whale individuals off the coast of Svalbard between 2002 and 2014 for the months of March through November (Storrie *et al.* 2018). More recently, Nieukirk *et al.* (2020) documented acoustic presence of sei whales in the Fram Strait (~79° N) from 2009-2014 for several months during all five years of a study to record multi-year, seasonal occurrence of vocalizing cetaceans via autonomous hydrophones. The authors suggest that due to the presence of warm Atlantic water and a strong front concentrating prey in this area, a 'hot spot' of oceanographic conditions is created suitable for foraging sei whales (Nieukirk *et al.* 2020). While this could be another example of a range expansion for this species, further monitoring is required to determine whether sei whale presence is ephemeral or a common occurrence for this region.

Perez-Jorge *et al.* (2020) tracked sei whales in mid-North Atlantic waters and found that all individuals traveled north-west towards the Labrador Sea, defining a clear migratory route for this species which indicated sei whales prefer deeper waters. Perez-Jorge *et al.* (2020) identified latitudes above 45°N, predominantly around the south-west of the Irminger Sea and in the Labrador Sea (except the shallow waters along the Greenland coast) as important habitats for sei whales.

A 60-day seismic survey conducted off the coast of Mauritania in winter (2012/2013), yielded a total of 33 sei whales in seven sighting events (Baines and Reichelt 2014), and visual observations and recordings of vocalizations were documented from a pair of sei whales off the Azores Archipelago during April, 2012 (Romagosa *et al.* 2015). Additionally, Zahn *et al.* (2020) observed 35 sei whales during two land- and boat-based surveys conducted in waters south of Pico (Azores, Portugal) in July/August and October 2020. Passive acoustic monitoring conducted along the U.S. east coast in 2015-2016 reported acoustic detections of sei whales off the southern edge of Georges Bank, as well as sporadic acoustic detections through the late fall and winter from Cape Hatteras to the Blake Plateau off Florida and Georgia (Cholewiak *et al.* 2018b; Baumgartner *et al.* 2021; Weiss *et al.* 2021). Sightings and acoustic data from these studies add new information to the distribution knowledge of sei whales within the North Atlantic.

North Pacific

Sei whales were sighted during the 2012-2016 IWC-POWER cruises at various locations in the North Pacific (Matusuoka *et al.* 2013; Matusuoka *et al.* 2014; (Matusuoka *et al.* 2015; Matusuoka *et al.* 2016). In the western North Pacific, Murase *et al.* (2014), found high concentrations of sei whales associated with three oceanic fronts (the Polar Front, Subarctic Front, and Kuroshio Extension Front) in July from 2000 to 2007. This subarctic-subtropical transition area should thus be considered an important feeding ground for sei whales (Murase *et al.* 2014).

A more recent study by Matsuoka *et al.* (2020a) reported 20 individual sei whales observed during the 2019 IWC-POWER survey conducted from July through September in the Gulf of Alaska within the exclusive economic zone.

Southern Hemisphere

Sightings data from various surveys indicate sei whale presence in peak summer (January– February), between 40°S and 50°S in the southern Indian oceans and the South Atlantic (Joiris *et al.* 2015), and between 45°S and 60°S in the South Pacific, but only the larger individuals are known to travel farther south than the Antarctic Convergence (± 55°S) (Elwen and Relton 2016). In recent decades, sei whale sightings have increased around the Falkland Islands, with the sei whale comprising around 50% of the reported sightings in coastal waters. Sei whales in the waters off South Africa are typically en route northwards from their summer feeding grounds (predominantly in May/June), or southwards from their tropical breeding grounds (generally between August and October) (Elwen and Relton 2016). Other studies report sei whale occurrence ranging from coastal Antarctica to South Africa, to within the Brazil-Malvinas Confluence, and the northern Indian Ocean (Reyes *et al.* 2014; Mandiola 2015; Matsuoka *et al.* 2015; Findlay and Best 2016; Heissler et al 2016; Isoda 2017). In addition, sei whales have been observed in north-eastern New Zealand waters, which suggests that the waters off of northern New Zealand may be part of their migratory route (Stephenson *et al.* 2020). Circumpolar sightings of sei whales have been reported by Murase *et al.* (2014) as part of a spatial distribution analysis from the period of the IWC IDCR/SOWER cruises. Sightings data from these studies add new information to the distribution knowledge of sei whales within the Southern Hemisphere. Matsuoka and Hakamada (2020b) sighted a total of 59 individual sei whales (with no calves observed) in the Indo-Pacific region of the Antarctic using JARPA and JARPAII sightings data obtained through 1987/88 – 2008/09 field seasons.

