FIN WHALE (*Balaenoptera physalus*): Western North Atlantic Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Fin whales have a global distribution, with populations found from temperate to polar regions in all ocean basins (Edwards *et al.* 2015). Within the Northern Hemisphere, populations in the North Pacific and North Atlantic oceans can be considered at least different subspecies, if not different species (Archer *et al.* 2019). The Scientific Committee of the International Whaling Commission (IWC) has proposed stock boundaries for North Atlantic fin whales. Fin whales off the eastern United States, Nova Scotia, and the southeastern coast of Newfoundland are believed to constitute a single stock under the present IWC scheme (Donovan 1991). Although the stock identity of North Atlantic fin whales has received much recent attention from the IWC, understanding of stock boundaries remains uncertain. The existence of a subpopulation structure was suggested by local depletions that resulted from commercial overharvesting (Mizroch *et al.* 1984).

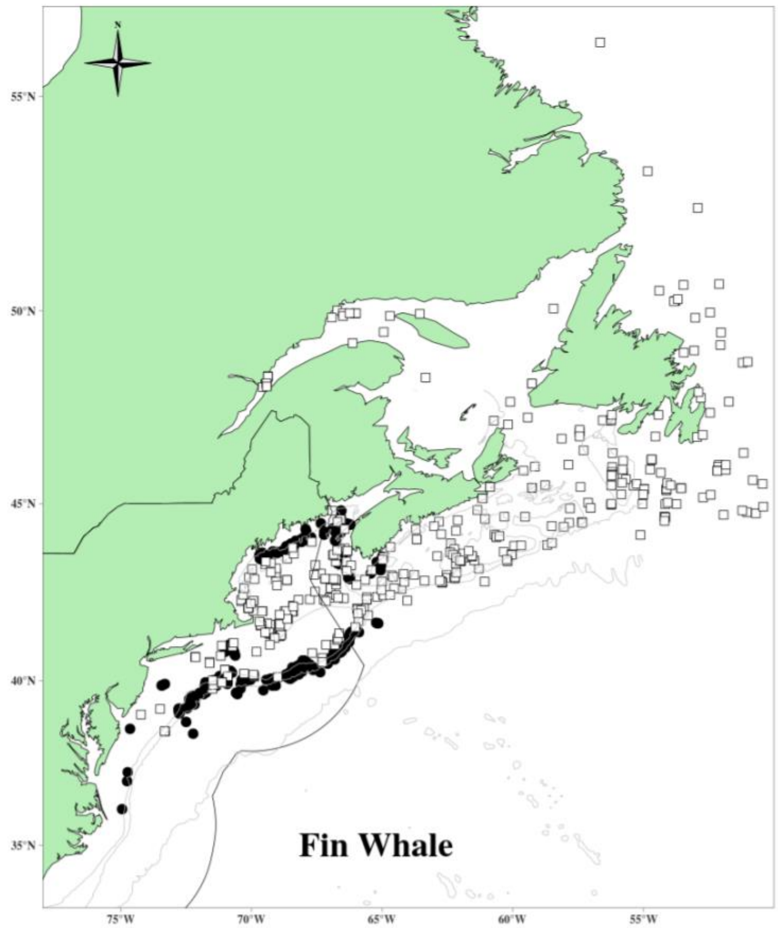

Figure 1. Distribution of fin whale sightings from NEFSC and SEFSC shipboard and aerial surveys during the summers of 1995, 1998, 1999, 2002, 2004, 2006, 2007, 2008, 2010, 2011 and 2016 and DFO's 2007 TNASS and 2016 NAISS surveys. Isobaths are the 100-m, 1,000-m and 4000-m depth contours. Circle symbols represent shipboard sightings and squares are aerial sightings.

