# GRAY SEAL (*Halichoerus grypus atlantica*): Western North Atlantic Stock

## STOCK DEFINITION AND GEOGRAPHIC RANGE

The gray seal (*Halichoerus grypus atlantica*) is found on both sides of the North Atlantic, with three major populations: Northeast Atlantic, Northwest Atlantic and the Baltic Sea (Haug *et al.* 2007). The Northeast Atlantic and the Northwest Atlantic populations are classified as the subspecies *H. g. atlantica* (Olsen *et al.* 2016). The western North Atlantic stock is equivalent to the Northwest Atlantic population, and ranges from New Jersey to Labrador (Davies 1957; Mansfield 1966; Katona *et al.* 1993; Lesage and Hammill 2001). This stock is separated by geography, differences in the breeding season, and mitochondrial and nuclear DNA variation from the northeastern Atlantic stocks (Bonner 1981; Boskovic *et al.* 1996; Lesage and Hammill 2001; Klimova *et al.* 2014). There are three breeding aggregations in eastern Canada: Sable Island, Gulf of St. Lawrence, and at sites along the coast of Nova Scotia (Laviguer and Hammill 1993). Outside the breeding period, there is overlap in the distribution of animals from the three colonies (Lavigueur and Hammill 1993; Harvey *et al.* 2008; Breed *et al.* 2006, 2009) and they are considered a single population based on genetic similarity (Boskovic *et al.* 1996; Wood *et al.* 2011). In the mid-1980s, small numbers of animals and pupping were observed on several isolated islands along the Maine coast and in Nantucket-Vineyard Sound, Massachusetts (Katona *et al.* 1993; Rough 1995: Gilbert *et al.* 2005). In December 2001, NMFS initiated aerial surveys to monitor gray seal pup production on Muskeget Island and adjacent sites in Nantucket Sound, and Green and Seal Islands off the coast of Maine (Wood *et al.* 2007). Tissue samples collected from Canadian and U.S. populations were examined for genetic variation using mitochondrial and nuclear DNA (Wood *et al.* 2011). All individuals were identified as belonging to one population, confirming that recolonization by Canadian gray seals is the source of the U.S. population. Sightings of seals in the U.S. that had been branded on Sable Island, resights of tagged animals, and satellite tracks of tagged animals (Puryear *et al.* 2016) provide further evidence that there is movement of individuals between the U.S. and Canada. However, the percentage of time that individuals are resident in U.S. waters is unknown.

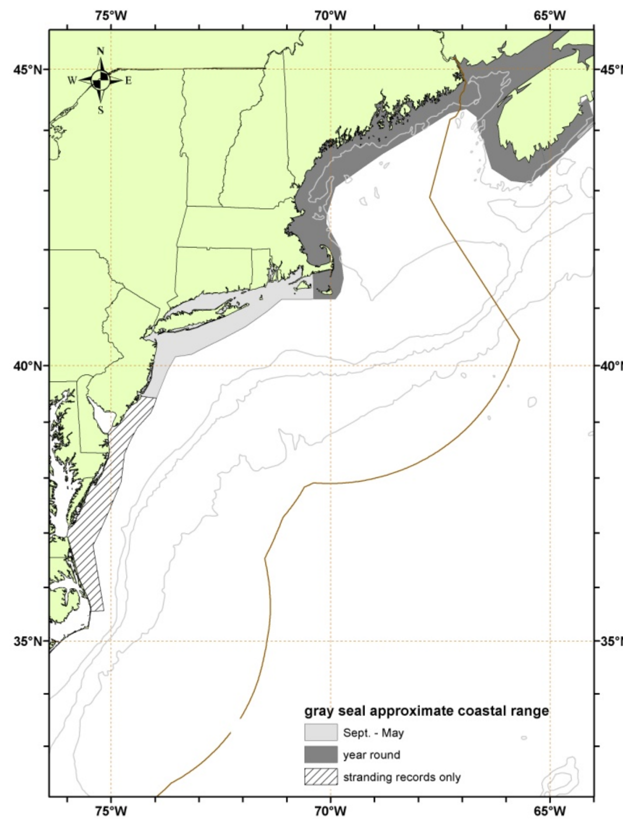


**Figure 1**. Approximate coastal range of gray seals. Isobaths are the 100-m, 1000-m, and 4000-m depth contours.

The genetic evidence (Boskovic *et al.* 1996; Wood *et al.* 2011) provides a high degree of certainty that the Western North Atlantic stock of gray seals is a single stock.

