May 2016

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

STOCK DEFINITION AND GEOGRAPHIC RANGE

The gray seal (*Halichoerus grypus grypus*) is found on both sides of the North Atlantic, with three major populations: eastern Canada, northwestern Europe and the Baltic Sea (Katona *et al.* 1993). The western North Atlantic stock is equivalent to the eastern Canada 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 herds in eastern Canada: Sable Island, Gulf of St. Lawrence, and 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, Hammill, pers. comm. DFO, Mont-Joli, Quebec, Canada) 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 the late 1990s, a year-round breeding population of approximately 400+ animals was documented on outer Cape Cod and Muskeget Island (D. Murley, pers. comm., Mass. Audubon Society, Wellfleet, MA). 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). To assess the stock structure of gray seals in the northwest Atlantic, tissue samples were collected from Canadian and US populations for genetic analyses (Wood et al. 2011). Based on examination of nine highly variable microsatellite loci, all individuals were placed into one population. This provides additional confirmation that recolonization by Canadian gray seals is the source of the U.S. population.

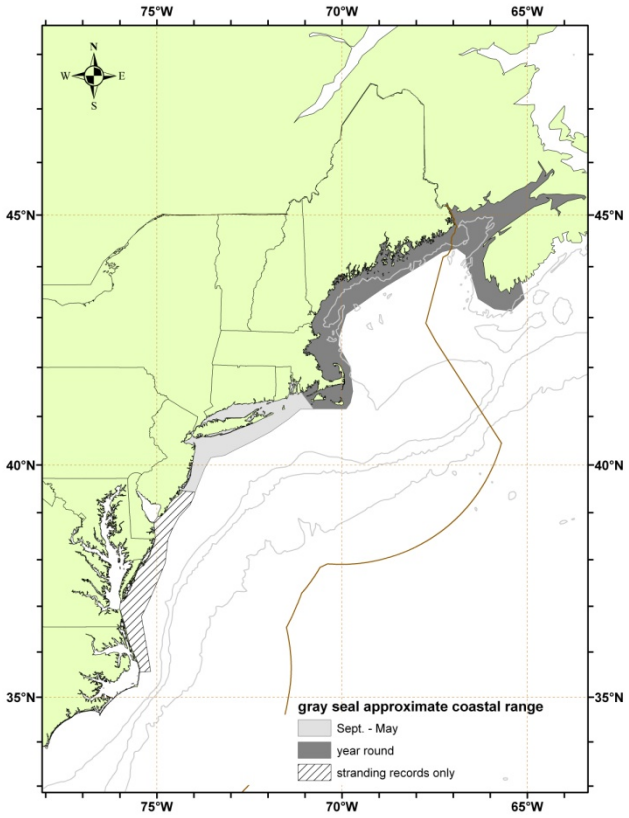

Figure 1. Approximate coastal range of gray seals. Isobaths are the 100-m, 1000-m, and 4000-m depth contours.

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. The Canadian gray seal stock assessment (DFO 2014) reports gray seal pup production in 2014 for the three Canadian herds (Gulf of St. Lawrence, Sable Island, and Nova Scotia) as 93,000 (95%CI=48,000-137,000) animals, and total population levels of 505,000 (95%CI=329,000-682,000) animals.

In U.S. waters, gray seals currently pup at four established colonies: Muskeget Island and Monomoy Island in Massachusetts, and Green and, Seal Islands in Maine. Although white-coated pups have stranded on eastern Long Island beaches, 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. A minimum of 2,620 pups (Muskeget= 2,095, Green= 59, Seal= 466) were born in the U.S. in 2008 (Wood LaFond 2009). Table 2 summarizes single-day pup counts from three of the U.S. pupping colonies from 2001/2002 to 2007/2008 pupping periods. The decrease in pup counts in some years is an artifact of survey timing and not indicative of true declines in those years. Additionally, minima of 2,750 and 3,037 pups were counted on Muskeget Island in 2013 and 2014, respectively. In recent years NMFS monitoring surveys have detected an increase in pupping, (i.e., from tens to hundreds) on Monomoy. Further, occasional mother/pup (white coats) pairs have been photographed on Nomans Land in Massachusetts. Some of the local breeders have been observed with brands and tags indicating they had been born on Sable Island, Canada (Rough 1995; L. Sette, pers. comm.). The increase in the number of gray seals observed in the U.S. is probably due to both natural increase and immigration.

