HUMPBACK WHALE (*Megaptera novaeangliae*): Gulf of Maine Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

In the western North Atlantic, humpback whales feed during spring, summer and fall over a geographic range encompassing the eastern coast of the United States (including the Gulf of Maine), the Gulf of St. Lawrence, Newfoundland/Labrador, and western Greenland (Katona and Beard 1990). Other North Atlantic feeding grounds occur off Iceland and in the Norwegian Sea, including off northern Norway, Bear Island, Jan Mayen, and Franz Josef Land (Christensen *et al.* 1992; Palsbøll *et al.* 1997). These six regions represent relatively discrete subpopulations, fidelity to which is determined matrilineally (Clapham and Mayo 1987), which is supported by studies of the mitochondrial genome (Palsbøll *et al.* 1995; Palsbøll *et al.* 2001) and individual animal movements (Stevick *et al*. 2006). During the 2002 Comprehensive Assessment of North Atlantic humpback whales, the International Whaling Commission acknowledged the evidence for treating the Gulf of Maine as a separate management unit (IWC 2002).

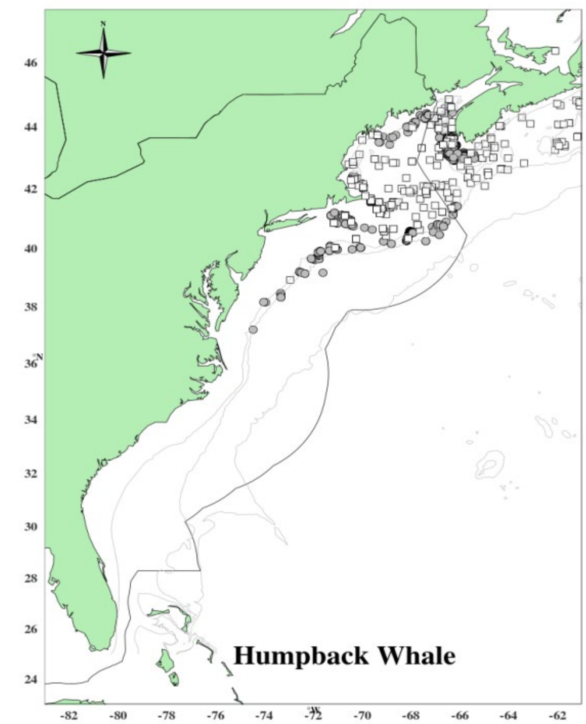

Figure 1. Distribution of humpback whale sightings from NEFSC and SEFSC shipboard and aerial surveys during the summers of 1995, 1998, 1999, 2002, 2004, 2006, 2007, 2008, 2010, 2011 and 2016. Isobaths are the 200-m, 1000-m and 4000-m depth contours. Circle symbols represent shipboard sightings and squares are aerial sightings.

During the summers of 1998 and 1999, the Northeast Fisheries Science Center conducted surveys for humpback whales on the Scotian Shelf to establish the occurrence and population identity of the animals found in this region, which lies between the well-studied populations of the Gulf of Maine and Newfoundland. Photographs from both surveys were compared to both the overall North Atlantic Humpback Whale Catalog and a large regional catalog from the Gulf of Maine (maintained by the College of the Atlantic and the Center for Coastal Studies, respectively); this work is summarized in Clapham *et al.* (2003). The match rate between the Scotian Shelf and the Gulf of Maine was 27% (14 of 52 Scotian Shelf individuals from both years). Comparable rates of exchange were obtained from the southern (28%, n=10 of 36 whales) and northern (27%, *n*=4 of 15 whales) ends of the Scotian Shelf (one whale was observed in both areas). In contrast, all of the 36 humpback whales identified by the same NMFS surveys elsewhere in the Gulf of Maine (including Georges Bank, southwestern Nova Scotia, and the Bay of Fundy) had been previously observed in the Gulf of Maine region. The sighting histories of the 14 Scotian Shelf whales matched to the Gulf of Maine suggested that many of them were transient through the latter area. There were no matches between the Scotian Shelf and any other North Atlantic feeding ground, except the Gulf of Maine; however, instructive comparisons are compromised by the often low sampling effort in other regions in recent years. Overall, it appears that the northern range of many members of the Gulf of Maine stock does not extend onto the Scotian Shelf. Some uncertainty in the stock definition for the Gulf of Maine stock of humpback whales is where along the Scotian shelf stock boundaries are drawn in a relatively contiguous range. However, exact placement of the boundary should have little effect on conservation status because the whales along the southern Scotian shelf represent a relatively small fraction of either the Gulf of Maine or Labrador stocks.