A genetic study conducted by Bérubé *et al.* (1998) using both mitochondrial and nuclear DNA provided strong support for an earlier population model proposed by Kellogg (1929) and others. This postulates the existence of several subpopulations of fin whales in the North Atlantic and Mediterranean with limited gene flow among them. Bérubé *et al.* (1998) also proposed that the North Atlantic population showed recent divergence due to climatic changes (i.e., postglacial expansion), as well as substructuring over even relatively short distances. The genetic data are consistent with the idea that different subpopulations use the same feeding ground, a hypothesis that was also originally proposed by Kellogg (1929). More recent genetic studies have called into question conclusions drawn from early allozyme work (Olsen *et al.* 2014) and North Atlantic fin whales show a very low rate of genetic diversity throughout their range excluding the Mediterranean (Pampoulie *et al*. 2008).

Fin whales are common in waters of the U.S. Atlantic Exclusive Economic Zone (EEZ), principally from Cape Hatteras northward (Figure 1). In a globally-scaled review of sightings data, Edwards *et al.* (2015) found evidence to confirm the presence of fin whales in every season throughout much of the U.S. EEZ north of 30º N; however, densities vary seasonally. Fin whales accounted for 46% of the large whales and 24% of all cetaceans sighted over the continental shelf during aerial surveys (CETAP 1982) between Cape Hatteras and Nova Scotia during 1978–1982. While much remains unknown, the magnitude of the ecological role of the fin whale is impressive. In this region fin whales are the dominant large cetacean species during all seasons, having the largest standing stock, the largest food requirements, and therefore the largest influence on ecosystem processes of any cetacean species (Hain *et al.* 1992; Kenney *et al.* 1997). Acoustic detections of fin whale singers augment and confirm these visual sighting conclusions for males. Recordings from the Atlantic Continental Shelf, and deep-ocean areas detected some level of fin whale singing year round (Watkins *et al*. 1987; Clark and Gagnon 2002; Morano *et al*. 2012; Davis *et al* 2020). These acoustic observations from both coastal and deep-ocean regions support the conclusion that male fin whales are broadly distributed throughout the western North Atlantic for most of the year.

New England and Gulf of St. Lawrence waters represent major feeding ground for fin whales. There is evidence of site fidelity by females, and perhaps some segregation by sexual, maturational, or reproductive class in the feeding area (Agler *et al.* 1993; Schleimer *et al.* 2019). Seipt *et al.* (1990) reported that 49% of identified fin whales sighted on the Massachusetts Bay area feeding grounds were resighted within the same year, and 45% were resighted in multiple years. The authors suggested that fin whales on these grounds exhibited patterns of seasonal occurrence and annual return that in some respects were similar to those shown for humpback whales. This was reinforced by Clapham and Seipt (1991), who showed maternally-directed site fidelity for fin whales in the Gulf of Maine. Hain *et al.* (1992), based on an analysis of neonate stranding data, suggested that calving takes place during October to January in latitudes of the U.S. mid-Atlantic region; however, it is unknown where calving, mating, and wintering occur for most of the population. Results from the Navy's SOSUS program (Clark 1995; Clark and Gagnon 2002) indicated a substantial deep-ocean distribution of fin whales. It is likely that fin whales occurring in the U.S. Atlantic EEZ undergo migrations into Canadian waters, open-ocean areas, and perhaps even subtropical or tropical regions (Edwards *et al.* 2015; Silve *et al.* 2019). However, the popular notion that entire fin whale populations make distinct annual migrations like some other mysticetes has questionable support in the data; in the North Pacific, year-round monitoring of fin whale calls found no evidence for large-scale migratory movements (Watkins *et al.* 2000).

POPULATION SIZE

The best available current abundance estimate for fin whales in the North Atlantic stock is 6,802 (CV=0.24), sum of the 2016 NOAA shipboard and aerial surveys and the 2016 NEFSC and Department of Fisheries and Oceans Canada (DFO) surveys ("Florida to Newfoundland/Labrador (COMBINED)" in Table 1). Because the survey areas did not overlap, the estimates from the two surveys were added together and the CVs pooled using a delta method to produce a species abundance estimate for the stock area.

Earlier Abundance Estimates

Please see Appendix IV for earlier abundance estimates. As recommended in the guidelines for preparing Stock Assessment Reports (NMFS 2016), estimates older than eight years are deemed unreliable for the determination of a current PBR.

