SEI WHALE (*Balaenoptera borealis borealis*): Nova Scotia Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Mitchell and Chapman (1977) reviewed the sparse evidence on stock identity of western North Atlantic sei whales, and suggested two stocks—a Nova Scotia stock and a Labrador Sea stock. The range of the Nova Scotia stock includes the continental shelf waters of the northeastern U.S., and extends northeastward to south of Newfoundland. The Scientific Committee of the International Whaling Commission (IWC), while adopting these general boundaries, noted that the stock identity of sei whales (and indeed all North Atlantic whales) was a major research problem (Donovan 1991). Telemetry evidence indicates a migratory corridor between animals foraging in the Labrador Sea and the Azores, based on seven individuals tagged in the Azores during spring migration (Prieto et al. 2014). These data support the idea of a separate foraging ground in the Gulf of Maine and Nova Scotia. However, recent genetic work based on both mitochondrial DNA and microsatellite analyses, did not reveal stock structure in the North Atlantic though the authors acknowledge that they cannot rule out the presence of multiple stocks (Huijser et al. 2018). Therefore, in the absence of clear evidence to the contrary, the proposed IWC stock definition is provisionally adopted, and the "Nova Scotia stock" is used as a stock for the purposes of management under the MMPA. The IWC considered the boundaries of this stock to be from the U.S. east coast to Cape Breton, Nova Scotia, thence east to longitude 42° W. A key uncertainty in the stock structure definition is due to the sparse availability of data to discern the relationship between animals from the Nova Scotia stock and other North Atlantic stocks and to determine if the Nova Scotia stock contains multiple demographically independent populations.

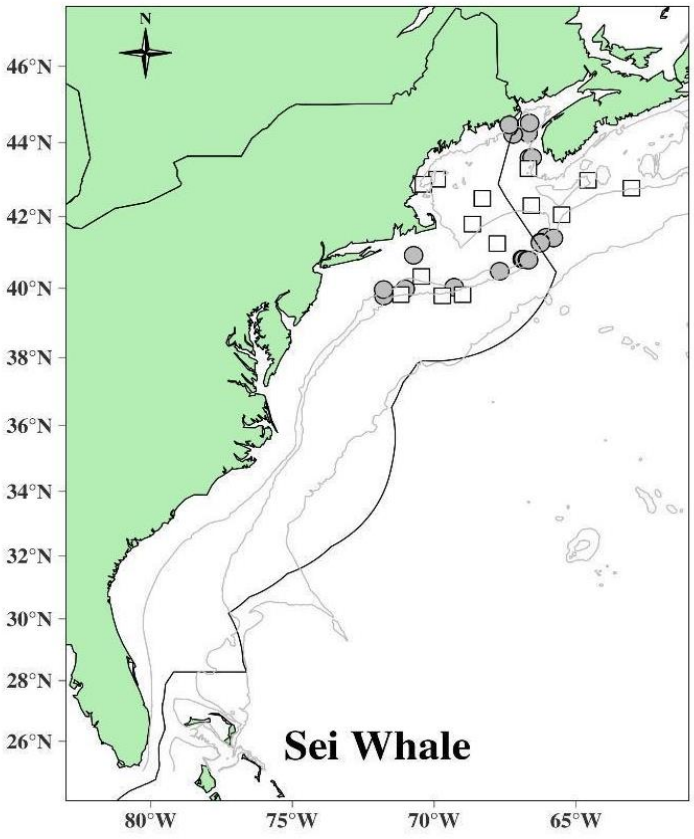

Figure 1. Distribution of sei whale sightings from NEFSC and SEFSC shipboard and aerial surveys during the summers of 1995, 1998, 1999, 2002, 2004, 2006, 2007, 2008, 2010, 2011, 2016 and 2021 and DFO's 2007 TNASS and 2016 NAISS surveys. Isobaths are the 100-m, 200-m, 1000-m and 4000-m depth contours.