Population Structure

North Atlantic

The IWC recognizes three defined stocks for North Atlantic sei whales: Nova Scotia; Iceland-Denmark Strait; and Eastern (including the waters of Spain, Portugal, British Isles, Faeroes and Norway) (Prieto *et al.* 2012a). Current IWC boundaries were adopted based on historical catch data rather than on scientific evidence of stock structure. Sei whale movements recorded via satellite telemetry (refer to Distribution section above) revealed a migratory route between the Azores and the Labrador Sea (Prieto *et al.* 2014); however, migratory routes for other populations are still unknown. In addition, genetic studies have revealed moderate haplotype diversity in the North Atlantic population (Pastene *et al.* 2016; Huijser *et al.* 2018). Analyzing mtDNA control region and cytochrome b sequences, Baker *et al.* (2004) found strong bootstrap support (i.e., 95 percent) separating the North Atlantic haplotypes (i.e., unique mtDNA sequences) from all others; however, there was less than 50 percent bootstrap support for separation between Southern Hemisphere and North Pacific haplotypes at both genetic markers (Baker *et al.* 2004). In addition, Huijser *et al.* (2018) did not find statistically significant differences among three locations within the North Atlantic Ocean (including the Azores) at the mtDNA control region nor between the microsatellite loci, however, the 95 percent confidence intervals varied widely ($\Phi ST = 0.00$ to 0.14) revealing some uncertainty in the microsatellite results. The authors noted that samples were not available from all potential stocks, limiting their ability to test for population structure within the North Atlantic Ocean.

North Pacific and Southern Hemisphere

The IWC only considers one stock of sei whales in the North Pacific, but some evidence exists for multiple populations (Mizroch *et al.* 1984). Recently, a genetics study conducted by Huijser *et al.* (2018) found high haplotype diversity in the North Pacific population; however, genetic analyses confirmed that there is no population structure within the pelagic North Pacific Ocean; although samples were not available from the other four putative stocks (Pastene *et al.* 2016).Taguchi *et al.* (2021) found that sei whales appear to be significantly differentiated among oceanic regions hierarchically, and sei whales in the Southern Hemisphere are more closely related to sei whales in the North Pacific compared to sei whales in the North Atlantic (refer to section 2.3.1.3 above).

2.3.1.5 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

As noted above in section 2.3.1.4 sei whale densities are predominantly highest in mid-latitude temperate regions in water temperatures of 8°C to 18°C (Horwood

1987). However, new evidence from Storrie *et al.* (2018) and Nieukirk *et al.* (2020), suggest a possible range expansion could be taking place in North Atlantic waters, since sei whales have been observed at the northern tip of the Svalbard Archipelago and in the Fram Strait.

The sei whale is primarily pelagic in nature, commonly found in deep ocean basins or along the continental slope, and infrequently venture over shelf waters (Prieto *et al.* 2012a). As noted above in section 2.3.1.4, this species undergoes seasonal migrations between tropical and subtropical latitudes in winter (where mating and calving occur) and temperate and subpolar latitudes in summer (where feeding areas are present). They usually move in small groups (between two to five individuals), although larger aggregations can occur in feeding grounds (Weir 2017). However, sei whales are notorious for their erratic appearance in specific feeding grounds, appearing plentiful in some years and absent (for years to even decades) in others (Elwen and Relton 2016).