During winter, whales from most North Atlantic feeding areas (including the Gulf of Maine) mate and calve in the West Indies, where spatial and genetic mixing among feeding groups occurs (Katona and Beard 1990; Clapham *et al.* 1993; Palsbøll *et al.* 1997; Stevick *et al.* 1998; Kennedy *et al.* 2013). Some whales using eastern North Atlantic feeding areas migrate to the Cape Verde Islands (Reiner *et al.* 1996; Wenzel *et al.* 2009; Stevick *et al.* 2016), and some individuals have been recorded in both the Cape Verde Islands and the southeast Caribbean (Stevick e*t al*. 2016). In the West Indies, the majority of whales are found in the waters of the Dominican Republic, notably on Silver Bank and Navidad Bank, and in Samana Bay (Balcomb and Nichols 1982; Whitehead and Moore 1982; Mattila *et al.* 1989, 1994). Humpback whales also are found at much lower densities throughout the remainder of the Antillean arc (Winn *et al.* 1975; Levenson and Leapley 1978; Price 1985; Mattila and Clapham 1989). Although recognition of 2 breeding areas for North Atlantic humpbacks is the prevailing model, our knowledge of breeding season distribution is far from complete (see Smith and Pike 2009; Stevick *et al.* 2016).

Not all whales from this stock migrate to the West Indies every winter, because significant numbers of animals are found in mid- and high-latitude regions at this time (Clapham *et al.* 1993; Swingle *et al.* 1993) and some individuals have been sighted repeatedly within the same winter season (Clapham *et al.* 1993; Robbins 2007). Acoustic recordings made within the Massachusetts Bay area detected some level of humpback song and non-song sounds in almost all months, with two prominent periods, March through May and September through December (Clark and Clapham 2004; Vu *et al*. 2012; Murray *et al*. 2013). This pattern of acoustic occurrence, especially for song, confirms the presence of male humpback whales in the area (a mid-latitude feeding ground) during periods that bracket male occurrence in the Caribbean region, where singing is highest during winter months. A complementary pattern of humpback singer occurrence was observed during the January–May period in deep-ocean regions north and west of the Caribbean and to the east of Bermuda during April (Clark and Gagnon 2002). These acoustic observations from both coastal and deep-ocean regions support the conclusion that at least male humpbacks are seasonally distributed throughout broad regions of the western North Atlantic. In addition, photographic records from Newfoundland have shown a number of adult humpbacks remain there year-round, particularly on the island's north coast.

Within the U.S. Atlantic EEZ, humpback whales have been sighted well away from the Gulf of Maine. Sightings of humpback whales in the vicinity of the Chesapeake and Delaware Bays occurred in 1992 (Swingle *et al.* 1993). Wiley *et al.* (1995) reported that 38 humpback whale strandings occurred during 1985–1992 in the U.S. mid-Atlantic and southeastern states. Humpback whale strandings increased, particularly along the Virginia and North Carolina coasts, and most stranded animals were sexually immature; in addition, the small size of many of these whales strongly suggested that they had only recently separated from their mothers. Wiley *et al.* (1995) concluded that these mid-Atlantic areas were becoming an increasingly important habitat for juvenile humpback whales. For the period 2013–2017, there are records of 95 humpback whale strandings between Maine and Florida in the Marine Mammal Health and Stranding Response database (accessed 23 October 2018). There have also been a number of wintertime humpback sightings in coastal waters of the southeastern U.S. (Zoodsma *et al.* 2016; Surrey-Marsden *et al.* 2018) Other sightings of note include 46 sightings of humpbacks in the New York-New Jersey Harbor Estuary documented between 2011 and 2016 (Brown *et al*. 2017). Multiple humpbacks were observed feeding off Long Island during July of 2016 (https://www.greateratlantic.fisheries.noaa.gov/mediacenter/2016/july/26_humpback_whales_visit_new_york.html, accessed 28 April 2017) and there were sightings during November–December 2016 near New York City (https://www.greateratlantic.fisheries.noaa.gov/mediacenter/2016/december/09_humans_and_humpbacks_of_new_york_2.html, accessed 28 April 2017). Additional sightings occurring during summer (about July – August) along the shelf break east of New Jersey and New York during the NEFSC abundance surveys have been increasing since about 2004 (2016 survey described below, Palka 2020). Whether the increased numbers of sightings represent a distributional change, or are simply due to an increase in sighting effort and/or whale abundance, is unknown.

Stock identity of individuals observed off southeastern and mid-Atlantic states was investigated using fluke photographs of living and dead whales observed in the region (Barco *et al.* 2002). In this study, photographs of 40 whales (alive or dead) were of sufficient quality to be compared to catalogs from the Gulf of Maine (i.e., the closest feeding ground) and other areas in the North Atlantic. Of 21 live whales, 9 (43%) matched to the Gulf of Maine, 4 (19%) to Newfoundland, and 1 (4.8%) to the Gulf of St Lawrence. Of 19 dead humpbacks, 6 (31.6%) were known Gulf of Maine whales. Although the population composition of the mid-Atlantic is apparently dominated by Gulf of Maine whales, lack of photographic effort in Newfoundland makes it likely that the observed match rates under-represent the true presence of Canadian whales in the region. Barco *et al.* (2002) suggested that the mid-Atlantic region primarily represents a supplemental winter feeding ground used by humpbacks. With populations recovering, additional surveys that include photo identification and genetic sampling should be conducted to determine which stocks are currently using the mid-Atlantic region.