Habitat suitability analyses suggest that the recent distribution patterns of sei whales in U.S. waters appear to be related to waters that are cool (<10°C), with high levels of chlorophyll and inorganic carbon, and where the mixed layer depth is relatively shallow (<50m; Palka et al. 2017; Chavez-Rosales et al. 2019). Sei whales have often been found in the deeper waters characteristic of the continental shelf edge region (Mitchell 1975; Hain et al. 1985). During the spring/summer feeding season, existing data indicate that a major portion of the Nova Scotia sei whale stock is centered in northerly waters, perhaps on the Scotian Shelf (Mitchell and Chapman 1977). Based on analysis of records of 825 sei whales taken between 1965 and 1972 at the Blandford, Nova Scotia whaling station, Mitchell (1975) described two "runs" of sei whales, in June–July and in September–October. He speculated that the sei whale stock migrates from south of Cape Cod and along the coast of eastern Canada in June and July, and returns on a southward migration again in September and October; however, the details of such a migration remain unverified.

The southern portion of the species' range during spring and summer includes the northern portions of the U.S. Atlantic Exclusive Economic Zone (EEZ)—the Gulf of Maine and Georges Bank. NMFS aerial surveys since 1999 have found concentrations of sei whales along the northern edge of Georges Bank in the spring. Indeed, the greatest abundance of sei whales in U.S. waters occurs during spring, with sightings concentrated along the eastern margin of Georges Bank, into the Northeast Channel area, south of Nantucket, and along the southwestern edge of Georges Bank, for example in the area of Hydrographer Canyon (CETAP 1982; Kraus et al. 2016; Roberts et al. 2016; Palka et al. 2017; Cholewiak et al. 2018).

Passive acoustic monitoring (PAM) conducted along the Atlantic Continental Shelf and Slope from 2004–2014, detected sei whale calls from south of Cape Hatteras to the Davis Strait with evidence of distinct seasonal and geographic patterns. Davis et al 2020 detected peak call occurrence in northern latitudes during summer, indicating feeding grounds ranging from Southern New England through the Scotian Shelf. Sei whales were recorded in the southeast on Blake's Plateau in the winter months, but only on the offshore recorders indicating a more pelagic distribution in this region. Persistent year-round detections in Southern New England and the New York Bight highlight this as an important region for the species. The general offshore pattern of sei whale distribution is disrupted during episodic incursions into shallower, more inshore waters. ,North Atlantic sei whales are largely planktivorous, feeding primarily on euphausiids and copepods (Flinn et al. 2002), although they are known to eat fish in other oceans (Flinn et al. 2002). A review of prey preferences by Horwood (1987) showed that, in the North Atlantic, sei whales seem to prefer copepods over all other prey species. In Nova Scotia, sampled sei whale stomachs from sei whales showed a clear preference for copepods between June and October, while euphausiids were taken only in May and November (Mitchell 1975). During some years sei whales were reported in more inshore locations, such as the Great South Channel (in 1987 and 1989) and Stellwagen Bank (in 1986) (Payne et al. 1990). An influx of sei whales into the southern Gulf of Maine occurred in the summer of 1986 (Schilling et al. 1993). Such episodes, often punctuated by years or even decades of absence from an area, have been reported for sei whales from various places worldwide (Jonsgård and Darling 1977).

POPULATION SIZE

The average spring 2010–2013 abundance estimate of 6,292 (CV=1.015) is the best available for the Nova Scotia stock of sei whales. This estimate is considered the best because it was derived from surveys covering the largest proportion of the range (Halifax, Nova Scotia to Florida), during the season when they are the most prevalent in U.S. waters (spring), and used aerial survey data corrected for availability bias. However, this estimate must be considered uncertain for the following reasons: 1) the entire known range of this stock was not surveyed 2)uncertainties exist regarding population structure and whale movements between surveyed and unsurveyed areas, 3) data collection includes ambiguous identification between fin and sei whales and 4) analytical challenges exist, such as how best to account for the ambiguous sightings and low encounter rates, and how to define the most appropriate species-specific availability bias correction factor.