Recently, a study by Prieto *et al.* (2014) utilized satellite tracking to show movements of tagged whales from the Azores to the Labrador Sea (a known feeding ground). Prieto *et al.* (2014) found evidence of sei whale migratory routes which comprised not only latitudinal movements but also longitudinal displacements. In addition, molecular sexing results from an earlier study indicated seasonal gender distribution, with a dominance of males in the beginning of the season (contrary to data from other regions), which may suggest that pregnant females are in the forefront of the migration or could be a result of different behavior by females both to and from feeding grounds (Prieto *et al.* 2012a). More recently, a 2020 study by Weir *et al.* documented movement and distribution of sei whales between Brazil and the Falkland Islands and provided the first definitive evidence via photographic recapture data of connectivity between a winter breeding ground (Brazil) and a summer feeding area (Falkland Islands) in the southwest Atlantic.

In the North Pacific, sei whales are known to occur all across the temperate regions north of 40°N latitude. In the south, they range from Baja California, Mexico, to Japan and Korea in the west, and have been documented in the Hawaiian Islands (NMFS 2011). Mark recapture studies indicate that sei whales travel great distances across this ocean basin-- from low latitudes in winter to high latitudes in spring/summer, and across high latitudes during the spring/summer (Mizroch *et al.* 2015). Long distance seasonal movements of up to 6,774 km have been documented (Mizroch *et al.* 2015). In the eastern North Pacific, sei whales regularly migrate past Vancouver Island, British Columbia from May to August (Wiles 2017) and past central California mainly in late summer and early fall (Rice 1974). Recently, sei whales have been more common in the California Current compared to previous years, and may be attributed to a distributional shift from pelagic waters in the North Pacific to more coastal waters found within the California Current (Barlow 2016). The locations of the eastern North Pacific stock's summering and wintering grounds have not been identified (Wiles 2017).

As noted previously, studies in both the North Pacific and North Atlantic Oceans show that sei whales are strongly associated with oceanic fronts and eddies (NMFS 2011). In the Southern Hemisphere, a similar affinity for oceanic fronts was observed among sei whales in Antarctic waters (NMFS 2011). These are oceanographic features that likely concentrate prey—and may be exploited by feeding sei whales—that, in turn, are dependent on prevailing currents. These whales may also use currents in large scale movements or migrations (NMFS 2011). During years with abundant squat lobsters, the Golfo de Penas off the coast of Chile has recently been described as one of the most important feeding grounds for sei whales, with some of the largest and densest reported sei whale aggregations (Häussermann *et al.* 2017). The first documented recordings of sei whale calls in the Southern Ocean have been reported, which share similar characteristics to low-frequency recordings of individual sei whales off of Cape Cod, Massachusetts in winter and summer, respectively (Calderan *et al.* 2014). This confirms that sei whales travel large distances, spanning ocean basins, between feeding and calving grounds.

Recent studies have indicated that mid-latitude habitats along baleen whale migration routes play an important role on feeding ecology for a number whales (Prieto *et al.* 2017). Sei whales are known to occur in the Azores as confirmed by Romagosa *et al.* (2015), who used acoustic recordings to document sei whale calls off the Azorean coast. Prieto *et al.* (2017) aimed to assess the function of a mid-latitude habitat (the Azores) for the sei whale using environmental niche models and compared niche overlap and relative habitat patch importance between sei, blue, and fin whales. However, variables considered in the sei whale model showed reduced influence on sei whale occurrence around the Azores and little environmental niche overlap was found between the sei whale and the other two rorquals. This suggests that this region is most likely not a foraging habitat for sei whales but rather an area they travel through en route to higher latitude feeding grounds (Prieto *et al.* 2017). Sei whales also may use the Azores Archipelago as topographic landmarks to aid in their navigation, though such use cannot be confirmed from this study (Prieto *et al.* 2017).

2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)

The sei whale recovery plan (NMFS 2011) did not identify recovery criteria for factor C: Disease or Predation, because there were no data to indicate this factor was more than a low threat. In this section, we provide updated information from studies related to factor C. In addition, we provide new information under factors C and E not related to the recovery criteria. See section 2.2.3 for updated information on the other factors.

