HARBOR SEAL (*Phoca vitulina vitulina*): Western North Atlantic Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

The harbor seal (*Phoca vitulina*) is widespread in all nearshore waters of the North Atlantic and North Pacific Oceans and adjoining seas above about 30ºN (Burns 2009, Desportes *et al*. 2010).

Harbor seals are year-round inhabitants of the coastal waters of eastern Canada and Maine (Katona *et al*. 1993), and occur seasonally along the coasts from southern New England to Virginia from September through late May (Schneider and Payne 1983, Schroeder 2000, Rees *et al*. 2016, Toth *et al*. 2018). Scattered sightings and strandings have been recorded as far south as Florida (NOAA National Marine Mammal Health and Stranding Response Database, accessed 23 October 2018). A general southward movement from the Bay of Fundy to southern New England and mid-Atlantic waters occurs in autumn and early winter (Rosenfeld *et al.* 1988, Whitman and Payne 1990, Jacobs and Terhune 2000). A northward movement to Maine and eastern Canada occurs prior to the pupping season, which takes place from early May through early June primarily along the Maine coast (Gilbert *et al.* 2005, Skinner 2006).

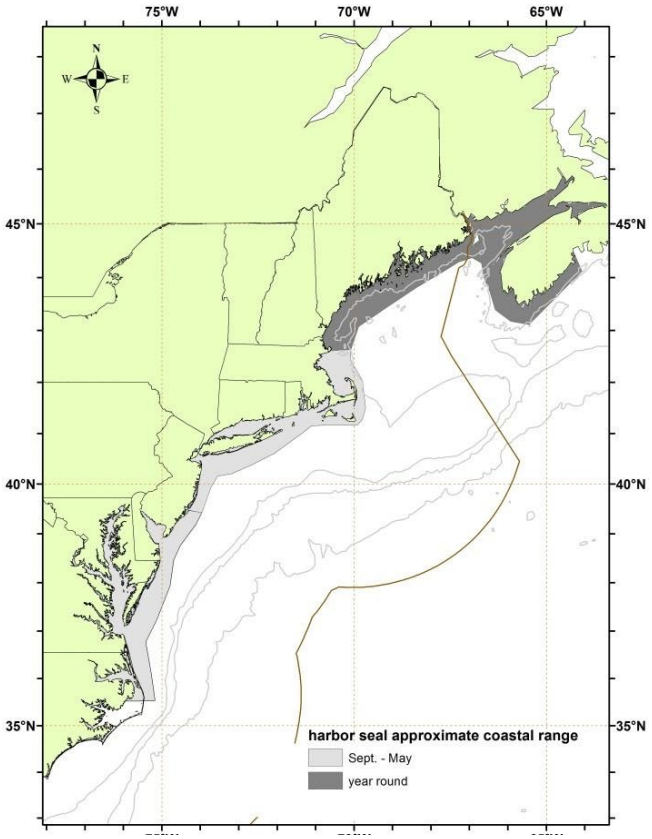

Figure 1. Approximate coastal range of harbor seals. Isobaths are the 100-m, 1000-m, and 4000-m depth contours.

Tagging studies of adult harbor seals demonstrate that adults can make long-distance migrations through the mid-Atlantic and Gulf of Maine (Waring *et al.* 2006, Jones *et al.* 2018). Prior to these studies, it was believed that the majority of seals moving into southern New England and mid-Atlantic waters were subadults and juveniles (Whitman and Payne 1990, Katona *et al.* 1993). The more recent studies demonstrate that various age classes utilize habitat along the eastern seaboard throughout the year. Reconnaissance flights for pupping south of Maine would help confirm the extent of the current pupping range.