Recent Surveys and Abundance Estimates

An abundance estimate for western North Atlantic fin whales was generated from vessel surveys conducted in U.S. waters of the western North Atlantic during the summer of 2016 (Table 1; Garrison 2020; Palka 2020). One survey was conducted from 27 June to 25 August in waters north of 38ºN latitude and consisted of 5,354 km of on-effort trackline along the shelf break and offshore to the outer limit of the U.S. EEZ (NEFSC and SEFSC 2018). The second vessel survey covered waters from Central Florida to approximately 38ºN latitude between the 100-m isobaths and the outer limit of the U.S. EEZ during 30 June–19 August. A total of 4,399 km of trackline was covered on effort (NEFSC and SEFSC 2018). 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.

DFO generated fin whale estimates from a large-scale aerial survey of Atlantic Canadian shelf and shelf break habitats extending from the northern tip of Labrador to the U.S. border off southern Nova Scotia in August and September of 2016 (Table 1; Lawson and Gosselin 2018). A total of 29,123 km of effort was flown over the Gulf of St. Lawrence/Bay of Fundy/Scotian Shelf stratum and 21,037 over the Newfoundland/Labrador stratum. The Bay of Fundy/Scotian shelf portion of the fin whale population was estimated at 2,235 (CV=0.41) and the Newfoundland/Labrador portion at 2,177 (CV=0.47). The Newfoundland estimate was derived from Twin Otter data using two-team mark-recapture multi-covariate distance sampling methods. The Gulf of St. Lawrence estimate was derived from the Skymaster data using single team multi-covariate distance sampling with left truncation (to accommodate the obscured area under the plane) where size-bias was also investigated, and the Otter-based perception bias correction was applied. An availability bias correction factor, which was based on the cetaceans' surface intervals, was applied to both abundance estimates.

Table 1. Summary of recent abundance estimates for western North Atlantic fin 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
Jun−Sep 2016	Florida to lower Bay of Fundy	2,390	0.40
Aug−Sep 2016	Bay of Fundy/Scotian Shelf	2,235	0.413
Aug−Sep 2016	Newfoundland/Labrador	2,177	0.465
Jun−Sep 2016	**Florida to Newfoundland/Labrador (COMBINED)**	**6,802**	**0.24**

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 fin whales is 6,802 (CV=0.24). The minimum population estimate for the western North Atlantic fin whale is 5,573 (Table 2).

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 variable survey design. 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). However, a decline in the abundance of fin whales within the northern Gulf of St. Lawrence has been noted for that portion of the stock (Schleimer *et al.* 2019). 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. Based on photographically identified fin whales, Agler *et al.* (1993) estimated that the gross annual reproduction rate was 8%, with a mean calving interval of 2.7 years.

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 65,573. The maximum productivity rate is 0.04, the default value for cetaceans. The recovery factor is 0.10 because the fin whale is listed as endangered under the Endangered Species Act (ESA). PBR for the western North Atlantic fin whale is 11.

Table 2. Best and minimum abundance estimates for the western North Atlantic fin whale (Balaenoptera physalus) with Maximum Productivity Rate (R_{max}), Recovery Factor (F_r.) and PBR.

N_{est}	CV	N_{min}	F_r	R_{max}	PBR
6,802	0.24	5,573	0.1	0.04	11

ANNUAL HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

The total annual estimated average human-caused mortality and serious injury for the western North Atlantic fin whale for the period 2015‒2019 is presented in Table 3 (Henry *et al.* 2022). Annual rates calculated from detected mortalities should not be considered an unbiased representation of human-caused mortality, but they represent a definitive lower bound. Detections are haphazard 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. The size of this bias is uncertain.

Table 3. The total annual observed average human-caused mortality and serious injury for the western North Atlantic fin whale (Balaenoptera physalus).