Factor C: Disease or Predation

Parasites have been known to cause major health issues for a number of cetaceans and have been noted as a significant source for natural mortality for sei whales (Horwood 1987; Prieto *et al.* 2012a). Helminth parasites can cause severe complications to respiratory and urinary systems (Prieto *et al.* 2012a). Several species of helminth parasites were found to infect genitalia and the gastrointestinal tract of sei whales within the Antarctic, and a high percentage of Acantocephalan *Bolbosoma* spp. infections were found in the colon or small bowel of a sample of sei whales from Iceland (n=24) (Lamberstsen 1990; Prieto *et al.* 2012a). Additionally, the first record of a sei whale carrying the endoparasites *Bolbosoma turbinella*, was documented in Malaysian waters within the straits of Malacca (Zakariah *et al.* 2021). A 2008 stranding of a sei whale along the Patagonian coast contained the first record of a host carrying helminth trematodes and nematodes in the southwest Atlantic, with 3,000 individuals counted in the stomach (Leonardi *et al.* 2011). Viral disease has been found in sei whales in the North Atlantic, where inflammation of the mucosa of the trachea and bronchi consistent with a viral pathogen was found within 18% of sei whales examined from Iceland. (Lambertsen 1990). However, overall impacts of these viral and bacterial infections are unknown.

Hermosilla *et al.* (2016) investigated gastrointestinal parasite fauna from feces of free-swimming sei whales around the Azores, and found that sei whales were parasitized with three protozoans (*Entamoeba* sp. and *Giardia* sp.). This finding includes the sei whale as a new host record for both *Entamoeba* sp. and *Giardia* sp., and confirms that the sei whale is exposed to anthropogenic parasites within its natural marine environment. More recently, Gomes *et al.* (2021) recorded sei whales off the Japanese coast that were infected with *Anisakis* nematodes. Since sei whales (and other large cetaceans) can range close to populated coastlines and/or tourist attractions such as whale watching tours, whales could become infected by human excretions. In terrestrial mammals, *Giardia* infections cause severe diarrhea and upset of the gastrointestinal tract (Hermosilla *et al.* 2016). In addition, Ohishi *et al.* (2016) found that *Brucella* (an intracellular bacteria known to cause reproductive disorders) was prevalent in western North Pacific sei whales, and marked granulomatous testes were observed in mature individuals. Further research is required to ascertain the pathogenesis of *Giardia* sp. in the marine environment, its associated impacts, and whether parasitized protozoans and pathogenic bacteria pose a significant threat to sei whales.

Sei whales are often observed with numerous oval scars on their flanks and back, primarily from cookie-cutter shark (*Isistius* sp.) bites (NMFS 2011; Weir 2017). In addition, killer whales (*Orcinus orca*) have been reported to prey on a number of large cetaceans, including the sei whales (NMFS 2011). However, the scale and ecological significance that predation by sharks and other cetaceans have on the sei whale population is still a debate within the scientific community (Prieto *et al.* 2012a). Further research is needed to assess whether predation from these species is a true threat to the sei whale population.

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

Injury from Marine Debris
The accumulation of debris in the marine environment is increasing. An estimated 6.4 million tons of marine litter is dumped into the oceans on an annual basis, with plastics