## POPULATION SIZE

Current estimates of the total western Atlantic gray seal population are not available; although estimates of portions of the stock are available for select time periods. Total pup production in 2016 at breeding colonies in Canada was 98,650 pups (CV=0.10) (den Heyer 2017; DFO 2017). Production at Sable Island, Gulf of St. Lawrence, and Coastal Nova Scotia colonies accounted for 85%, 11% and 4%, respectively, of the estimated total number of pups born. Population models, incorporating estimates of age-specific reproductive rates and removals, are fit to these pup production estimates to estimate total population levels in Canada. The total estimated Canadian gray seal population in 2016 was 424,300 (95% CI=263,600 to 578,300) (DFO 2017). Uncertainties in the population estimate derive from uncertainties in life history parameters such as mortality rates and sex ratios (DFO 2017).

In U.S. waters, gray seals primarily pup at four established colonies: Muskeget and Monomoy islands in Massachusetts, and Green and Seal islands in Maine. Since 2010 pupping has also been observed at Noman's Island in Massachusetts and Wooden Ball and Matinicus Rock in Maine. Although white-coated pups have stranded on eastern Long Island beaches in New York, no pupping colonies have been detected in that region. Gray seals have been observed using the historic pupping site on Muskeget Island in Massachusetts since 1988. Pupping has taken place on Seal and Green Islands in Maine since at least the mid-1990s. Aerial survey data from these sites indicate that pup production is increasing (Table 2), although aerial survey quality and coverage has varied significantly among surveys. Table 2 summarizes single-day pup counts from U.S. pupping colonies from 2001/2002 to 2015/2016 pupping periods. A minimum of 6,308 of pups were born in 2016 at U.S. breeding colonies, approximately 6% of the total pup production over the entire range of the stock. The percentage of pup production in the U.S. is considered a minimum because pup counts are single day counts that have not been adjusted to account for pups born after the survey, or that left the colony prior to the survey.

The number of pups born at U.S. breeding colonies can be used to approximate the total size (pups and adults) of the gray seal population in U.S. waters, based on the ratio of total best population size to pups in Canadian waters (4.3:1). This ratio falls within the range of other adult to pup ratios suggested for pinniped populations (Harwood and Prime 1978). Using this approach, the population estimate in U.S. waters is 27,131 (95% CI: 22,162 – 33,215) animals. There is uncertainty in this abundance level in the U.S. because life history parameters that influence the ratio of pups to total individuals in this portion of the population are unknown.

Table 1. Summary of recent abundance estimates for the western North Atlantic gray seal (*Halichoerus grypus atlantica*) by year, and area covered, resulting total abundance estimate and 95% confidence interval.

| Month/Year | Area | $N_{best}$ [a] | CI |
|---|---|---|---|
| 2012[b] | Gulf of St Lawrence + Nova Scotia Eastern Shore + Sable Island | 331,000 | 95% CI 263,000-458,000 |
| 2014[c] | Gulf of St Lawrence + Nova Scotia Eastern Shore + Sable Island | 505,000 | 95%CI=329,000-682,000 |
| 2016[d] | Gulf of St Lawrence + Nova Scotia Eastern Shore + Sable Island | 424,300 | 95%CI=263,600-578,300 |
| 2016 | U.S | 27,131[e] | 95% CI = 22,162 – 33,215 |

[a]These are model-based estimates derived from pup surveys.

[b] DFO 2013

[c] DFO 2014

[d] DFO 2017

[e]This is derived from total population size to pup ratios in Canada, applied to U.S. pup counts.

Table 2 Single day pup counts from five U.S. pupping colonies during 2001-2016 from aerial surveys. 'CIP' = Counting in Progress. As single day pup counts, these counts do not represent the entire number of pups born in a pupping season. * indicates counts that need to be reviewed