Years	Source	Annual Avg.
2015‒2019	Incidental fishery interactions	1.45
2015‒2019	Vessel collisions	0.40
TOTAL		1.85

Fishery-Related Serious Injury and Mortality

United States

U.S. fishery interaction records for large whales come through 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 fin whales have been reported in the NMFS Sea Sampling bycatch database (fishery observers) during this reporting period. Records of stranded, floating, or injured fin whales for the reporting period in the Greater Atlantic Regional Fisheries Office/NMFS entanglement/stranding database with substantial evidence of fishery interactions causing injury or mortality are presented in Table 4 (Henry *et al.* 2022). These records are not statistically quantifiable in the same way as the observer fishery records, and they almost surely undercount entanglements for the stock.

Canada

The audited Greater Atlantic Regional Fisheries Office/NMFS entanglement/stranding database also contains records of fin whales first reported in Canadian waters or attributed to Canada, of which the confirmed mortalities and serious injuries from the current reporting period are reported in Table 4.

Table 4. Confirmed human-caused mortality and serious injury records of fin whales (Balaenoptera physalus) where the cause was assigned as either an entanglement (EN) or a vessel strike (VS): 2015–2019[a].

Date[b]	Fate	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
06Jun15	Serious Injury	-	off Bar Harbor, ME	EN	1	XU	NR	Free-swimming with 2 buoys and 80 ft of line trailing from fluke. Line cutting deeply into right fluke blade. Emaciated. No resights.
06Jul16	Prorated Injury	-	off Truro, MA	EN	0.75	XU	NR	Free-swimming with line trailing 60-70 ft aft of flukes. Attachment point(s) and configuration unknown. No resights.
08Jul16	Prorated Injury	-	off Virginia Beach, VA	EN	0.75	XU	H/MF	Free-swimming with lures in tow along left flipper area. Attachment point(s) and configuration unknown. No resights.
14Dec16	Prorated Injury	-	off Provincetown, MA	EN	0.75	XU	NR	Free-swimming with buoy trailing 6-8ft aft of flukes. Attachment point(s) and configuration unknown. No resights.
30May17	Mortality	-	Port Newark, NJ	VS	1	US	-	Fresh carcass on bow of 656 ft vessel. Speed at strike unknown.
25Aug17	Mortality	-	off Miscou Island, QC	EN	1	CN	PT	Fisher found fresh carcass when hauling gear. Entangled at 78m depth, 51m from trap. Full configuration unknown, but unlikely to have drifted post-mortem into gear.
22Jun18	Mortality	-	16.5 nm E of Gaspe, QC	EN	1	CN	NP	No gear present. Fresh carcass with evidence of constricting entanglement across ventral pleats and peduncle with raw injuries to fluke. Evidence of associated bruising. No necropsy, but COD due to entanglement most parsimonious.
14Oct18	Mortality	Ladders	Cape Cod Bay	VS	1	US	-	Floating carcass with great white shark actively scavenging. Landed on 18 Oct. Necropsied on 19 Oct. Left side not examined due to remote location & no heavy equipment. Additional exam conducted on 30 Oct. Evidence of blunt force trauma - fractured mandibles and rostrum with associated hemorrhaging. Histopathology results support findings.
19Jun19	Mortality	-	20nm E of Miscou, QC	EN	1	CN	NR	No necropsy and no gear present but evidence of extensive constricting entanglement injuries across ventral surface, peduncle and fluke insertion. Entanglement as COD is most parsimonious.
18Jul19	Mortality	-	Portugal Cove South, Avalon, NL	EN	1	CN	PT	Carcass anchored in gear with line through mouth. No necropsy but COD from entanglement is most parsimonious.

Assigned Cause	**5-Year mean (US/CN/XU/XC)**
Vessel Strike	0.4 (0.4/0/0/0)
Entanglement	1.45 (0/0.8/0.65/0)

a. For more details on events please see Henry *et al.* 2022.