Recent Surveys and Abundance Estimates

The springtime (March–May) average abundance estimate generated from spatially- and temporally-explicit density models was 6,292 (CV=1.02) sei whales. This was derived from visual two-team abundance survey data collected between 2010 and 2013 (Table 1; Palka et al. 2017). This estimate is for waters between Halifax, Nova Scotia and Florida, where the highest densities of animals were predicted to be on the Scotian shelf outside of U.S. waters. Surveys included over 25,000 km of shipboard and over 99,000 km of aerial visual line-transect data collected in all seasons in Atlantic waters from Florida to Nova Scotia. These data were divided into 10x10 km spatial grid cells and 8-day temporal periods. Mark-recapture covariate Distance sampling was used to estimate abundance in each spatial-temporal cell, which was corrected for perception bias. These density estimates and spatially- and temporally-explicit static and dynamic environmental data were used in Generalized Additive Models (GAMs) to develop spatially- and temporally-explicit animal density-habitat statistical models. These estimates also accounted for platform- and species-specific availability bias, with correction factors that were based on dive time patterns.

An abundance estimate of 28 (CV=0.55) sei whales was generated from a summer shipboard and aerial survey conducted during 27 June–28 September 2016 (Table 1; Palka 2020) spanning 425,192 km^2. The estimate is only for waters along the continental shelf break from New Jersey to south of Nova Scotia. The aerial portion included 11,782 km of tracklines that were over waters north of New Jersey from the coastline to the 100-m depth contour, throughout U.S. waters. The shipboard portion included 4,351 km of tracklines that were in waters offshore of central Virginia to Massachusetts (waters that were deeper than the 100-m depth contour out to beyond the outer limit of the EEZ). Both visual platforms used a two-team data collection procedure, which allows estimation of abundance to correct for

perception bias of the detected species (Laake and Borchers 2004). The estimates were also corrected for availability bias.

An abundance estimate of 34 (CV=0.99) sei whales was generated from vessel surveys conducted in U.S. waters of the western North Atlantic during the summer of 2021 (Table 1; Garrison and Dias 2023; Palka 2023). One survey was conducted from 16 June to 23 August in waters north of 36ºN latitude and consisted of 5,871 km of on-effort trackline along the shelf break and offshore to the outer edge of the U.S. EEZ (NEFSC and SEFSC 2022). The second vessel survey covered waters from central Florida (25ºN latitude) to approximately 38ºN latitude between the 200-m isobaths and the outer edge of the U.S. EEZ during 12 June–31 August. A total of 5,659 km of trackline was covered on effort (NEFSC and SEFSC 2022). Both surveys utilized two visual teams and an independent observer approach to estimate detection probability on the trackline (Laake and Borchers 2004). Mark-recapture distance sampling was used to estimate abundance. Additionally aerial surveys were concurrently conducted from Nova Scotia to Florida from the coast to the shelf break and did not record any sei whales.

Comprehensive summer aerial surveys of Canadian east coast waters in 2007 and 2016 identified only 7 sei whales, suggesting a population of a few hundred animals or less, a substantial reduction from pre-whaling numbers. The population is currently thought to number fewer than 1,000 in eastern Canadian waters (https://www.canada.ca/en/environment-climate-change/services/committee-status-endangered-wildlife.html).

Table 1. Summary of recent abundance estimates for Nova Scotia sei whales with month, year, and area covered during each abundance survey, and resulting abundance estimate (N_{est}) and coefficient of variation (CV). The estimate considered best is in bold font.