Gray seals are also observed in New England outside of the pupping season. In April–May 1994 a maximum count of 2,010 was obtained for Muskeget Island and Monomoy combined (Rough 1995). Maine coast-wide surveys conducted during summer revealed 597 and 1,731 gray seals in 1993 and 2001, respectively (Gilbert *et al.* 2005). In March 1999 a maximum count of 5,611 was obtained in the region south of Maine (between Isles of Shoals, Maine and Woods Hole, Massachusetts) (Barlas 1999). In March 2011 a maximum count of 15,756 was obtained in southeastern Massachusetts coastal waters (NMFS unpubl. data). No gray seals were recorded at haul-out sites between Newport, Rhode Island and Montauk Point, New York (Barlas 1999), currently several hundred gray seals have been recorded in surveys conducted off eastern Long Island (R. DiGiovanni, pers. comm).

Table 1. Summary of recent abundance estimates for the western North Atlantic gray seal (*Halichoerus grypus grypus*) by year, and area covered during each abundance survey, 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

[a]These are model based estimates derived from pup surveys.
[b] DFO 2013
[c] DFO 2014

Table 2. The number of pups observed on Muskeget, Seal, and Green Islands 2002–2008. Data are from aerial surveys[1, 2]. These are single-day counts, not estimates of total pup production (Wood LaFond 2009).

Pupping Season	Muskeget Island	Seal Island	Green Island
2001-2	883	No data	34
2002-3	509	147	No data
2003-4	824	150	26
2004-5	992	365	33
2005-6	868	239	43
2006-7	1704	364	57
2007-8	2095	466	59
2012-13[1]	2750		
2013-14[1]	3037		

1 Survey data for the 2008–9 through 2011–2 seasons have not been counted.

Minimum Population Estimate

Based on modeling, the total Canadian gray seal population was estimated to be 505,000 (95% CI = 329,000-682,000) (DFO 2014) . Present data are insufficient to calculate the minimum population estimate for U.S. waters.

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). Recent population modeling indicates that the combined population increased at an annual rate of 5.2% between 2007 and 2010, and since has continued to grow at a rate of 4.5% per year (DFO 2011, 2014). The non-Sable Island population increased from approximately 25,000 in the mid-1980s to a peak of 112,000 in 2014 (Thomas *et al.* 2011; DFO 2014). Modeling estimates of pup production increased from approximately 6,000 in 1985 to 21,500 in 2014 (Thomas *et al.* 2011; DFO 2014). Approximately 75% of the western North Atlantic population is from the Sable Island stock. In the early 1990s pupping was established on Hay Island, off the Cape Breton coast (Lesage and Hammill 2001; Hammill *et al*. 2007, Hamill and Stenson 2010).

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 herds 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).

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 unknown. 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 gray seals in U.S. waters is unknown.

ANNUAL HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

For the period 2009–2013, the total estimated human caused mortality and serious injury to gray seals was 5,004 per year. The average was derived from five components: 1) 1193.4 (CV=0.11) (Table 3) from the 2009–2013 U.S. observed fishery; 2) 7.6 from average 2009–2013 non-fishery related, human interaction stranding mortalities (NMFS unpublished data); 3) 172 from average 2009–2013 kill in the Canadian hunt (DFO 2014)*;* 4) 82 from DFO scientific collections (DFO 2011); and 5) 3,549 removals of nuisance animals in Canada (DFO 2014). Analysis of bycatch rates from fisheries observer program records likely greatly under-represents sub-lethal fishery interactions. Photographic analysis of gray seals at haulout sites on Cape Cod, Massachusetts revealed 5-8% of seals exhibited signs of entanglement (Sette *et al.* 2009).

Fishery Information

Detailed fishery information is given in Appendix III.

U.S.

Northeast Sink Gillnet

Gray seal bycatch in the northeast sink gillnet fishery were 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 (Orphanides 2013; Hatch and Orphanides 2014, 2015). There were 8, 7, 9, 1, and 8 unidentified seals observed during 2009–2013, 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 (Orphanides 2013; Hatch and Orphanides 2014, 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.

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 2009–2013 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.

Mid-Atlantic Mid-Water Trawl

One gray seal mortality was observed in 2010 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 2009–2013 is calculated as 0.2 animals (1 animal /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 4 gray seals were captured and released alive in 2010, 34 in 2011, 33 in 2012, and 1 in 2013. In addition, during this time period 8 seals of unknown species were captured and released alive in 2011. 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 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. No mortalities were observed prior to 2005, when four mortalities were attributed to this fishery. 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

One gray seal mortality was observed in this fishery in 2009, 2 in 2011, 1 in 2012, and 2 in 2013 (Table 2). 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). In addition to incidental catches, some mortalities (e.g., seals trapped in herring weirs) were the result of direct shooting, and there were culls of about 1,700 animals annually during the 1970s and early 1980s on Sable Island (Anonymous 1986).