Although the stock structure of western North Atlantic harbor seals is unknown, it is thought that harbor seals found along the eastern U.S. and Canadian coasts represent one population (Temte *et al.* 1991, Andersen and Olsen 2010). However, uncertainty in the single stock designation is suggested by multiple sources, both in this population and by inference from other populations. Stanley *et al.* (1996) demonstrated some genetic differentiation in Atlantic Canada harbor seal samples. Gilbert *et al.* (2005) noted regional differences in pup count trends along the coast of Maine. Goodman (1998) observed high degrees of philopatry in eastern North Atlantic populations. In addition, multiple lines of evidence have suggested fine-scaled sub-structure in Northeast Pacific harbor seals (Westlake and O'Corry-Crowe 2002, O'Corry-Crowe *et al.* 2003, Huber *et al*. 2010).

POPULATION SIZE

The best current abundance estimate of harbor seals is 75,834 (CV=0.15) which is from a 2012 survey (Waring *et al.* 2015). Aerial photographic surveys and radio tracking of harbor seals on ledges along the Maine coast were

conducted during the pupping period in late May 2012. Twenty-nine harbor seals (20 adults and nine juveniles) were captured and radio-tagged prior to the aerial survey. Of these, 18 animals were available during the survey to develop a correction factor for the fraction of seals not observed. A key uncertainty is that the area from which the samples were drawn in 2012 may not have included the area the entire population occupied in late May and early June. Additionally, since the most current estimate dates from a survey done in 2012, the ability for that estimate to accurately represent the present population size has become increasingly uncertain. A population survey was conducted in 2018 to provide updated abundance estimates and these data are being analyzed.

Table 1. Summary of recent abundance estimates for the western North Atlantic harbor seal (Phoca vitulina vitulina) by month, year, and area covered during each abundance survey, and resulting abundance estimate (N_{est}) and coefficient of variation (CV).

Month/Year	Area	N_{est}	CV
May/June 2012	Maine coast	75,834	0.15

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 harbor seals is 75,834 (CV=0.15). The minimum population estimate is 66,884 based on corrected available counts along the Maine coast in 2012.

Current Population Trend

A trend analysis is currently underway using the 2018 survey data combined with historical data, but the results are not yet available. There are some lines of evidence that support an apparent decline in abundance and/or changing distributions. In 2001, the population was estimated to be 99,340 (95%CI: 83,118–121,397; Gilbert *et al.* 2005). While the estimated population size was lower in 2012, Waring *et al.* (2015) did not consider the population to be declining because the 2012 and 2001 estimates were not significantly different and there was uncertainty over whether some fraction of the population was not in the survey area. In southeastern Massachusetts, counts of harbor seals progressively declined after 2009 (Pace *et al.* 2019), and reduced population size has been hypothesized from declining rates of stranded and bycaught animals (Johnston *et al.* 2015). However, the occupancy patterns of harbor seals at haul-out sites has also changed through time in relation to the growth of the sympatric gray seal population (Pace *et al.* 2019), so inferences about abundance could reflect a sampling and monitoring plan that needs to be revisited. If juvenile seals are redistributing to new areas they may be missed during population surveys, designed around historical pupping habitat. This may have explained differences in the estimated size of the population between 2001 and 2012 (Waring *et al.* 2015).

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 0.12. This value is based on theoretical modeling showing that pinniped populations may not grow at rates much greater than 12% given the constraints of their reproductive life history (Barlow *et al.* 1995). Key uncertainties about the maximum net productivity rate are due to the limited understanding of the stock-specific life history parameters; thus the default value was used.

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 66,884 animals. The maximum productivity rate is 0.12, the default value for pinnipeds. The recovery factor (F_R) is 0.5, the default value for stocks of unknown status relative to optimum sustainable population (OSP) and with the CV of the average mortality estimate less than 0.3 (Wade and Angliss 1997). PBR for the western North Atlantic stock of harbor seals is 2,006.

Table 2. Best and minimum abundance estimates for the Western North Atlantic harbor seal (Phoca vitulina vitulina) with Maximum Productivity Rate (R_{max}), Recovery Factor (F_r) and PBR.