| | Massachusetts | | | Maine | | | |
|---|---|---|---|---|---|---|---|
| Pupping Season | Muskeget Island | Monomoy Island | Nomans Island | Seal Island | Green Island | Wooden Ball | Matinicus Rock |
| 2001-02 | 883 | Not surveyed | Not surveyed | No data | 34 | Not surveyed | Not surveyed |
| 2002-03 | 509 | Not surveyed | Not surveyed | 147 | No data | Not surveyed | Not surveyed |
| 2003-04 | 824 | Not surveyed | Not surveyed | 150 | 26 | Not surveyed | Not surveyed |
| 2004-05 | 992 | 1 | Not surveyed | 365 | 33 | Not surveyed | Not surveyed |
| 2005-06 | 868 | 8 | Not surveyed | 239 | 43 | Not surveyed | Not surveyed |
| 2006-07 | 1704 | 9 | Not surveyed | 364 | 57 | Not surveyed | Not surveyed |
| 2007-08 | 2095 | 2 | Not surveyed | 466 | 59 | Not surveyed | Not surveyed |
| 2008-09 | CIP | 68 | 0 | CIP | 48 | Not surveyed | Not surveyed |
| 2009-10 | 1841 | 154 | 0 | CIP | 51 | Not surveyed | Not surveyed |
| 2010-11 | 3173 | 325 | 1 | CIP | 65 | Not surveyed | 112* |
| 2011-12 | 2796* | 80 | 8 | CIP | 41 | 2 | 57* |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2012-13 | 2750 | 633 | 4 | CIP | Not surveyed | Not surveyed | CIP |
| 2013-14 | 3073 | 507 | 16 | CIP | 30 | Not surveyed | 201* |
| 2014-15 | 1633 | 768 | 23 | CIP | 33 | 185 | 182* |
| 2015-16 | 3787 | 935 | 32 | 1043 | 34 | 284 | 193 |

**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 $20^{th}$ percentile of the log-normal distribution as specified by Wade and Angliss (1997). Based on an estimated U.S. population of 27,131 (CV=0.19), the minimum population estimate in U.S. waters is 23,158. Similar to the best abundance estimate, there is uncertainty in this minimum abundance level in the U.S. because life history parameters that influence the ratio of pups to total individuals in this population are unknown.

**Current Population Trend**

Gray seal abundance is likely increasing in the U.S. Atlantic Exclusive Economic Zone (EEZ), but the rate of increase is unknown.

The population in eastern Canada was greatly reduced by hunting and bounty programs, and in the 1950s the gray seal was considered rare (Lesage and Hammill 2001). The Sable Island, Nova Scotia, population was less affected and has been increasing for several decades. Pup production on Sable Island increased exponentially at a rate of 12.8% per year between the 1970s and 1997 (Stobo and Zwanenburg 1990; Mohn and Bowen 1996; Bowen *et al.* 2003; Trzcinski *et al.* 2005; Bowen *et al.* 2007; DFO 2011). Since 1997, the rate of increase has been slower (Bowen *et al.* 2011, den Heyer *et al.* 2017), supporting the hypothesis that density-dependent changes in vital rates may be limiting population growth. Pupping also occurs on Hay Island off Nova Scotia, in colonies off southwestern Nova Scotia, and in the Gulf of St. Lawrence. Pup production is increasing on Sable Island and in southwest Nova Scotia, and stabilizing on Hay Island in the Gulf of St. Lawrence (DFO 2017, den Heyer *et al.* 2017). In the Gulf of St. Lawrence, the proportion of pups born on the ice has declined from 100% in 2004 to 1% in 2016 due to a decline in winter ice cover in the area, and seals have responded by pupping on nearby islands (DFO 2017).

The projected population trends for all Canadian aggregations are still increasing. The model projections in 2016 differed from previous analyses due to changes in adult sex ratio and adult mortality rates (DFO 2017). Uncertainties in the population abundance estimates and mortality could have impacts on the abundance trends.

**CURRENT AND MAXIMUM NET PRODUCTIVITY RATES**

Current and maximum net productivity rates are unknown for this stock. Recent studies estimated the current annual rate of increase at 4.5% for the combined breeding aggregations in Canada (DFO 2014), continuing a decline in the rate of increase (Trzcinski *et al*. 2005; Bowen *et al*. 2007; Thomas *et al*. 2011; DFO 2014). 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); the realized growth rate for over two decades through 1997 was slightly higher.

**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 for the stock in U.S. waters is 23,158. The maximum productivity rate is 0.12, the default value for pinnipeds. The recovery factor ($F_R$) for this stock is 1.0, the value for stocks of unknown status, but which are known to be increasing. PBR for the western North Atlantic stock of gray seals in U.S. waters is 1,389 animals. Uncertainty in the PBR level arises from the same sources of uncertainty in calculating a minimum abundance estimate in U.S. waters.