comprising 60% - 80% of the total (Baulch and Perry 2014). As lost and discarded debris increases so does the concern for marine fauna. For many marine species, marine debris is considered a major threat, and is now an emerging threat to baleen whales, including the sei whale. Ingestion of marine debris by cetaceans may include internal injuries or cause complete blockage to the digestive tract leading to malnutrition, starvation, and mortality (Simmonds 2012; Baulch and Perry 2014). Most observations of cetacean ingestion of marine debris is through necropsies of stranded animals, and has been documented in 48 (56% of) cetacean species, including nine mysticete species, with ingestion rates as high as 31% in certain populations (Baulch and Perry 2014; Weir 2017). Marine debris ingestion has been documented in the stomach of one of three sei whales found stranded along the UK coast, yielding an ingestion rate of 33% (Baulch and Perry 2014). The Institute of Cetacean Research (ICR) reported a plastic bowl found in the stomach of a sei whale during the sampling and sighting surveys of the NEWREP-NP (ICR 2017). Anecdotal reports from necropsies document a broken DVD case found in the belly of a young female sei whale in August 2014 in Virginia, which had lacerated the stomach, preventing it from feeding (National Geographic article about a broken DVD case found in a sei whale off the coast of Virginia). In February 2016, plastic debris was found in the stomach of a beached sei whale in the southern Malaysian state of Johor (EcoWatch article about garbage found in a beached sei whale in Malaysia). Since the feeding mechanisms used by sei whales are primarily non-selective (Prieto *et al.* 2012a), one could expect that plastics and other marine detritus could be ingested along with prey. Recently, a study conducted by Burkhardt-Holm and N'Guyen (2019) reported sei whales feeding on fish species have potential for ingesting microplastics via their prey. Thus, while sei whale mortalities could not be definitively attributed to ingestion of marine debris, one can assume that sei whales can (and do) ingest plastics. Further research is needed to understand the effects, if any, of marine debris on sei whale populations.

Contaminants and Pollutants

Information on contaminant loads in sei whales is scarce. Studies that compared organochlorine compound contamination between odontocetes and mysticetes from the same area found that contamination levels were an order of magnitude higher in odontocetes comparted to mysticetes (Prieto *et al.* 2012a). This is because mysticetes generally feed at lower trophic levels compared to their odontocete counterparts, thus resulting in lower contaminant loads (Clapham *et al.* 1999; Prieto *et al.* 2012a). High levels of organochlorines can affect reproduction, immune and endocrine function (Harwood 2001; Islam and Tanaka 2004). However, sei whale blubber samples from South Africa and Iceland all found low concentrations of polychlorinated aromatic hydrocarbons (PCBs) and of isomers and metabolites of dichloro-diphenyl trichloroethane (DDT) (Henry and Best 1983; Weir 2017). Yet higher concentrations of persistent organic pollutants (POPs), specifically PCBs were found in the blubber of sei whales in the western North Pacific, possibly because temperate locations in the northern hemisphere (ca. 30-70°N) are where anthropogenic usage and atmospheric emissions have been concentrated (Yasunaga *et al.* 2020). The sei whale's preference for low trophic prey organisms (i.e. euphausiides and copepods), directly influences their contaminant load (Wiles 2017). This was confirmed by Yasunaga and Fujise (2017) who measured total mercury (Hg) concentration in the western North Pacific sei whale from 1994-2014. They found that temporal changes in total Hg concentrations reflect changes in food habits of sei whales rather than changes in Hg levels in the marine environment.

2.4 Synthesis

There are insufficient data to undertake an assessment of the sei whale's present status. Due to a lack of comprehensive abundance and distribution data for all three ocean basins, and absence of dedicated systematic surveys, there is no scientifically rigorous estimate of global abundance (see section 2.2.3, criterion 1). However, a crude estimate of global decline from approximately 250,000 whales before whaling to perhaps 32,000 whales by the 1970s to 1980s is reported (Wiles 2017). This 5-year review reports a new and scientifically reliable abundance estimate of approximately 35,000 individuals for a subset of the North Pacific (see section 2.2.3, criterion 1). However, scientifically reliable abundance estimates are not available for the North Atlantic and Southern Hemisphere, due to inherent uncertainties in (1) sampling design, (2) data collection methodologies, and (3) use of outdated CPUE-based abundance estimates (which are no longer accepted in IWC stock assessments). While a new abundance estimate has surfaced for a subset of the North Pacific, no reliable trend information is available because basin-wide and global estimates remain relatively fragmented and incomplete. This challenge coupled with limited survey effort and data deficient (and imprecise) pre-whaling population estimates prevents scientifically rigorous abundance estimates to determine global population trends. In addition, wide-ranging, off-shore distribution of sei whales further complicate efforts to estimate abundance and produce trend data. Consequently, the extent of depletion and degree of recovery of sei whale populations remain unknown.