Month/Year	Area	N_{est}	CV
Mar−May 2010−2013	**Halifax, Nova Scotia to Florida**	**6,292**	**1.02**
Jun−Aug 2016	Continental shelf break waters from New Jersey to south of Nova Scotia	28	0.55
Jun–Aug 2021	New Jersey to southern Nova Scotia	34	0.99
Jun–Aug 2021	Central Florida to New Jersey	0	0
Jun–Aug 2021	Central Florida to southern Nova Scotia (COMBINED)	34	0.99

Minimum Population Estimate

The minimum population estimate is the lower limit of the two-tailed 60% confidence interval of the log-normally distributed best abundance estimate. This is equivalent to the 20th percentile of the log-normal distribution as specified by (Wade and Angliss 1997). The best estimate of abundance for the Nova Scotia stock sei whales is 6,292 (CV=1.02). The minimum population estimate is 3,098.

Current Population Trend

There are insufficient data to determine population trends for this species. The statistical power to detect a trend in abundance for this stock is poor due to the relatively imprecise abundance estimates and long survey interval. For example, the power to detect a precipitous decline in abundance (i.e., 50% decrease in 15 years) with estimates of low precision (e.g., CV>0.30) remains below 80% (alpha=0.30) unless surveys are conducted on an annual basis (Taylor et al. 2007). There is current work to standardize the strata-specific previous abundance estimates to consistently represent the same regions and include appropriate corrections for perception and availability bias. These standardized abundance estimates will be used in state-space trend models that incorporate environmental factors that could potentially influence the process and observational errors for each stratum.

Although not a formal trend analysis, during all seasons, the seasonal average habitat-based abundance estimates generated by Palka et al. (2021) resulted in lower recent abundance estimates (2014–2017) as compared to those from the past (2010–2013), where the center of the distribution moved southwesterly (Chavez-Rosales et al. 2022).

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. This value is based on theoretical modeling showing that

cetacean populations may not grow at rates much greater than 4% given the constraints of their reproductive life history (Barlow et al. 1995).

POTENTIAL BIOLOGICAL REMOVAL

Potential Biological Removal (PBR) is the product of minimum population size, one-half the maximum productivity rate, and a recovery factor (MMPA Sec. 3. 16 U.S.C. 1362; Wade and Angliss 1997). The minimum population size is 3,098. The maximum productivity rate is 0.04, the default value for cetaceans. The recovery factor is 0.10 because the sei whale is listed as endangered under the Endangered Species Act (ESA). PBR for the Nova Scotia stock of the sei whale is 6.2 (Table 2).

Table 2. Best and minimum abundance estimates for Nova Scotia sei whales (*Balaenoptera borealis borealis*) with Maximum Productivity Rate (R_{max}), Recovery Factor (F_r) and PBR.

N_{est}	CV	N_{min}	F_r	R_{max}	PBR
6,292	1.02	3,098	0.1	0.04	6.2

ANNUAL HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

For the period 2017 through 2021, the annual detected (i.e., observed) human-caused mortality and serious injury to Nova Scotia sei whales averaged 0.60 individuals per year (Table 3). This is derived from two components: 1) incidental fishery entanglement records at 0.40 per year, and 2) other human caused mortality averaging 0.20 per year.

Injury determinations are made based upon the best available data; these determinations may change with the availability of new information (Henry et al. 2023). Only records considered to be confirmed human-caused mortalities or serious injuries are reported in the observed mortality and serious injury (M/SI) rows of Table 4.

Table 3. The total annual observed average human-caused mortality and serious injury for Nova Scotia sei whales (*Balaenoptera borealis borealis*).

Years	Source	Annual Avg.
2017− 2017	Fishery entanglement	0.40
2017− 2021	Vessel strikes	0
2017− 2021	Other human-caused mortality	0.20
TOTAL		0.60

Fishery-Related Mortality and Serious Injury

No confirmed fishery-related mortalities or serious injuries of sei whales have been reported in the NMFS Sea Sampling bycatch database. Records of stranded, floating, or injured sei whales for the period 2017 through 2021 on file at NMFS indicate two sei whales with substantial evidence of fishery interaction that caused mortality or serious injury (Table 4), suggesting an annual mortality and serious injury rate of 0.4 sei whales from fishery interactions.