Nest	CV	Nmin	Fr	Rmax	PBR
75,834	0.15	66,883	0.5	0.12	2,006

ANNUAL HUMAN-CAUSED SERIOUS INJURY AND MORTALITY

For the period from 2014–2018, the average annual estimated human-caused mortality and serious injury to harbor seals in the U.S. is 365 (Table 3). Mortality in U.S. fisheries is explained in further detail below.

Table 3. The total annual estimated average human-caused mortality and serious injury for the Western North Atlantic harbor seal (Phoca vitulina vitulina).

Years	Source	Annual Avg.	CV
2014–2018	U.S. fisheries using observer data	351	0.12
2014–2018	Non-fishery human interaction stranding mortalities	14.2	
2014–2018	Research mortalities	0	
Total		**365.2**	

Fishery Information

Detailed fishery information is given in Appendix III.

United States

Northeast Sink Gillnet

The Northeast sink gillnet fishery is a Category I fishery. The average annual observed mortality from 2014–2018 was 51 animals, and the average annual total mortality was 319 (CV=0.13; Hatch and Orphanides 2015, 2016; Orphanides and Hatch 2017; Orphanides 2019, 2020, 2021; Josephson *et al.* 2021). See Table 4 for bycatch estimates and observed mortality and serious injury for the current 5-year period, and Appendix V for historical bycatch information.

Mid-Atlantic Gillnet

The mid-Atlantic gillnet fishery is a Category I fishery. The average annual observed mortality from 2014–2018 was two animals, and the average annual total mortality was 23 (CV=0.34; Hatch and Orphanides 2015, 2016; Orphanides and Hatch 2017; Orphanides 2019, 2020, 2021; Josephson *et al.* 2021). See Table 4 for bycatch estimates and observed mortality and serious injury for the current 5-year period, and see Appendix V for historical bycatch information.

Northeast Bottom Trawl

The Northeast bottom trawl fishery is a Category II fishery. The average annual observed mortality from 2014–2018 was <1 animal, and the average annual total mortality was four (CV=0.54; Lyssikatos *et al*. 2021). See Table 4 for bycatch estimates and observed mortality and serious injury for the current 5-year period, and see Appendix V for historical bycatch information.

Mid-Atlantic Bottom Trawl

The mid-Atlantic bottom trawl fishery is a Category II fishery. The average annual observed mortality from 2014–2018 was <1 animal, and the average annual total mortality was five (CV=0.57; Lyssikatos *et al*. 2021). See Table 4 for bycatch estimates and observed mortality and serious injury for the current 5-year period, and see Appendix V for historical bycatch information.

Northeast Mid-water Trawl Fishery (Including Pair Trawl)

The Northeast mid-water and pair trawl fisheries are Category II fisheries. The average annual observed mortality from 2014–2018 was <1 animal. An expanded bycatch estimate has not been calculated for the current 5-year period. See Table 4 for observed mortality and serious injury during the current 5-year period, and Appendix V for historical bycatch information.

Gulf of Maine Atlantic Herring Purse Seine Fishery

No mortalities have been observed in this fishery, and no harbor seals were captured and released alive in 2014–2018.

Canada

Currently, scant data are available on bycatch in Atlantic Canada fisheries due to limited observer programs (Baird 2001). An unknown number of harbor seals have been taken in Newfoundland, Labrador, Gulf of St. Lawrence and Bay of Fundy groundfish gillnets; Atlantic Canada and Greenland salmon gillnets; Atlantic Canada cod traps; and in Bay of Fundy herring weirs (Read 1994, Cairns *et al.* 2000). Furthermore, some of these mortalities (e.g., seals trapped in herring weirs) are the result of direct shooting under nuisance permits.

Table 4. Summary of the incidental mortality of harbor seals (Phoca vitulina vitulina) by commercial fishery including the years sampled (Years), the type of data used (Data Type), the annual observer coverage (Observer Coverage), the mortalities recorded by on-board observers (Observed Mortality), the estimated annual mortality (Estimated Mortality), the estimated CV of the annual mortality (Estimated CVs) and the mean annual mortality (CV in parentheses).