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

Death or injury as a result of vessel collision has an anthropogenic impact on this stock (Schleimer *et al.* 2019). Known vessel strike cases are reported 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 western north Atlantic stock of fin 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; Head *et al*. 2010; 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 fin whale is listed as an endangered species under the ESA. NMFS records represent coverage of only a portion of the area surveyed for the population estimate for the stock. The total fishery-related mortality and serious injury for this stock derived from the available records is likely biased low and is not less than 10% of the calculated PBR. Therefore, entanglement rates cannot be considered insignificant and approaching a zero mortality and serious injury rate. The status of this stock relative to Optimum Sustainable Population (OSP) in the U.S. Atlantic EEZ is unknown. There are insufficient data to determine the population trend for fin whales. Because the fin whale is ESA-listed, uncertainties with regard to the negatively biased estimates of human-caused mortality and the incomplete survey coverage relative to the stock's defined range would not change the status of the stock.

REFERENCES CITED

Agler, B.A., R.L. Schooley, S.E. Frohock, S.K. Katona and I.E. Seipt. 1993. Reproduction of photographically identified fin whales, *Balaenoptera physalus*, from the Gulf of Maine. J. Mamm. 73:577–587.

Archer, F.I., R.L. Brownell, Jr., B.L. Hancock-Hanser, P.A. Morin, K.M. Robertson, K.K. Sherman, J. Calambokidis, J. Urbán-R., P.E. Rosel, S.A. Mizroch, S. Panigada and B.L. Taylor. 2019. Revision of fin whale *Balaenoptera physalus* (Linnaeus, 1758) subspecies using genetics. J. Mamm. 100:1653–1670.

Barlow, J., S.L. Swartz, T.C. Eagle and P.R. Wade. 1995. U.S. marine mammal stock assessments: Guidelines for preparation, background, and a summary of the 1995 assessments. NOAA Tech. Memo. NMFS-OPR-6. 73pp. https://repository.library.noaa.gov/view/noaa/6219

Bérubé, M., A. Aguilar, D. Dendanto, F. Larsen, G.N.di Sciara, R. Sears, J. Sigurjónsson, J. Urban-R. and P.J. Palsbøll. 1998. Population genetic structure of North Atlantic, Mediterranean and Sea of Cortez fin whales, *Balaenoptera physalus* (Linnaeus 1758): Analysis of mitochondrial and nuclear loci. Mol. Ecol. 15:585–599.

CETAP. 1982. A characterization of marine mammals and turtles in the mid- and North Atlantic areas of the U.S. outer continental shelf, final report #AA551-CT8-48, Cetacean and Turtle Assessment Program, University of Rhode Island. Bureau of Land Management, Washington, DC. 576pp.

Clapham, P.J. and I.E. Seipt. 1991. Resightings of independent fin whales, *Balaenoptera physalus*, on maternal summer ranges. J. Mamm. 72:788–790.

Clark, C.W. 1995. Application of U.S. Navy underwater hydrophone arrays for scientific research on whales. Rep. Int. Whal. Comm. 45:210–212.

Clark, C.W., and Gagnon, G.C. 2002. Low-frequency vocal behaviors of baleen whales in the North Atlantic: Insights from IUSS detections, locations and tracking from 1992 to 1996. J. Underwater Acoust. (U.S. Navy) 52:609–640.

Davis, G.E., M.F. Baumgartner, P.J. Corkeron, J. Bell, C. Berchok, J.M. Bonnell, J.B. Thornton, S. Brault, G.A. Buchanan, D.M. Cholewiak, C.W. Clark, J. Delarue, L.T. Hatch, H. Klinck, S.D. Kraus, B. Martin, D.K. Mellinger, H. Moors-Murphy, S. Nieukirk, D.P. Nowacek, S.E. Parks, D. Parry, N. Pegg, A.J. Read, A.N. Rice, D. Risch, A. Scott, M.S. Soldevilla, K.M. Stafford, J.E. Stanistreet, E. Summers, S. Todd and S.M. Van Parijs. 2020. Exploring movement patterns and changing distributions of baleen whales in the western North Atlantic using a decade of passive acoustic data. Glob. Change Biol. 00:1-29. https://doi.org/10.1111/gcb.15191

Donovan, G.P. 1991. A review of IWC stock boundaries. Rep. Int. Whal. Comm. (Special Issue) 13:39–68.

Edwards, E.F., C. Hall, T.J. Moore, C. Sheredy and J. Redfern. 2015. Global distribution of fin whales (*Balaenoptera physalus*) in the post-whaling era (1980 to 2012). Mamm. Rev. 45:197–214.