**ANNUAL HUMAN-CAUSED MORTALITY AND SERIOUS INJURY**

For the period 2011–2015, the average annual estimated human caused mortality and serious injury to gray seals in the U.S. and Canada was 5,207 per year. The average was derived from six components: 1) 1,088 (CV=0.09) (Table 3) from the 2011–2015 U.S. observed fishery; 2) 7.8 from average 2011–2015 non-fishery related, human interaction stranding mortalities; 308 from the average 2011–2015 Canadian commercial harvest; 4) 132 from the average 2011–2015 DFO scientific collections; 5) 3,674 removals of nuisance animals in Canada (DFO 2017); and 6) 0.2 from U.S. research mortalities.

A source of unquantified human-caused mortality or serious injury for this stock is the fact that observed serious injury rates are lower than would be expected from the anecdotally-observed numbers of gray seals living with ongoing entanglements. Reports of seal shootings and other non-fishery-related human interactions are minimum counts. Canadian reporting of nuisance seal removal is known to be incomplete and there is also limited information on Canadian fishery bycatch (DFO 2017).

**Fishery Information**

Detailed fishery information is given in Appendix III.

**U.S.**

**Northeast Sink Gillnet**

Gray seal bycatch in the northeast sink gillnet fishery was usually observed in the first half of the year in waters to the east and south of Cape Cod, Massachusetts in 12-inch gillnets fishing for skates and monkfish (Hatch and Orphanides 2014, 2015, 2016, Orphanides and Hatch 2017). There were 9, 1, 8, 8, and 10 unidentified seals observed during 2011–2015, respectively. Since 1997 unidentified seals have not been prorated to a species. This is consistent with the treatment of other unidentified mammals that do not get prorated to a specific species. See Table 3 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**

Gray seal interactions were first observed in this fishery in 2010, since then, when they are observed, it is usually in waters off New Jersey in gillnets that have mesh sizes ≥ 7 in (Hatch and Orphanides 2014, 2015, 2016; Orphanides and Hatch 2017). See Table 3 for bycatch estimates and observed mortality and serious injury for the current 5-year period, and Appendix V for historical bycatch information.

**Northeast Mid-Water Trawl**

One gray seal mortality was observed in 2012 and one in 2013 in this fishery. An expanded bycatch estimate has not been generated. Until this bycatch estimate can be developed, the average annual fishery-related mortality and serious injury for 2011–2015 is calculated as 0.4 animals (2 animals /5 years). See Table 3 for bycatch estimates and observed mortality and serious injury for the current 5-year period, and Appendix V for historical bycatch information.

**Gulf of Maine Atlantic Herring Purse Seine Fishery**

The Gulf of Maine Atlantic Herring Purse Seine Fishery is a Category III fishery. This fishery was not observed until 2003, and was not observed in 2006.No mortalities have been observed, but during this time period 34 gray seals were captured and released alive in 2011, 33 in 2012, 1 in 2013, and 2 in 2014, and 0 in 2015. In addition, during this time period 8 seals of unknown species were captured and released alive in 2011 and 2 in 2015 (Josephson *et al.* 2017).

**Northeast Bottom Trawl**

Vessels in the North Atlantic bottom trawl fishery, a Category III fishery under MMPA, were observed in order to meet fishery management, rather than marine mammal management needs. Nineteen gray seal mortalities were observed in this fishery in 2011, 8 in 2012, 5 in 2013, 4 in 2014, and 2 in 2015.See Table 3 for bycatch estimates and observed mortality and serious injury for the current 5-year period, and Appendix V for historical bycatch information.

**Mid-Atlantic Bottom Trawl**

Three gray seal mortalities were observed in this fishery in 2011, 1 in 2012, 2 in 2013, 1 in 2014, and none in 2015. See Table 3 for bycatch estimates and observed mortality and serious injury for the current 5-year period, and Appendix V for historical bycatch information.

**CANADA**

Historically, an unknown number of gray seals have been taken in Newfoundland and Labrador, Gulf of St. Lawrence, and Bay of Fundy groundfish gillnets; Atlantic Canada and Greenland salmon gillnets; Atlantic Canada cod traps, and Bay of Fundy herring weirs (Read 1994).