Fishery	Years	Data Type[a]	Observer Coverage[b]	Observed Serious Injury[c]	Observed Mortality	Est. Serious Injury	Est. Mortality	Est. Comb. Mortality	Est. CVs	Mean Annual Combined Mortality
Northeast Sink Gillnet	2014	Obs. Data, Weighout, Logbook	0.18	0	59	0	390	390	0.39	319 (0.13)
	2015		0.14	0	87	0	474	474	0.17	
	2016		0.10	0	36	0	245	245	0.29	
	2017		0.12	0	63	0	298	298	0.18	
	2018		0.11	0	22	0	188	188	0.36	
Mid-Atlantic Gillnet	2014	Obs. Data, Weighout	0.05	0	1	0	19	19	1.06	23 (0.34)
	2015		0.06	0	5	0	48	48	0.52	
	2016		0.08	0	2	0	18	18	0.95	
	2017		0.09	0	1	0	3	3	0.62	
	2018		0.09	0	3	0	26	26	0.52	
Northeast Bottom Trawl	2014	Obs. Data, Weighout	0.19	0	4	0	19	19	0.63	3.8 (0.54)
	2015		0.19	0	4	0	23	23	0	
	2016		0.12	0	0	0	0	0	0	
	2017		0.12	0	2	0	16	16	0.96	
	2018		0.12	0	5	0	32	32	0.52	
Mid-Atlantic Bottom Trawl	2014	Obs. Data, Dealer	0.09	0	2	0	10	10	0.95	4.6 (0.57)
	2015		0.09	0	1	0	7	7	1	
	2016		0.10	0	0	0	0	0	0	
	2017		0.14	0	0	0	0	0	0	
	2018		0.12	0	1	0	6	6	0.94	
Northeast Mid-water Trawl – Incl. Pair Trawl	2014	Obs. Data, Weighout, Trip Logbook	0.42	0	1	0	na	na	na	0.8 (na)
	2015		0.08	0	2	0	na	na	na	
	2016		0.27	0	1	0	na	na	na	
	2017		0.16	0	0	0	0	0	0	
	2018		0.14	0	0	0	0	0	0	
Total										**351 (0.12)**

a. Observer data (Obs. Data) are used to measure bycatch rates, and the data are collected within the Northeast Fisheries Observer Program (NEFOP). NEFSC collects landings data (Weighout), and total landings are used as a measure of total effort for the sink gillnet fishery. Mandatory logbook (Logbook) data are used to determine the spatial distribution of fishing effort in the northeast sink gillnet fishery.
b. The observer coverages for the northeast sink gillnet fishery and the mid-Atlantic gillnet fisheries are ratios based on tons of fish landed and coverages for the bottom and mid-water trawl fisheries are ratios based on trips. Total observer coverage reported for bottom trawl gear and gillnet gear in the years 2014–2018 includes samples collected from traditional fisheries observers in addition to fishery monitors through NEFOP.
c. Serious injuries were evaluated for the 2014–2018 period and include both at-sea monitor and traditional observer data (Josephson *et al.* 2021).

Other Mortality

United States

Historically, harbor seals were bounty-hunted in New England waters, which may have caused a severe decline of this stock in U.S. waters (Katona *et al*. 1993, Lelli *et al*. 2009). Bounty-hunting ended in the mid-1960s.

Harbor seals strand each year throughout their migratory range. Stranding data provide insight into some of these

sources of mortality. Tables 5 and 6 present summaries of harbor seal stranding mortalities as reported to the NOAA National Marine Mammal Health and Stranding Response Database (accessed 20 November 2019). In an analysis of mortality causes of stranded marine mammals on Cape Cod and southeastern Massachusetts between 2000 and 2006, Bogomolni *et al.* (2010) reported that 13% of harbor seal stranding mortalities were attributed to human interaction.