Garrison, L.P. 2016. Abundance of marine mammals in waters of the U.S. East Coast during summer 2011. PRBD Contribution #PRBD-2016-08. Southeast Fisheries Science Center, Protected Resources and Biodiversity Division, Miami, FL. 21pp.

Garrison, L.P. 2020. Abundance of cetaceans along the southeast U.S. east coast from a summer 2016 vessel survey. PRD Contribution Southeast Fisheries Science Center, Protected Resources and Biodiversity Division, Miami, FL. 17pp.

Grieve, B.D., J.A. Hare and V.S. Saba. 2017. Projecting the effects of climate change on *Calanus finmarchicus* distribution within the US Northeast continental shelf. Sci. Rep. 7:6264.

Hain, J.H.W., M.J. Ratnaswamy, R.D. Kenney and H.E. Winn. 1992. The fin whale, *Balaenoptera physalus*, in waters of the northeastern United States continental shelf. Rep. Int. Whal. Comm. 42:653–669.

Hall, A.J., B.J. McConnell, L.J. Schwacke, G.M. Ylitalo, R. Williams and T.K. Rowles. 2018. Predicting the effects of polychlorinated biphenyls on cetacean populations through impacts on immunity and calf survival. Environ. Poll. 233:407–418.

Hare, J.A., W.E. Morrison, M.W. Nelson, M.M. Stachura, E.J. Teeters, R.B. Griffis, M.A. Alexander, J.D. Scott, L. Alade, R.J. Bell, A.S. Chute, K.L. Curti, T.H. Curtis, D. Kurcheis, J.F. Kocik, S.M. Lucey, C.T. McCandless, L.M. Milke, D.E. Richardson, E. Robillard, H.J. Walsh, M.C. McManus, K.E. Maranick and C.A. Griswold. 2016. A vulnerability assessment of fish and invertebrates to climate change on the Northeast U.S. continental shelf. PLoS ONE. 11:e0146756.

Head, E.J.H. and P. Pepin. 2010. Spatial and inter-decadal variability in plankton abundance and composition in the Northwest Atlantic (1958–2006). J. Plankton Res. 32:1633–1648. https://doi.org/10.1371/journal.pone.0146756.s014

Henry, A.G., M. Garron, D. Morin, A. Smith, A. Reid, W. Ledwell and T.V.N. Cole. 2022. Serious injury and mortality determinations for baleen whale stocks along the Gulf of Mexico, United States East Coast and Atlantic Canadian Provinces, 2015–2019. NOAA Tech Memo. NMFS-NE-280.

Jepson, P.D., R. Deaville, J.L. Barber, A. Aguilar, A. Borrell, S. Murphy, J. Barry, A. Brownlow, J. Barnett, S. Berrow and A.A. Cunningham. 2016. PCB pollution continues to impact populations of orcas and other dolphins in European waters. Sci. Rep.-U.K. 6:18573.

Kellogg, R. 1929. What is known of the migration of some of the whalebone whales. Ann. Rep. Smithsonian Inst. 1928:467–494.

Kenney, R.D., G.P. Scott, T.J. Thompson and H.E. Winn. 1997. Estimates of prey consumption and trophic impacts of cetaceans in the USA northeast continental shelf ecosystem. J. Northw. Atl. Fish. Sci. 22:155–171.

Laake, J.L., J. Calambokidis, S.D. Osmek and D.J. Rugh. 1997. Probability of detecting harbor porpoise from aerial surveys: Estimating g (0). J. Wildl. Manage. 61:63–75.

Laake, J.L. and D.L. Borchers. 2004. Methods for incomplete detection at distance zero. Pages 108-189 *in*: S.T. Buckland, D.R. Andersen, K.P. Burnham, J.L. Laake and L. Thomas (eds). Advanced distance sampling. Oxford University Press, New York, New York.

Lawson, J. and J-F. Gosselin. 2018. Estimates of cetacean abundance from the 2016 NAISS aerial surveys of eastern Canadian waters, with a comparison to estimates from the 2007 TNASS NAAMCO SC/25/AE/09. 40pp.