Table 3. Summary of the incidental serious injury and mortality of gray seal (*Halichoerus grypus atlantica*) by commercial fishery including the years sampled, the type of data used, the annual observer coverage, the serious injuries and mortalities recorded by on-board observers, the estimated annual mortality, the estimated CV of the annual mortality and the mean annual combined mortality (CV in parentheses).

| Fishery | Years | Data Type [a] | Observer Coverage [b] | Observed Serious Injury[c] | Observed Mortality | Estimated Serious Injury | Estimated Mortality | Estimated Combined Mortality | Estimated CVs | Mean Annual Combined Mortality |
|---|---|---|---|---|---|---|---|---|---|---|
| Northeast Sink Gillnet | 11–15 | Obs. Data,Weighout, Trip Logbook | .19, .15, .11, .18, .14 | 0, 0, 0, 0, 0 | 222, 91, 69, 159, 131 | 0, 0, 0, 0, 0 | 1491, 542, 1127, 917, 1021 | 1491, 542, 1127, 917, 1021 | .22, .19, .20, .14, .25 | 1020 (0.10) |
| Mid-Atlantic Gillnet | 11–15 | Obs. Data, Trip Logbook, Allocated Dealer Data | .02, .02, .03, .05, .06 | 0, 0, 0, 0, 0 | 2, 1, 0, 1, 1 | 0, 0, 0, 0, 0 | 19, 14, 0, 22, 15 | 19, 14, 0, 22, 15 | .60, .98, 0, 1.09, 1.04 | 14 (0.48) |
| Northeast Bottom Trawl | 11–15 | Obs. Data,Trip Logbook | .26, 17, .15, .17, .19 | 0, 0, 0, 0, 0 | 19, 8, 5, 4, 2 | 0, 0, 0, 0, 0 | 58, 37, 20, 19, 23 | 58, 37, 20, 19, 23 | .25, .49, .37, .45, .46 | 31 (0.16) |
| Mid-Atlantic Bottom Trawl | 11–15 | Obs. Data,Trip Logbook | .08, .05, .06, .08, .09 | 0, 0, 0, 0, 0 | 3, 1, 2, 1, 0 | 0, 0, 0, 0, 0 | 38, 42, 25, 7, 0 | 38, 42, 25, 7, 0 | .54, .96, .67, .96, 0 | 22 (0.43) |
| Northeast Mid-water Trawl - Including Pair Trawl | 11–15 | Obs. Data, Trip Logbook | .41, .45, .37, .42, .08 | 0, 0, 0, 0, 0 | 0, 1, 1, 0, 0 | 0, 0, 0, 0, 0 | 0, na, na, 0, 0 | 0, na, na, 0, 0 | 0, na, na, 0, 0 | 0.4 (na) [d] |
| TOTAL | | | | | | | | | | 1,088 (0.09) |

a. Observer data (Obs. Data) are used to measure bycatch rates, and the data are collected within the Northeast Fisheries Observer Program. The Northeast Fisheries Observer Program 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 multispecies 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. North Atlantic bottom trawl mid-Atlantic bottom trawl, and mid-Atlantic mid-water trawl fishery coverages are ratios based on trips. Total observer coverage reported for bottom trawl gear and gillnet gear includes traditional fisheries observers in addition to fishery monitors through the Northeast Fisheries Observer Program (NEFOP).

c. Serious injuries were evaluated for the 2011–2015 period (Josephson *et al.* 2017)

**Other Mortality**
**U.S.**

Gray seals, like harbor seals, were hunted for bounty in New England waters until the late 1960s (Katona *et al.* 1993; Lelli *et al*. 2009). This hunt may have severely depleted this stock in U.S. waters (Rough 1995; Lelli *et al*. 2009). Other sources of mortality include human interactions, storms, abandonment by the mother, disease, and shark predation. Mortalities caused by human interactions include research mortalities, boat strikes, fishing gear interactions, power plant entrainment, oil spill/exposure, harassment, and shooting. Seals entangled in netting have been reported at several major haul-out sites in the Gulf of Maine.

From 2011 to 2015, 570 gray seal stranding mortalities were recorded, extending from Maine to North Carolina (Table 4; NOAA National Marine Mammal Health and Stranding Response Database, accessed 16 September 2016). Most stranding mortalities were in Massachusetts, which is the center of gray seal abundance in U.S. waters. Sixty-nine (12%) of the total stranding mortalities showed signs of human interaction (20 in 2011, 4 in 2012, 17 in 2013, 8 in 2014, and 20 in 2015), 32 of which had some indication of fishery interaction (5 in 2011, 2 in 2012, 9 in 2013, 2 in 2014, and 14 in 2015). Eight gray seals are recorded in the stranding database during the 2011 to 2015 period as having been shot—7 in Massachusetts in 2011, none in 2012–2014, and 1 in Maine in 2015. 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 45% of gray seal stranding mortalities were attributed to human interaction.