A number of Unusual Mortality Events (UMEs) have affected harbor seals over the past decade. A UME was declared for harbor seals in northern Gulf of Maine waters in 2003 and continued into 2004. No consistent cause of death could be determined. The UME was declared over in spring 2005 (MMC 2006). NMFS declared another UME in the Gulf of Maine in autumn 2006 based on infectious disease. A UME was declared in November of 2011 that involved 567 harbor seal stranding mortalities between June 2011 and October 2012 in Maine, New Hampshire, and Massachusetts. The UME was declared closed in February 2013 (https://www.fisheries.noaa.gov/national/marine-life-distress/active-and-closed-unusual-mortality-events). Another UME was declared by NMFS beginning in July 2018 due to increased numbers of harbor and gray seal strandings along the U.S. coasts of Maine, New Hampshire, and Massachusetts. Strandings remained elevated over the summer and the UME area was expanded to include nine states from Maine to Virginia with strandings continuing into 2019. From July to December 2018, 1,100 harbor seals stranded predominantly in Maine, New Hampshire and Massachusetts. The preliminary cause of the UME was attributed to a phocine distemper outbreak (https://www.fisheries.noaa.gov/new-england-mid-atlantic/marine-life-distress/2018-2020-pinniped-unusual-mortality-event-along).

Stobo and Lucas (2000) have documented shark predation as an important source of natural mortality at Sable Island, Nova Scotia. They suggest that shark-inflicted mortality in pups, as a proportion of total production, was less than 10% in 1980–1993, approximately 25% in 1994–1995, and increased to 45% in 1996. Also, shark predation on adults was selective towards mature females. The decline in the Sable Island population appears to result from a combination of shark-inflicted mortality on both pups and adult females and inter-specific competition with the much more abundant gray seal for food resources (Stobo and Lucas 2000, Bowen *et al.* 2003).

Canada

Aquaculture operations in eastern Canada can be licensed to shoot nuisance seals, but the number of seals killed is unknown (Jacobs and Terhune 2000, Baird 2001). Small numbers of harbor seals are taken in subsistence hunting in northern Canada (DFO 2011).

Table 5. Harbor seal (Phoca vitulina vitulina) stranding mortalities along the U.S. Atlantic coast (2014–2018) with subtotals of animals recorded as pups in parentheses.

State	2014	2015	2016	2017	2018	Total
ME	127 (94)	73 (47)	76 (58)	120 (84)	819 (75)	1,215 (344)
NH	38 (22)	56 (43)	45 (27)	26 (20)	113 (60)	278 (171)
MA	58 (15)	81 (24)	55 (19)	78 (29)	204 (58)	476 (145)
RI	7 (1)	8 (0)	5 (1)	9 (3)	9 (0)	38 (5)
CT	0	2 (1)	1 (0)	2 (0)	2 (1)	7 (2)
NY	13 (4)	21 (0)	1 (0)	11 (0)	12 (1)	58 (5)
NJ	2 (1)	9 (4)	4 (0)	9 (3)	14 (2)	38 (10)
DE	3 (0)	1 (0)	1 (1)	1 (0)	2 (1)	8 (2)
MD	2 (0)	0	0	1 (0)	4 (0)	7 (0)
VA	2 (0)	1 (0)	1 (0)	2 (0)	1 (0)	7 (0)
NC	3 (1)	5 (2)	4 (2)	4 (4)	7 (2)	23 (11)
SC	1 (0)	0	0	0	0	1 (0)
Total	**256**	**257**	**193**	**263**	**1,187**	**2,156 (635)**
Unspecified seals (all states)	38	31	13	86	92	260

Table 6. Harbor seal (Phoca vitulina vitulina) human-interaction stranding mortalities along the U.S. Atlantic coast (2014–2018) by type of interaction.

