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 did not reveal stock structure in the North Atlantic based on both mitochondrial DNA and microsatellite analyses, 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 here as the management unit for this stock assessment. The IWC boundaries for this stock are from the U.S. east coast to Cape Breton, Nova Scotia, thence east to longitude 42^{o} 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.

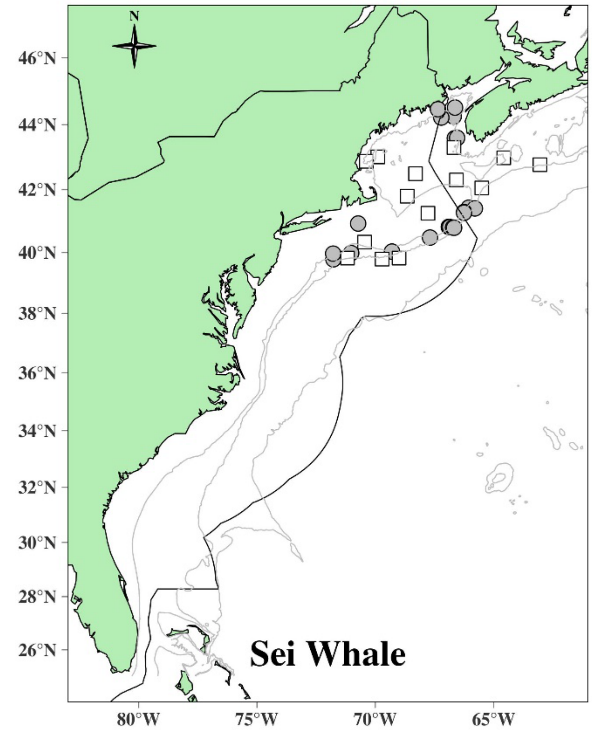

Figure 1. Distribution of sei whale sightings from NEFSC and SEFSC shipboard and aerial surveys during the summers of 1995, 1998, 1999, 2002, 2004, 2006, 2007, 2008, 2010, 2011, and 2016 and DFO's 2007 TNASS and 2016 NAISS surveys. Isobaths are the 100-m, 200-m, 1000-m and 4000-m depth contours.

Habitat suitability analyses suggest that the recent distribution patterns of sei whales in U.S. waters appear to be related to water 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 (Mitchel 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 from the Blandford, Nova Scotia whaling station, where 825 sei whales were taken between 1965 and 1972, 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. Spring is the period of greatest abundance in U.S. waters, 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).

The wintering habitat for sei whales remains largely unknown. In passive acoustic monitoring (PAM) conducted off Georges Bank in 2015–2016, sei whales calls were consistently detected from late fall through the winter along the southern Georges Bank region, off Heezen and Oceanographer Canyons (Cholewiak *et al.* 2018). Sei whale calls were also sporadically detected at PAM sites from Cape Hatteras southward. This included sparsely detected sei whale calls on the Blake Plateau during November–February in 2015 and 2016 (Cholewiak *et al.* 2018).

The general offshore pattern of sei whale distribution is disrupted during episodic incursions into shallower, more inshore waters. Although known to eat fish in other oceans (Flinn *et al.* 2002), North Atlantic sei whales are largely planktivorous, feeding primarily on euphausiids and copepods (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 stomachs from captured sei whales showed a clear preference for copepods between June and October, and euphausiids were taken only in May and November (Mitchell 1975). Sei whales are reported in some years in more inshore locations, such as the Great South Channel (in 1987 and 1989) and Stellwagen Bank (in 1986) areas (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 considered the best available for the Nova Scotia stock of sei whales 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 (in spring), using only recent data (2010–2013), and correcting aerial survey data for availability bias. However, this estimate must be considered uncertain because all of the known range of this stock was not surveyed, because of uncertainties regarding population structure and whale movements between surveyed and unsurveyed areas, and because of issues in the data collection (ambiguous identification between fin and sei whales) and analysis (in particular, how best to handle the ambiguous sightings, low encounter rates, and defining the most appropriate species-specific availability bias correction factor).

Earlier Abundance Estimates

Please see Appendix IV for earlier abundance estimates. As recommended in the GAMMS Workshop Report (Wade and Angliss 1997), estimates older than eight years are deemed unreliable for determination of the current PBR.