Table 4. Confirmed human-caused mortality and serious injury records of sei whales (*Balaenoptera borealis*) where the cause was assigned as either an entanglement (EN) or a vessel strike (VS): 2017–2021 [a].

Date[b]	Injury Determination	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
11May17	Serious Injury	-	Cape Lookout Bight, NC	EN	1	XU	-	Free-swimming, emaciated, and carrying a large mass of heavily fouled gear consisting of line & buoys crossing over back. Full configuration unknown, but evidence of significant health decline.

Date[b]	Injury Determination	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
12Mar18	Mortality	-	Fanny Keys, FL	EN	1	XU	NR	Carcass with line exiting left side of mouth, across rostrum, and entering right side. Bundle of frayed line lodged in baleen mid-rostrum. Severely emaciated, extensive scavenging. Partial necropsy conducted. Partial healing of lesions + epibiotic growth on line + emaciation = chronic entanglement. Gear not recovered

Assigned Cause	Five-year Mean (US/CN/XU/XC)
Vessel Strike	0 (0/0/0/0)
Entanglement	0.40 (0/0/0.40/0)

a. For more details on events please see Henry et al. 2023.
b. The date sighted and location provided in the table are not necessarily when or where the serious injury or mortality occurred; rather, this information indicates when and where the whale was first reported beached, entangled, or injured.
c. Mortality events are counted as 1 against PBR. Serious injury events have been evaluated using NMFS guidelines (NOAA 2012).
d. US=United States, XU=Unassigned 1st sight in US, CN=Canada, XC=Unassigned 1st sight in CN**.**
e. H=hook, GN=gillnet, GU=gear unidentifiable, MF=monofilament, NP=none present, NR=none recovered/received, PT=pot/trap, WE=weir.

Other Mortality

No sei whale vessel collisions were recorded during 2017-2021. One sei whale in 2019 was reported with cause of death as starvation due to plastic ingestion (see Table 3 - other mortality).

STATUS OF STOCK

This is a strategic stock because the sei whale is listed as an endangered species under the ESA. The total fishery-related mortality and serious injury for this stock derived from the available records was less than 10% of the calculated PBR, and therefore could be considered insignificant and approaching a zero mortality and serious injury rate. However, evidence for fisheries interactions with large whales are subject to imperfect detection, and caution should be used in interpreting these results. The status of this stock relative to Optimum Sustainable Population (OSP) is unknown. There are insufficient data to determine population trends for sei whales.

OTHER FACTORS THAT MAY BE AFFECTING THE STOCK

Habitat Issues

The chronic impacts of contaminants (polychlorinated biphenyls [PCBs] and chlorinated pesticides [DDT, DDE, dieldrin, etc.]) on marine mammal reproduction and health are of concern (e.g., Pierce et al. 2008; Jepson et al. 2016; Hall et al. 2018; Murphy et al. 2018), but research on contaminant levels for the Nova Scotia stock of sei whales is lacking.

Climate-related changes in spatial distribution and abundance, including poleward and depth shifts, have been documented in or predicted for plankton species and commercially important fish stocks (Nye et al. 2009; Pinsky et al. 2013; Poloczanska et al. 2013; Hare et al. 2016; Grieve et al. 2017; Morley et al. 2018) and cetacean species (e.g., MacLeod 2009; Sousa et al. 2019). There is uncertainty in how, if at all, the distribution and population size of this species will respond to these changes and how the ecological shifts will affect human impacts to the species.

Chavez-Rosales et al. (2022) documented an overall 178 km northeastward spatial distribution shift of the seasonal core habitat of Northwest Atlantic cetaceans that was related to changing habitat/climatic factors. Results varied by season and species. This study used sighting data collected during seasonal aerial and shipboard line transect abundance surveys during 2010 to 2017. During this time frame, the weighted centroid of the sei whale core habitat moved farthest during winter (179 km towards the southwest) and least during spring (70 km). There is uncertainty in how, if at all, the changes in distribution and population size of cetacean species may interact with changes in distribution of prey species and how the ecological shifts will affect human impacts to the species.

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