MacLeod, C.D. 2009. Global climate change, range changes and potential implications for the conservation of marine cetaceans: A review and synthesis. Endang. Species Res. 7:125–136.

Mizroch, S.A., D.W. Rice and J.M. Breiwick. 1984. The fin whale, *Balaenoptera physalus*. Mar. Fish. Rev. 46:20–24.

Morano, J.L., D.P. Salisbury, A.N. Rice, K.L. Conklin, K.L. Falk and C.W. Clark. 2012. Seasonal changes in fin whale (*Balaenoptera physalus*) 20-Hz song in the western North Atlantic Ocean. J. Acoust. Soc. Am. 132:1207–1212.

Morley, J.W., R.L. Selden, R.J. Latour, T.L. Frolicher, R.J. Seagraves and M.L. Pinsky. 2018. Projecting shifts in thermal habitat for 686 species on the North American continental shelf. PLoS ONE. 13(5):e0196127.
Murphy, S., R.J. Law, R. Deaville, J.Barnett, M W. Perkins, A. Brownlow, R. Penrose, N.J. Davison, J.L. Barber and P.D. Jepson. 2018. Organochlorine contaminants and reproductive implication in cetaceans: A case study of the common dolphin. Pages 3–38 *in*: M.C. Fossi and C. Panti (eds). Marine mammal ecotoxicology: Impacts of multiple stressors on population health. Academic Press, New York, New York.
Nye, J., J. Link, J. Hare and W. Overholtz. 2009. Changing spatial distribution of fish stocks in relation to climate and population size on the Northeast United States continental shelf. Mar. Ecol. Prog. Ser. 393:111–129.
Olsen, M. T., C. Pampoulie, A.K. Daníelsdóttir, E. Lidh, M. Bérubé, G.A. Víkingsson and P.J. Palsbøll. 2014. Fin whale MDH-1 and MPI allozyme variation is not reflected in the corresponding DNA sequences. Ecol. Evol. 4:1787–1803. DOI: 10.1002/ece3.1046
NOAA [National Oceanic and Atmospheric Administration]. 2012. National process for distinguishing serious from non-serious injuries of marine mammals. Federal Register. 77:3233−3275. https://www.fisheries.noaa.gov/webdam/download/64690371
NMFS [National Marine Fisheries Service]. 2016. Guidelines for preparing stock assessment reports pursuant to the 1994 amendments to the Marine Mammal Protection Act. 23pp. https://www.fisheries.noaa.gov/national/marine-mammal-protection/guidelines-assessing-marine-mammal-stocks.
NEFSC [Northeast Fisheries Science Center] and SEFSC [Southeast Fisheries Science Center]. 2018. Annual report of a comprehensive assessment of marine mammal, marine turtle, and seabird abundance and spatial distribution in US Waters of the Western North Atlantic Ocean. Northeast Fish. Sci. Cent. Ref. Doc. 18-04. 141pp. https://repository.library.noaa.gov/view/noaa/22040
Palka, D.L. and P.S. Hammond. 2001. Accounting for responsive movement in line transect estimates of abundance. Can. J. Fish. Aquat. Sci. 58:777–787.
Palka, D. 2020. Cetacean abundance estimates in US northwestern Atlantic Ocean waters from summer 2016 line transect surveys conducted by the Northeast Fisheries Science Center. Northeast Fish. Sci. Cent. Ref. Doc. 20-05.
Pampoulie, C., A. Daníelsdóttir, M. Bérubé, P. Palsbøll, A. Arnarson, T. Gunnlaugsson, D. Olafsdottir, N. Øien, L. Witting and G. Vikingsson. 2008. Lack of genetic divergence among samples of the North Atlantic fin whale collected at feeding grounds; Congruence among microsatellite loci and mtDNA in the new Icelandic dataset. Unpublished Scientific Committee meeting document SC/60/PFI11. International Whaling Commission, Cambridge, UK. 17pp.
Pierce, G.J., M.B. Santos, S. Murphy, J.A. Learmonth, A.F. Zuur, E. Rogan, P. Bustamante, F. Caurant, V. Lahaye, V. Ridoux, B.N. Zegers, A. Mets, M. Addink, C. Smeenk, T. Jauniaux, R.J. Law, W. Dabin, A. López, J.M. Alonso Farré, A.F. González, A. Guerra, M. García-Hartmann, R.J. Reid, C.F. Moffat, C. Lockyer, J.P. Boon. 2008. Bioaccumulation of persistent organic pollutants in female common dolphins (*Delphinus delphis*) and harbour porpoises (*Phocoena phocoena*) from western European seas: Geographical trends, causal factors and effects on reproduction and mortality. Environ. Poll. 153:401–415.
Pinsky, M.L., B. Worm, M.J. Fogarty, J.L. Sarmiento and S.A. Levin. 2013. Marine taxa track local climate velocities, Science 341:1239–1242.
Poloczanska, E.S., C.J. Brown, W.J. Sydeman, W. Kiessling, D.S. Schoeman, P.J. Moore, K. Brander, J.F. Bruno, L.B. Buckley, M.T. Burrows, C.M. Duarte, B.S. Halpern, J. Holding, C.V. Kappel, M.I. O'Connor, J.M. Pandolfi, C. Parmesan, F. Schwing, S.A. Thompson and A.J. Richardson. 2013. Global imprint of climate change on marine life. Nat. Clim. Change. 3:919–925.
Schleimer, A., C. Ramp, J. Delarue, A. Carpentier, M. Bérubé, P.J. Palsbøll, R. Sears and P.S. Hammond. 2019. Decline in abundance and apparent survival rates of fin whales (*Balaenoptera physalus*) in the northern Gulf of St. Lawrence. Ecol. Evol. 9:4231–4244.
Seipt, I.E., P.J. Clapham, C.A. Mayo and M.P. Hawvermale. 1990. Population characteristics of individually identified fin whales *Balaenoptera physalus* in Massachusetts Bay. Fish. Bull. 88:271–278.
Silva, M.A., A. Borrell, R. Prieto, P. Gauffier, M. Bérubé, P.J. Palsbøll and A. Colaço. 2019. Stable isotopes reveal winter feeding in different habitats in blue, fin and sei whales migrating through the Azores. R. Soc. Open Sci. 6:181800. http://dx.doi.org/10.1098/rsos.181800
Sousa, A., F. Alves, A. Dinis, J. Bentz, M.J. Cruz and J.P. Nunes. 2019. How vulnerable are cetaceans to climate change? Developing and testing a new index. Ecol. Indic. 98:9–18.