**CANADA**

Between 2011 and 2015, the average annual human-caused mortality and serious injury to gray seals in Canadian waters from commercial harvest was 308 per year (http://www.dfo-mpo.gc.ca/fm-gp/seal-phoque/statistics-eng.htm accessed 1/4/2017), though more are permitted (up to 60,000 seals/year, see http://www.dfo-mpo.gc.ca/decisions/fm-2015-gp/atl-001-eng.htm). This included: 195 in 2011, 8 in 2012, 243 in 2013, 82 in 2014 and 1,145 in 2015. In addition, between 2011 and 2015, an average of 3,674 nuisance animals per year were killed. This included 1,722 in 2011, 5,428 in 2012, and 3,757 in 2013, 3,732 in 2014 and 3,732 in 2015 (DFO 2017). Lastly, DFO took 320 animals in 2011, 159 animals in 2012, 58 animals in 2013, 83 animals in 2014, and 42 animals in 2015 for scientific collections, for an annual average of 132 (DFO 2017).

Table 4. Gray seal (*Halichoerus grypus atlantica*) stranding mortalities along the U.S. Atlantic coast (2011-2015) with subtotals of animals recorded as pups in parentheses.

| State | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|
| ME | 4 (2) | 10 (2) | 9 (4) | 3 (1) | 5 | 31 |
| NH | 8 (1) | 1 (1) | 1 (0) | 3 (2) | 2 | 15 |
| MA | 89 (14) | 38 (21) | 82 (8) | 62 (6) | 77 (3) | 348 |
| RI | 14 (2) | 13 (5) | 11 (2) | 8 (1) | 7 (1) | 53 |
| CT | 2 (0) | 0 | 0 | 0 | 0 | 2 |
| NY | 22 (6) | 5 (3) | 18 (5) | 7 (4) | 10 | 67 |
| NJ | 10 (0) | 4 (0) | 7 (2) | 7 (6) | 7 (6) | 35 |

| | | | | | | |
|---|---|---|---|---|---|---|
| DE | 0 | 0 | 0 | 3 (3) | 3 (3) | 6 |
| MD | 4 (2) | 0 | 0 | 1 (0) | 0 | 5 |
| VA | 1 (0) | 0 | 0 | 0 | 3 | 4 |
| NC | 2 (2) | 0 | 0 | 2 (2) | 0 | 4 |
| Total | 156 (29) | 71 (32) | 128 (21) | 96 (25) | 114 | 570 |
| Unspecified seals (all states) | 63 | 28 | 25 | 38 | 31 | 176 |

**STATUS OF STOCK**

Gray 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 2011–2015 average annual human-caused mortality and serious injury does not exceed the portion of PBR in U.S. waters. The status of the gray seal population relative to OSP in U.S. Atlantic EEZ waters is unknown, but the stock's abundance appears to be increasing in Canadian and U.S. waters. 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.

Uncertainties described in the above sections could have an effect on the designation of the status of this stock in U.S waters.

**REFERENCES CITED**


Barlas, M.E. 1999. The distribution and abundance of harbor seals (*Phoca vitulina concolor)* and gray seals (*Halichoerus grypus*) in southern New England, winter 1998-summer 1999. M.A. thesis. Graduate School of Arts and Sciences Boston University, Boston, MA. 52 pp.

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. 73 pp.

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.

Bonner, W.N. 1981. Grey seal *Halichoerus grypus* Fabricus, 1791. Pages 111–144 *in*: S.H. Ridgway and R.J. Harrison, (eds.) Handbook of marine mammals, Vol. 2: Seals. Academic Press, London, UK.

Boskovic, R., K.M. Kovacs, M.O. Hammill and B.N. White. 1996. Geographic distribution of mitochondrial DNA haplotypes in grey seals (*Halichoerus grypus*). Can. J. Zool. 74:1787–1796.

Bowen, W.D., J. McMillan and R. Mohn. 2003. Sustained exponential population growth of grey seals at Sable Island, Nova Scotia. ICES J. Mar. Sci. 60:1265–1274.