The relative impact of directed hunts to the recovery of sei whales is ranked in the recovery plan as medium due to a medium severity and a medium level of uncertainty. Directed hunts have largely been addressed and no longer pose a threat to sei whales in most of their range as long as the IWC moratorium remains in place. However, hunting of sei whales has continued under the ICRW's provision for scientific whaling. Since the mid-1970s, there has been some demand in world markets (most of it centered in Japan) for baleen whale meat, and genetic evidence of illegal international trade of sei whale meat between the United States and South Korea has been found. Beginning in 2002, Japan has hunted sei whales on the high seas as part of its special permit whaling program and was recently found in non-compliance of Article III of CITES because it introduced sei whale meat from the sea for primarily commercial purposes. Japan withdrew from the ICRW effective June 30, 2019. In announcing its withdrawal from the ICRW, Japan indicated that it will cease its special permit whaling for sei whales on the high seas, and will begin commercial whaling for sei whales (and other whale species) in its exclusive economic zone at levels considered sustainable by the IWC Scientific Committee (see section 2.2.3 criterion 2, Factor B).

All other threats in the sei whale recovery plan were ranked as either 'low', 'unknown', 'unknown, but potentially low', or 'unknown, but potentially high' in terms of relative impact to recovery. The threat that was categorized as 'unknown, but potentially high' was loss of prey base due to climate and ecosystem change or shifts in habitat. However, this potential threat was identified as having a high degree of uncertainty regarding extent of impact, if any, to sei whales. Although new information has emerged regarding impacts of climate and oceanographic change on prey species especially as it pertains to the North Atlantic, it remains unknown whether reduced prey abundance due to climate change is a legitimate threat to sei whales on a global scale. The feeding range of the sei whale is wide, and while there may be differences between sei whale stocks and their associated prey species, this large feeding range may make them more resilient to climate change on a global scale, should it affect prey, compared to a species with a narrower range (see section 2.2.3 criterion 2, Factor A; NMFS 2011). Therefore further research is required to determine impacts (if any) on loss of prey base due to climate and ecosystem changes.

Sei whales may face additional threats. Potential threats include anthropogenic noise, ship collisions, and fisheries entanglements. The magnitude of threats from anthropogenic noise and ship collisions is highly uncertain, whereas fisheries entanglements have a medium uncertainty ranking. In addition, new information identified in this 5-year review regarding contaminants and pollution, disease from parasites, and injury from marine debris warrants further research to determine whether these stressors threaten sei whales. Lack of comprehensive information on this species' status and trends creates a challenge to successfully evaluating recovery. If we knew whether this population was increasing or decreasing, we could better understand if and how these factors are limiting sei whale recovery. Furthermore, some threats may be intensifying (e.g., such as climate change and anthropogenic noise) and new information continues to surface about emerging potential impacts (e.g., injury from marine debris). Currently, there is insufficient data to undertake an assessment of the sei whale's present status due to a number of uncertainties and unknowns for this species: (1) lack of scientifically reliable population estimates for the North Atlantic and Southern Hemisphere; (2) lack of comprehensive information on status and trends; (3) existence of critical knowledge gaps; and (4) emergence of potential new threats. Thus, further research is needed to fill critical knowledge gaps. In addition, Canada's 2019 COSEWIC report recommended uplisting the Canadian Atlantic population of sei whales to endangered, and this population has now been added under Schedule I of SARA due to record low numbers in Canadian east coast waters. Consequently, reclassification should not occur, and the status of the sei whale should remain as 'endangered'.