Cause	2014	2015	2016	2017	2018	Total
Fishery Interaction	2	2	3	1	5	13
Boat Strike	2	1	5	3	2	13
Shot	1	0	0	0	0	1
Human Interaction — Other	6	15	8	6	22	57
Total	**11**	**18**	**16**	**10**	**29**	**84**

STATUS OF STOCK

Harbor seals are not listed as threatened or endangered under the Endangered Species Act, and the western North Atlantic stock is not considered strategic under the Marine Mammal Protection Act. The 2014–2018 average annual human-caused mortality and serious injury does not exceed PBR. The status of the western North Atlantic harbor seal stock, relative to OSP, in the U.S. Atlantic EEZ is unknown. Total fishery-related mortality and serious injury for this stock is not less than 10% of the calculated PBR and, therefore, cannot be considered to be insignificant and approaching zero mortality and serious injury rate.

REFERENCES CITED

Anderson, L.W. and M.T. Olsen. 2010. Distribution and population structure of North Atlantic harbour seals (*Phoca vitulina*). Pages 173–188 *in*: Harbour Seals of the North Atlantic and the Baltic. NAMMCO Scientific Publications 8.

Baird, R.W. 2001. Status of harbor seals, *Phoca vitulina*, in Canada. Can. Field-Nat. 115:663–675.

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.

Bogomolni, A.L., K.R. Pugliares, S.M. Sharp, K. Patchett, C.T. Harry, J.M. LaRocque, K.M. Touhey and M. Moore. 2010. Mortality trends of stranded marine mammals on Cape Cod and southeastern Massachusetts, USA, 2000 to 2006. Dis. Aq. Org. 88:143–155.

Bowen, W.D., S.L. Ellis, S.J. Iverson and D.J. Boness. 2003. Maternal and newborn life-history traits during periods of contrasting population trends: Implications for explaining the decline of harbour seals (*Phoca vitulina*), on Sable Island. J. Zool. 261:155–163.

Burns, J.J. 2009. Harbor seal and spotted seal (*Phoca vitulina* and *P. largha*). Pages 533–542 *in*: W.F. Perrin, B. Wursig and J.G.M. Thewissen (Eds.). Encyclopedia of marine mammals, second edition. Academic Press, San Diego, CA.

Cairns, D.K., D.M. Keen, P-Y. Daoust, D.J. Gillis and M. Hammill. 2000. Conflicts between seals and fishing gear on Prince Edward Island. Can. Tech. Rep. of Fish. and Aq. Sci. 2333. 39pp.

Desportes G., A. Bjorge, A. Rosing-Asvid and G.T. Waring, eds. 2010. Harbour seals of the North Atlantic and the Baltic. NAMMCO Scientific Publications, vol. 8. North Atlantic Marine Mammal Commission, Tromsø, Norway. 377pp.

DFO [Dept of Fisheries and Oceans]. 2011. 2011–2015 Integrated fisheries management plan for Atlantic seals. Available from: http://www.dfo-mpo.gc.ca/fm-gp/seal-phoque/reports-rapports /mgtplan-planges20112015/mgtplan-planges20112015-eng.htm#c2

Gilbert, J.R., G.T. Waring, K.M. Wynne and N. Guldager. 2005. Changes in abundance and distribution of harbor seals in Maine, 1981–2001. Mar. Mamm. Sci. 21:519–535.

Goodman, S.J. 1998. Patterns of extensive genetic differentiation and variation among European harbor seals (*Phoca vitulina vitulina)* revealed using microsatellite DNA polymorphisms. Mol. Biol. Evol. 15:104–118.

Hatch, J.M. and C.D. Orphanides. 2015. Estimates of cetacean and pinniped bycatch in the 2013 New England sink and mid-Atlantic gillnet fisheries. Northeast Fish. Sci. Cent. Ref. Doc. 15-15. 33pp. Available from: https://www.fisheries.noaa.gov/resource/publication-database/marine-mammal-mortality-and-serious-injury-reports

Hatch, J.M. and C.D. Orphanides. 2016. Estimates of cetacean and pinniped bycatch in the 2014 New England sink and mid-Atlantic gillnet fisheries. Northeast Fish. Sci. Cent. Ref. Doc. 16-05. 22pp. Available from: https://www.fisheries.noaa.gov/resource/publication-database/marine-mammal-mortality-and-serious-injury-reports

Huber, H. R., S.J. Jeffries, D.M. Lambourn and B.R. Dickerson. 2010. Population substructure of harbor seals (*Phoca vitulina richardsi*) in Washington State using mtDNA. Can. J. Zool. 88:280–288.