Taylor, B.L., M. Martinez, T. Gerrodette, J. Barlow and Y.N. Hrovat. 2007. Lessons from monitoring trends in abundance in marine mammals. Mar. Mamm. Sci. 23:157–175.

Thomas L, J.L. Laake, E. Rexstad, S. Strindberg, F.F.C. Marques, S.T. Buckland, D.L. Borchers, D.R. Anderson, K.P. Burnham, M.L. Burt, S.L. Hedley, J.H. Pollard, J.R.B. Bishop and T.A. Marques. 2009. Distance 6.0. Release 2. [Internet]. University of St. Andrews, Research Unit for Wildlife Population Assessment, St. Andrews, UK. http://distancesampling.org/Distance/

Wade, P.R. and R.P. Angliss. 1997. Guidelines for assessing marine mammal stocks: Report of the GAMMS Workshop April 3–5, 1996, Seattle, Washington. NOAA Tech. Memo. NMFS-OPR-12. 93pp.

Watkins, W.A., P. Tyack, K.E. Moore and J.E. Bird. 1987. The 20-Hz signals of finback whales (*Balaenoptera physalus*). J. Acoust. Soc. Am. 82:1901–1912.

Watkins, W.A., M.A. Daher, G.M. Reppucci, J.E. George, D.L. Martin, N.A. DiMarzio and D.P. Gannon. 2000. Seasonality and distribution of whale calls in the North Pacific. Oceanography 13:62–67.