3.0 RESULTS

3.1 Recommended Classification

_____Downlist to Threatened
_____Uplist to Endangered
_____Delist *(Indicate reason for delisting per 50 CFR 424.11):*
_____*Extinction*
_____*Recovery*
_____*Original data for classification in error*
__X___No change is needed

3.2 New Recovery Priority Number: 6C[8]

Brief Rationale: The new recovery priority number (6C) is based on new guidelines, which were implemented in 2019 and cannot be compared to the number before this review (11). Because basin-wide and global estimates remain relatively fragmented and incomplete, sei whale population trends are still unknown, indicating a high demographic risk. Insufficient data and critical knowledge gaps on threats to sei whales exist, indicating low to moderate understanding of major threats. Many actions to recover the species are outside U.S. jurisdiction indicating the existence of low to moderate U.S. jurisdiction, authority, or influence for management or protective actions to address major threats, with high certainty that management or protective actions will be effective. In addition, this species is in conflict with construction or other development projects or other forms of economic activity (e.g. sei whale mortality from vessel strikes, see section 2.2.3 Factor E). Therefore, the priority number of '6C' was determined based on a combination of the aforementioned demographic risk rank, evaluation of the recovery potential components, and potential conflict with construction, development projects, or other forms of economic activity.

[8] The recovery priority number 11 was based on NMFS' 1990 (55 FR 24296) priority system. However, in 2019, NMFS changed the recovery priority number process and issued final Recovery Priority Guidelines (April 30, 2019; 84 FR 18243). This new priority system goes from 1-11 (for species that are not in conflict with construction or other development projects or other forms of economic activity) or 1C-11C (for species that are in conflict).

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

Insufficient data and critical knowledge gaps remain for the sei whale, resulting in a lack of global status and trend information called for under Criterion 1. While this 5-year review reported a new abundance estimate within a subset of the North Pacific, basin-wide and global estimates remain relatively fragmented and incomplete. This highlights the need for global surveys that cover a wide latitude and longitudinal range, to accurately ascertain the status of sei whales and gain an understanding of the effect of the IWC's moratorium on the sei whale population. Additionally, continuing routine surveys in U.S. waters would greatly enhance information on U.S. populations and provide a better picture of trend data in the North Atlantic and North Pacific. In the past, research on the sei whale has been primarily hampered due to its pelagic nature and erratic appearance in certain coastal waters and feeding grounds, which can make studying this species logistically difficult compared to more coastal, consistently present species. With the advent of techniques to derive and analyze data, such as satellite telemetry and passive acoustic monitoring, it is now possible to conduct cetacean research more effectively and efficiently in pelagic habitats. Furthermore, while new information has emerged on genetic diversity and spatial structure for North Atlantic and North Pacific sei whales, more research is necessary to identify and delineate potential population segments and to evaluate population structures in the Southern Hemisphere.

In this 5-year review, we determined that further research is needed on the following recovery criteria: (a) effects of reduced prey abundance due to climate change continue to be investigated and action is being taken to address the issue, as necessary; (b) effects of anthropogenic noise continue to be investigated and action taken to minimize potential effects, as necessary; (c) ship collisions continue to be investigated and actions taken to minimize potential effects, as necessary; and (d) entanglement with gear associated with the offshore gillnet fishery continues to be investigated and actions taken to minimize potential effects, as necessary. In addition, we provided new and updated information under factors C and E not related to the recovery criteria: (a) disease from parasites, (b) contaminants and pollutants, and (c) injury from marine debris. Both require additional research to understand the effects, if any, on sei whale populations. The aforementioned recovery criteria should continue to be assessed for progress made on investigations and whether appropriate actions should be taken. Emerging information relating to disease from parasites and/or injury from marine debris should continue to be monitored and assessed to determine whether these issues threaten sei whales. In addition, further work should be conducted to assess distribution and population structure, to better elucidate habitat use, migratory corridors and potential stock structure within ocean basins.

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NATIONAL MARINE FISHERIES SERVICE
5-YEAR REVIEW
Sei Whale

Current Classification: Endangered

Recommendation resulting from the 5-Year Review

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
__ **X**_No change is needed

Review Conducted By: Heather Austin, Office of Protected Resources

LEAD OFFICE APPROVAL:

Director, Office of Protected Resources, NOAA Fisheries

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Approve: ____ Date: ________

HEADQUARTERS APPROVAL:

Assistant Administrator, NOAA Fisheries

__X___Concur _____ Do Not Concur

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