Bowen, W.D., J.I. McMillan and W. Blanchard. 2007. Reduced population growth of gray seals at Sable Island: Evidence from pup production and age of primiparity. Mar. Mamm. Sci. 23:48-64.

Bowen, W.D., C. den Heyer, J.I. McMillan, and M.O. Hammill. 2011. Pup production at Scotian Shelf grey seal (*Halichoerus grypus*) colonies in 2010. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/066: vi + 25pp.

Bravington, M.V. and K.D. Bisack. 1996. Estimates of harbour porpoise bycatch in the Gulf of Maine sink gillnet fishery, 1990-1993. Rep. Int. Whal. Comm. 46:567–574.

Breed, G.A., W.D. Bowen, J.I. McMillan and M.L. Leonard. 2006. Sexual segregation of seasonal foraging habitats in a non-migratory marine mammal. Proc. Royal Soc. B 273:*2319*–2326.

Breed, G.A., I.D. Jonsen, R.A. Myers, W.D. Bowen, and M.L. Leonard. 2009. Sex-specific, seasonal foraging tactics of adult grey seals (*Halichoerus grypus*) revealed by state--space analysis. Ecology 90:3209–3221.

Chavez-Rosales, S., M.C. Lyssikatos, and J. Hatch. 2017. Estimates of cetacean and pinniped bycatch in northeast and mid-Atlantic bottom trawl fisheries, 2011-2015. Northeast Fish. Sci. Cent. Ref. Doc. 17-16. 18 pp.

Davies, J.L. 1957. The geography of the gray seal. J. Mamm. 38:297-310.

deHart, P.A.P. 2002. The distribution and abundance of harbor seals (*Phoca vitulina concolor)* in the Woods Hole region. M.A. thesis. Graduate School of Arts and Sciences, Boston University, Boston, MA. 88 pp.

den Heyer, C.E., Lang, S.L.C., Bowen, W.D., and Hammill, M.O. 2017. Pup production at Scotian Shelf grey seal (*Halichoerus grypus*) colonies in 2016. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/056. v + 34 p.DFO [Dept. of Fisheries and Oceans]. 2011. Stock assessment of Northwest Atlantic grey seals (*Halichoerus grypus*), Can. Sci. Advis. Sec. Advis. Rep. 2010/091 12 pp.

DFO [Dept. of Fisheries and Oceans]. 2013. Stock assessment of Northwest Atlantic grey seals (*Halichoerus grypus*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/008 11 pp

DFO [Dept. of Fisheries and Oceans]. 2014. Stock assessment of Canadian grey seals (*Halichoerus grypus*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/010 13 pp.

DFO [Dept. of Fisheries and Oceans]. 2017. Stock assessment of Canadian Northwest Atlantic grey seals (*Halichoerus grypus*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2017/045 13 pp.

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.

Hammill, M.O. 2005. Abundance of Northwest Atlantic grey seals in the Gulf of St. Lawrence and along the Nova Scotia eastern shore. DFO Research Document 2005/036. Canadian Department of Fisheries and Oceans. Ottawa, Ontario, Canada.11pp.http://www.dfo-mpo.gc.ca/csas/Csas/Publications/ResDocs-DocRech/2005/2005_036_e.

Hammill, M.O. and J.F. Gosselin. 2005. Pup production of non-Sable Island grey seals in 2004. DFO Research Document 2005/036. Canadian Department of Fisheries and Oceans. Ottawa, Ontario. 20 pp. http://www.dfo-mpo.gc.ca/csas/Csas/Publications/ResDocs-DocRech/2005/2005_033_e.htm.

Harvey, V., S.D. Côté, and M.O. Hammill 2008. The ecology of 3-D space use in a sexually dimorphic mammal. Ecography 31:371–380.

Harwood, J. and J.H. Prime. 1978. Some factors affecting the size of British grey seal populations. J. Appl. Ecol. 15: 401-411.