Jacobs, S.R. and J.M. Terhune. 2000. Harbor seal (*Phoca vitulina*) numbers along the New Brunswick coast of the Bay of Fundy in autumn in relation to aquaculture. Northeast. Nat. 7:289–296.

Johnston, D.W., J. Frungillo, A. Smith, K. Moore, B. Sharp, J. Schuh and A.J. Read. 2015. Trends in stranding and by-catch rates of gray and harbor seals along the northeastern coast of the United States: Evidence of divergence in the abundance of two sympatric phocid species? PLoS ONE 10(7):e0131660. https://doi.org/10.1371/journal.pone.0131660

Jones, D.V, D.R. Rees and B.A. Bartlett. 2018. Haul-out counts and photo-identification of pinnipeds in Chesapeake Bay and Eastern Shore, Virginia: 2017/2018 Annual Progress Report. Final Report. Prepared for U.S. Fleet Forces Command, Norfolk, Virginia. 21 December 2018.

Josephson, E., F. Wenzel and M.C. Lyssikatos. 2021. Serious injury determinations for small cetaceans and pinnipeds caught in commercial fisheries off the northeast U.S. coast, 2014–2018. Northeast Fish. Sci. Cent. Ref. Doc. 21-04. 33pp. Available from: https://www.fisheries.noaa.gov/resource/publication-database/marine-mammal-mortality-and-serious-injury-reports

Katona, S.K., V. Rough and D.T. Richardson. 1993. A field guide to whales, porpoises, and seals from Cape Cod to Newfoundland. Smithsonian Institution Press, Washington, DC. 316pp.

Lelli, B., D.E. Harri and A-M. Aboueissa. 2009. Seal bounties in Maine and Massachusetts, 1888 to 1962. Northeast. Nat. 16:239–254.

Lyle, J.M. and S.T. Willcox. 2008. Dolphin and seal interactions with mid-water trawling in the commonwealth small pelagic fishery, including an assessment of bycatch mitigation. Australian Fisheries Management Authority, Final Report Project R05/0996. 49p.

Lyssikatos, M., S. Chavez-Rosales and J. Hatch. 2021. Estimates of cetacean and pinniped bycatch in northeast and mid-Atlantic bottom trawl fisheries, 2014–2018. Northeast Fish. Sci. Cent. Ref. Doc. 21-02. 12pp.

MMC [Marine Mammal Commission]. 2006. US Marine Mammal Commission annual report to Congress, 2005. Bethesda, MD. vi+163pp. Available from: http://www.mmc.gov/reports/annual/pdf/2005annualreport.pdf

O'Corry-Crowe, G.M., K.K. Martien and B.L. Taylor. 2003. The analysis of population genetic structure in Alaskan harbor seals, *Phoca vitulina*, as a framework for the identification of management stocks. Southwest Fish. Sci. Cent. Admin. Rep. LJ-03-08. 66pp. Available from: https://alaskafisheries.noaa.gov/sites/default/files/geneticstructure_occrowe03.pdf

Orphanides, C.D. and J. Hatch. 2017. Estimates of cetacean and pinniped bycatch in the 2015 New England sink and mid-Atlantic gillnet fisheries. Northeast Fish. Sci. Cent. Ref. Doc. 17-18. 21pp.

Orphanides, C.D. 2019. Estimates of cetacean and pinniped bycatch in the 2016 New England sink and mid-Atlantic gillnet fisheries. Northeast Fish. Sci. Cent. Ref. Doc. 19-04. 17pp.