Table 3. Summary of the incidental serious injury and mortality of gray seal (*Halichoerus grypus grypus*) 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[e]	Observed Mortality	Estimated Serious Injury	Estimated Mortality	Estimated Combined Mortality	Estimated CVs	Mean Annual Combined Mortality
Northeast Sink Gillnet[c]	09-13	Obs. Data,Weighout, Trip Logbook	.04, .17, .19, .15, .11	0, 0, 0, 0, 0	52, 107, 222, 91, 69	0, 0, 0, 0, 0	1063, 1155, 1491, 542, 982	1063, 1155, 1491, 542, 1,127	.26, .28, .22, .19, .20	1076 (0.11)
Mid-Atlantic Gillnet	09-13	Obs. Data, Trip Logbook, Allocated Dealer Data	.03, .04, .02, .02, .03	0, 0, 0, 0, 0	0, 9, 2, 1 ,0	0, 0, 0, 0, 0	0, 267, 19, 14, 0	0, 267, 19, 14, 0	0, .75, .60, .98, 0	60 (0.67)
Northeast Bottom Trawl [d]	09-13	Obs. Data,Trip Logbook	.09, .16, .26, 17, .15	0, 0, 0, 0, 0	5, 9, 19, 8, 5	0, 0, 0, 0, 0	22, 30, 58, 37, 20	22, 30, 58, 37, 20	.46, .34, .25, .49, .37	33.4 (0.18)
Mid-Atlantic Bottom Trawl	09-13	Obs. Data,Trip Logbook	.05, .06, .08, .05, .06	0, 0, 0, 0, 0	3, 0, 3, 1, 2	0, 0, 0, 0, 0	38, 0, 25, 30, 29	38, 0, 25, 30, 29	.7, 0, .57, 1.1, .67	24.4(0.4)
Northeast Mid-water Trawl - Including Pair Trawl	09-13	Obs. Data, Trip Logbook	.42, .53, .41, .45, .37	0, 0, 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	0.4 (na) [d]
Mid-Atlantic Mid-water Trawl - Including Pair Trawl	09-13	Obs. Data, Trip Logbook	.13, .25, .41, .21, .07	0, 0, 0, 0, 0	0, 1, 0, 0, 0	0, 0, 0, 0, 0	0, na, 0, 0, 0	0, na, 0, 0, 0	0, na, 0, 0, 0	0.2 (na)
TOTAL										1193.4 (0.11)

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 in the years 2010–2013 includes traditional fisheries observers in addition to fishery monitors through the Northeast Fisheries Observer Program (NEFOP).

c. Since 1998, takes from pingered and non-pingered nets within a marine mammal time/area closure that required pingers, and takes from pingered and non-pingered nets not within a marine mammal time/area closure were pooled. The pooled bycatch rate was weighted by the total number of samples taken from the stratum and used to estimate the mortality. In 2009–2013, respectively, 13, 17, 125, 54 and 38 takes were observed in nets with pingers. In 2009 -2013, respectively, 27, 39, 90, 97, 10 and 31 takes were observed in nets without pingers.

d. Fishery related bycatch rates for years 2009–2013 were estimated using an annual stratified ratio-estimator. These estimates replace the 2008-2011 annual estimates reported in the 2013 stock assessment report that were generated using a different method.

e. Serious injuries were evaluated for the 2009–2013 period using new guidelines (Waring *et al.* 2014, 2015; Wenzel *et al.* 2015)

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 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 2009 to 2013 521 gray seal stranding mortalities were recorded, extending from Maine to North Carolina (Table 4; NOAA National Marine Mammal Health and Stranding Response Database unpublished data, accessed 20 August 2014). Most stranding mortalities were in Massachusetts, which is the center of gray seal abundance in U.S. waters. Sixty-seven (13%) of the total stranding mortalities showed signs of human interaction (14 in 2009, 12 in 2010, 20 in 2011, 4 in 2012, and 17 in 2013), 29 of which had some indication of fishery interaction (9 in 2009, 4 in 2010, 5 in 2011, 2 in 2012, and 9 in 2013). Ten gray seals are recorded in the NE stranding database during the 2009 to 2013 period as having been shot—1 in Maine in 2009, 1 in Maine and 2 in Massachusetts in 2010, 6 in Massachusetts in 2011, and none in 2012 or 2013.

CANADA

There is a small commercial harvest of gray seals in the Gulf of St. Lawrence and Nova Scotia. During the 2009–2013 period, commercial harvest statistics were as follows: 263 removals in 2009, 58 in 2010, 215 in 2011, 218 in 2012, and 106 in 2013 (DFO 2014). Further, between 2009 and 2013 the lethal removal of nuisance seals was: 2009 (5,218), 2010 (1,853), 2011 (1,722), 2012 (5,428), and 2013 (3,525) (DFO 2014).

For scientific collections, DFO took 320 animals in 2011 and 90 animals in 2012 (DFO 2014).

Table 4. Gray seal (*Halichoerus grypus grypus*) stranding mortalities [a] along the U.S. Atlantic coast (2009–2013) with subtotals of animals recorded as pups in parentheses.