Hatch, J.M. and C.D. Orphanides 2014. Estimates of cetacean and pinniped bycatch in the 2012 New England sink and mid-Atlantic gillnet fisheries. Northeast Fish Sci Cent Ref Doc.14-02. 20 pp.
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. 33 pp.
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. 22 pp.
Haug T, M.O. Hammill, and D. Ólafsdóttir, eds. 2007. Grey seals in the North Atlantic and the Baltic. NAMMCO Scientific Publications 6: 7–12.
Josephson, E. Wenzel F, M.C. Lyssikatos. 2017. Serious injury determinations for small cetaceans and pinnipeds caught in commercial fisheries off the northeast U.S. coast, 2011-2015. Northeast Fish. Sci. Cent. Ref. Doc. 17-15. 32 pp.
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. 316 pp.
Klimova, A., C.D. Phillips, K. Fietz, M.T. Olsen, J. Harwood, W. Amos, and J.I. Hoffman 2014. Global population structure and demographic history of the grey seal. Mol. Ecol. 23(16):3999–4017.
Laviguer, L. and M.O. Hammill. 1993. Distribution and seasonal movements of grey seals, *Halichoerus grypus*, born in the Gulf of St. Lawrence and eastern Nova Scotia shore. Can. Field-Nat. 107:329–340.
Lesage, V. and M.O. Hammill. 2001. The status of the grey seal, *Halichoerus grypus*, in the Northwest Atlantic. Can. Field-Nat. 115:653–662.
Lelli, B., D.E. Harris, and A-M Aboueissa. 2009. Seal bounties in Maine and Massachusetts, 1888 to 1962. Northeast. Nat. 16:239–254.
Mansfield, A.W. 1966. The grey seal in eastern Canadian waters. Can. Audubon Mag. 28:161–166.
Mohn, R. and W.D. Bowen. 1996. Grey seal predation on the eastern Scotian Shelf: Modeling the impact on Atlantic cod. Can. J. Fish. Aquat. Sci 53:2722–2738.
Olsen, M.T., A. Galatius, V. Biard, K. Gregersen, and C.C. Kinze. 2016. The forgotten type specimen of the grey seal [*Halichoerus grypus* (Fabricius, 1791)] from the island of Amager, Denmark. Zoo. J. Linnean Soc. 178:713–720.
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. 21 pp.
Puryear, W.B., M. Keogh, N. Hill, J. Moxley, E. Josephson, K.R. Davis, C. B**a**ndoro, D. Lidgard, A. Bogomolni, M.Levin, S. Lang, M. Hammill, D. Bowen, D.W Johnston, T. Romano, G.Waring, and J. Runstadler. 2016. Prevalence of influenza A virus in live-captured North Atlantic gray seals: a possible wild reservoir. Emerg. Microbes Infect. 5:e81. doi:10.1038/emi.2016.77
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
Rough, V. 1995. Gray seals in Nantucket Sound, Massachusetts, winter and spring, 1994. Final report to Marine Mammal Commission. Contract T10155615 28 pp.
Stobo, W.T. and K.C.T. Zwanenburg. 1990. Grey seal (*Halichoerus grypus*) pup production on Sable Island and estimates of recent production in the Northwest Atlantic. Pages 171–184 *in*: W. D. Bowen, (ed.) Population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts. Can. Bull. Fish. Aquat. Sci. 222.
Thomas, L., M.O. Hammill, and W.D. Bowen. 2011. Estimated size of the Northwest Atlantic grey seal population, Can. Sci. Advis. Sec. Res. Doc. 2011/017 23 pp.
Trzcinski, M.K., R. Mohn and W.D. Bowen. 2005. Estimation of grey seal population size and trends at Sable Island. DFO Research Document 2005/067. Canadian Department of Fisheries and Oceans. Ottawa, Ontario, Canada. 10pp. http://www.dfo-mpo.gc.ca/csas/Csas/Publications/ResDocs-DocRech/2005/2005_067_e.htm
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. 93 pp.
Wood LaFond, S. 2009. Dynamics of recolonization: a study of the gray seal (*Halichoerus grypus*) in the northeast U.S. Ph.D. dissertation. University of Massachusetts, Boston, MA. 83 p.
Wood, S.A., S. Brault and J.R. Gilbert. 2007. 2002 aerial survey of grey seals in the northeastern United States. Pages 117–121 *in*: T. Haug, M. Hammill and D. Ólafsdóttir, (eds.) Grey seals in the North Atlantic and Baltic. NAMMCO Sci. Pub. 6, Tromsø, Norway.

Wood, S.A., T.R. Frasier, B.A. McLeod, J.R. Gilbert, B.N. White, W.D. Bowen, M.O. Hammill, G.T. Waring, and S. Brault. 2011. The genetics of recolonization: an analysis of the stock structure of grey seals (*Halichoerus grypus*) in the Northwest Atlantic. Can. J. Zool. 89:490–497.