Recent Surveys and Abundance Estimates

An estimate of 6,292 (CV=1.015) was the springtime (March–May) average abundance estimate generated from spatially- and temporally-explicit density models 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 Scotia shelf outside of U.S. waters. Over 25,000 km of shipboard and over 99,000 km of aerial visual line-transect survey data collected in all seasons in Atlantic waters from Florida to Nova Scotia during 2010–2014 were divided into 10x10 km^2 spatial grid cells and 8-day temporal time 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 were also corrected by platform- and species-specific availability bias 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) within a region covering 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 sighting 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.

Comprehensive 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, and 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).

Seasonal average habitat-based density estimates generated by Roberts *et al*. (2016) produced abundance estimates of 627 (CV=0.14) for spring in U.S. waters only and 717 (CV=0.30) for summer in waters from the mouth of Gulf of St. Lawrence to Florida. These were based on data from 1995–2013. Their models were created using GAMs, with environmental covariates projected to 10x10 km grid cells. Three model versions were fit to the data, including a climatological model with 8-day estimates of covariates, a contemporaneous model, and a combination of the two. Several differences in modeling methodology result in abundance estimates that are different than the estimates generated from the above surveys.

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). Estimate considered best is bolded.

Month/Year	Area	N_{est}	CV
Apr−Jun 1999−2013	Maine to Florida in U.S. waters only	627	0.14
Jul−Sep 1995−2013	Gulf of St Lawrence entrance to Florida	717	0.30
Mar−May 2010−2013	**Halifax, Nova Scotia to Florida**	**6,292**	**1.015**
Jun−Aug 2016	Continental shelf break waters from New Jersey to south of Nova Scotia	28	0.55

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=1.015). The minimum population estimate is 3,098.

Current Population Trend

A trend analysis has not been conducted for this stock. 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.

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

The most recent 5-year average human-caused mortality and serious injury rates are summarized in Table 3. Annual rates calculated from detected mortalities should not be considered unbiased estimates of human-caused mortality, but they represent definitive lower bounds. Detections are haphazard, incomplete, and not the result of a designed sampling scheme. As such they represent a minimum estimate of human-caused mortality which is almost certainly biased low.

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

Years	Source	Annual Average
2014−2018	Incidental fishery interactions	0.40
2014−2018	Vessel collisions	0.80
Total		**1.20**

Fishery-Related Serious Injury and Mortality

U.S. fishery interaction records for large whales come from two main sources—dedicated fishery-observer data and opportunistic reports collected in the Greater Atlantic Regional Fisheries Office/NMFS entanglement/ stranding database. No confirmed fishery-related mortalities or serious injuries of sei whales have been reported in the NMFS Sea Sampling bycatch database (fishery observers). Records of stranded, floating, or injured sei whales for the reporting period in the audited Greater Atlantic Regional Fisheries Office/NMFS entanglement/stranding database with substantial evidence of fishery interactions causing injury or mortality are presented below (Table 4).

Date[b]	Fate	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
05/04/2014	Mortality	-	Hudson River, NY	VS	1	US	-	Fresh carcass on bow of vessel. Extensive skeletal fractures w/ associated hemorrhage along right side.
05/07/2014	Mortality	-	Delaware River, PA	VS	1	US	-	Fresh carcass on bow of vessel.
08/14/2014	Mortality	-	James River, VA	VS	1	US	-	Live stranded and died. Emaciated. Fragment of plastic DVD case in stomach. Broken bones w/ associated hemorrhaging. Proximate COD: starvation by ingestion of plastic debris. Ultimate COD: blunt trauma from vessel strike
07/25/2016	Mortality	-	Hudson River, Newark, NJ	VS	1	US	-	Fresh carcass on bow of ship (>65 ft). Speed at strike unknown.
05/11/2017	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]	Fate	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
03/12/2018	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	0.80 (0.80/0/0/0)
Entanglement	0.40 (0/0/0.40/0)

a. For more details on events, see Henry *et al.* 2021.
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

Records with substantial evidence of vessel collision causing serious injury or mortality are presented in Table 4.

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.

STATUS OF STOCK

This is a strategic stock because the sei whale is listed as an endangered species under the ESA. The total U.S. 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 OSP in the U.S. Atlantic EEZ is unknown. There are insufficient data to determine population trends for sei whales.

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