State	2009	2010	2011	2012	2013	Total
Maine	3	8 (4)	4 (2)	10 (2)	9 (4)	34
New Hamphire	1 (1)	0	8 (1)	1 (1)	1 (0)	11
Massachusetts	52 (7)	43 (5)	89 (14)	38 (21)	82 (8)	303
Rhode Island	10 (2)	8 (3)	14 (2)	13 (5)	11 (2)	56
Connecticut	1(1)	0	2 (0)	0	0	3
New York	16 (7)	10 (7)	22 (6)	5 (3)	18 (5)	71
New Jersey	4 (0)	4 (1)	10 (0)	4 (0)	7 (2)	29
Maryland	1 (0)	1 (0)	4 (2)	0	0	6
Virginia	2 (0)	1 (0)	1 (0)	0	0	4
North Carolina	1 (1)	1 (0)	2 (2)	0	0	4
Total	91 (19)	76 (20)	156 (29)	71 (32)	128 (21)	521
Unspecified seals (all states)	34	22	63	28	25	172

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 level of human-caused mortality and serious injury in the U.S. Atlantic EEZ is low relative to the total stock size. 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. The total U.S. fishery-related mortality and serious injury for this stock is

low relative to the stock size in Canadian and U.S. waters and can be considered insignificant and approaching zero mortality and serious injury rate.

REFERENCES CITED

Anonymous. 1986. Seals and sealing in Canada. Rep. of the Royal Commission on Seals and Sealing, Vol. 1. Canadian Government Publishing Centre, Ottawa, Ontario, Canada, 65 pp.

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.

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.

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.

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(11):3209–3221.

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.

DFO 2011. Stock assessment of Northwest Atlantic grey seals (*Halichoerus grypus*), Canadian Science Advisory Secretariat (CSAS) Res. Doc. 2010/091 12 pp.

DFO, 2013. Stock assessment of Canadian grey seals (*Halichoerus grypus*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/008

DFO, 2014. Stock assessment of Canadian grey seals (*Halichoerus grypus*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/010

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.

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.

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. 11 pp. 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

Hammill, M. O., J. W. Lawson, G. B. Stenson, and D. Ligard 2007. Pup production of Northwest Atlantic grey seals in the gulf of St. Lawrence and along the Nova Scotia Eastern Shore. Canadian Science Advisory Secretariat (CSAS) Res. Doc. 2007/084.

Hammill, M. O., and G. B. Stenson 2010. Pup production of Northwest Atlantic grey seals in the Gulf of St. Lawrence, Canadian Science Advisory Secretariat (CSAS) Res. Doc. 2010/122

Hammill, M.O., W.D.Bowen, and C. den Heyer. 2012. Northwest Atlantic grey seal population trends, 1960-2012. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/169. iv + 35 p. available at http://www.dfo-mpo.gc.ca/csas.

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

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(4): 653-662.

Lelli, B., D.E. Harris, and A-M Aboueissa. 2009. Seal bounties in Maine and Massachusetts, 1888 to 1962. Northeast. Nat. 16(2): 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.

Orphanides, C. D. 2013. Estimates of cetacean and pinniped bycatch during 2010 and 2011 in the New England Sink Gillnet fishery, Mid-Atlantic Gillnet fishery, and two NMFS gillnet experiments. Northeast Fish Sci Cent Ref Doc. 13-13 38 pp. Available at: http://nefsc.noaa.gov/publications/crd/crd1313/.

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.

Sette, L. A., G. T. Waring, K. Touhey, S. Sharp, B. Sharp, and S. Landry. 2009. Photographic surveys of entanglement occurrence at grey seal (*Halichoerus grypus*) and harbor seal (*Phoca vitulina*) haul-outs on Cape Cod, Massachusetts. Poster presentation, 18th Biennial Conference on the Biology of Marine Mammals

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, Canadian Science Advisory Secretariat (CSAS) 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.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.

Waring, G.T., M. Rossman and F. Wenzel. 2014 Serious injury determinations for small cetaceans and pinnipeds caught in commercial fisheries off the northeast U.S. Coast, 2007-2011. Northeast Fish. Sci. Cent. Ref. Doc. 14-13. 32 pp.

Waring, G.T., M. Lyssikatos and F. Wenzel. 2015. Serious injury determinations for small cetaceans and pinnipeds caught in commercial fisheries off the northeast U.S. Coast, 2012. Northeast Fish. Sci. Cent. Ref. Doc. 15-12. 19 pp.

Wenzel, F., Waring, G.T., E. Josephson, M.C. Lyssikatos, B.L. Byrd, S.C. Horstman, and J.R. Powell. 2015. Serious injury determinations for small cetaceans and pinnipeds caught in commercial fisheries off the northeast U.S. coast, 2013. NOAA Tech. Memo. NMFS-NE-236. 36 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. 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.