Orphanides, C.D. 2020. Estimates of cetacean and pinniped bycatch in the 2017 New England sink and mid-Atlantic gillnet fisheries. Northeast Fish. Sci. Cent. Ref. Doc. 20-03. 16pp. Available from: https://www.fisheries.noaa.gov/resource/publication-database/marine-mammal-mortality-and-serious-injury-reports

Orphanides, C.D. 2021. Estimates of cetacean and pinniped bycatch in the 2018 New England sink and mid-Atlantic gillnet fisheries. Northeast Fish. Sci. Cent. Ref. Doc. 21-01. Available from: https://www.fisheries.noaa.gov/resource/publication-database/marine-mammal-mortality-and-serious-injury-reports

Pace, R.M., E. Josephson, S. Wood and K. Murray. 2019. Trends and patterns of seal abundance at haul-out sites in a gray seal recolonization zone. Northeast Fish. Sci Center Tech Memo. NMFS-NE-251.

Read, A.J. 1994. Interactions between cetaceans and gillnet and trap fisheries in the northwest Atlantic. Rep. Int. Whal. Comm. (Special Issue) 15:133–147.

Rees, D.R., D.V. Jones and B.A. Bartlett. Haul-out counts and photo-identification of pinnipeds in Chesapeake Bay, Virginia: 2015/16 Annual Progress Report. Final Report. Prepared for U.S. Fleet Forces Command, Norfolk, Virginia. 15 November 2016.

Rosenfeld, M., M. George and J.M. Terhune. 1988. Evidence of autumnal harbour seal, *Phoca vitulina*, movement from Canada to the United States. Can. Field-Nat. 102:527–529.

Schneider, D.C. and P.M. Payne. 1983. Factors affecting haul-out of harbor seals at a site in southeastern Massachusetts. J. Mamm. 64:518–520.
Schroeder, C.L. 2000. Population status and distribution of the harbor seal in Rhode Island waters. M.S. thesis. University of Rhode Island, Kingston, RI. 197pp.
Skinner, J.P. 2006. Physical and behavioral development of nursing harbor seal (*Phoca vitulina*) pups in Maine. M.S. thesis. University of Maine, Orono, ME. 140pp.
Stanley, H.F., S. Casey, J.M. Carnahan, S. Goodman, J. Harwood and R.K. Wayne. 1996. Worldwide patterns of mitochondrial DNA differentiation in the harbor seal (*Phoca vitulina*). Mol. Biol. Evol. 13:368–382.
Stobo, W.T. and Z. Lucas. 2000. Shark-inflicted mortality on a population of harbour seals (*Phoca vitulina*) at Sable Island, Nova Scotia. J. Zool. 252:405–414.
Temte, J.L., M.A. Bigg and O. Wiig. 1991. Clines revisited: The timing of pupping in the harbour seal (*Phoca vitulina*). J. Zool. 224:617–632.
Toth, J., S. Evert, E. Zimmermann, M. Sullivan, L. Dotts, K.W. Able, R. Hagan and C. Slocum. 2018. Annual residency patterns and diet of *Phoca vitulina concolor* (Western Atlantic harbor seal) in a southern New Jersey estuary. Northeastern Naturalist. 25(4):611–626.
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. Available from: https://repository.library.noaa.gov/view/noaa/15963
Waring, G.T., J.R. Gilbert, J. Loftin and N. Cabana. 2006. Short-term movements of radio-tagged harbor seals in New England. Northeast. Nat. 13:1–14.
Waring, G.T., R.A. DiGiovanni Jr, E. Josephson, S. Wood and J.R. Gilbert. 2015. 2012 population estimate for the harbor seal (*Phoca vitulina concolor*) in New England waters. NOAA Tech. Memo. NMFS NE-235. 15pp.
Westlake R.L. and G.M. O'Corry-Crowe. 2002. Macrogeographic structure and patterns of genetic diversity in harbor seals (*Phoca vitulina*) from Alaska to Japan. J. Mamm. 83:111–1126.
Whitman, A.A. and P.M. Payne. 1990. Age of harbour seals, *Phoca vitulina concolor*, wintering in southern New England. Can. Field-Nat. 104:579–582.