In New England waters, feeding is the principal activity of humpback whales, and their distribution in this region has been largely correlated to abundance of prey species, although behavior and bathymetry are factors influencing foraging strategy (Payne *et al.* 1986, 1990). Humpback whales are frequently piscivorous when in New England waters, feeding on herring (*Clupea harengus*), sand lance (*Ammodytes* spp.), and other small fishes. In the northern Gulf of Maine, euphausiids are also frequently taken (Paquet *et al.* 1997). Humpback whales were densest over the sandy shoals in the southwestern Gulf of Maine favored by the sand lance during much of the late 1970s and early 1980s, and humpback distribution appeared to have shifted to this area (Payne *et al.* 1986). An apparent reversal began in the mid-1980s, and herring and mackerel increased as sand lance again decreased (Fogarty *et al.* 1991). Humpback whale abundance in the northern Gulf of Maine increased markedly during 1992–1993, along with a major influx of herring (P. Stevick, pers. comm.). Humpback whales were few in nearshore Massachusetts waters in the 1992–1993 summer seasons. They were more abundant in the offshore waters of Cultivator Shoal, the Northeast Peak of Georges Bank, and Jeffreys Ledge; these latter areas are traditional locations of herring occurrence. In 1996 and 1997, sand lance and therefore humpback whales were once again abundant in the Stellwagen Bank area. However, unlike previous cycles, when an increase in sand lance corresponded to a decrease in herring, herring remained relatively abundant in the northern Gulf of Maine, and humpbacks correspondingly continued to occupy this portion of the habitat, where they also fed on euphausiids (Weinrich *et al.* 1997). Recent observations of humpbacks foraging along the shelf break off New York and New Jersey may be indicative of changing forage distribution**.**

POPULATION SIZE

The best abundance estimate available for the Gulf of Maine humpback whale stock is 1,396 (95% credible intervals 1363−1429). This is based on a state-space model of the sighting histories of individual whales identified using photo-identification techniques (Pace *et al.* 2017). Sightings histories were constructed from the photo-ID recapture data through October 2016. The median abundance value was produced using a hierarchical, state-space Bayesian open population model of these histories.

Gulf of Maine stock - Earlier estimates

Please see Appendix IV for earlier estimates. As recommended in the 2016 guidelines for preparing stock assessment reports (NMFS 2016), estimates older than eight years are deemed unreliable and should not be used for PBR determinations.

Gulf of Maine Stock - Recent surveys and abundance estimates

Humpback whales are uniquely identifiable based primarily on coloration patterns of the ventral side of the fluke and identification can be augmented by other features such as dorsal fin shape, scars and genetic data (Smith *et al.* 1999). A recent count of the minimum number alive (MNA) for 2015 was produced by counting the number of unique individuals seen in 2015 in the Gulf of Maine stock area as well as seen both before and after 2015 (data provided by J. Robbins, Center for Coastal Studies, Provincetown, MA, USA). The humpback MNA for 2015 was 896 and includes not only cataloged whales but some calves born in 2015 but not yet identifiable. By comparison, an abundance of 335 (CV=0.42) humpback whales was estimated from a line-transect survey conducted during June–August 2011 by ship and plane (Palka 2012). The aerial portion that contributed to the abundance estimate covered 5,313 km of tracklines over waters north of New Jersey and shallower than the 100-m depth contour through the U.S. and Canadian Gulf of Maine and up to and including the lower Bay of Fundy. The shipboard portion covered 3,107 km of tracklines in waters deeper than the 100-m depth contour out to beyond the U.S. EEZ. Both sighting platforms used a two-simultaneous-team data collection procedure, which allows estimation of abundance corrected for perception bias (Laake and Borchers 2004). Estimation of abundance was based on the independent-observer approach assuming point independence (Laake and Borchers 2004) and calculated using the mark-recapture distance sampling option in the computer program Distance (version 6.0, release 2, Thomas *et al.* 2009). This estimate did not include the portion of the Scotian Shelf that is known to be part of the range used by Gulf of Maine humpback whales. This estimate should not be compared to previous estimates that were derived using a different methodology. The now-outdated estimate of 823 humpbacks in the Gulf of Maine and Bay of Fundy in 2008 was based on a minimum number alive calculation. While that type of estimate is generally more accurate than one derived from line-transect survey, the 2016 GAMMS guidelines (NMFS 2016) notes the decline of confidence in the reliability of abundance estimates older than eight years. For this report, two new independent estimates are available from different methods- one based upon ship and aerial line transect surveys, and a second from applying mark and recapture methods to photo identification records from the J. Robbins studies (Robbins and Pace 2018).

An abundance estimate of 2,368 (CV=0.48) humpback whales was generated from a shipboard and aerial survey conducted during 27 June–28 September 2016 (Figure 2, Palka 2020) in a region covering 425,192 km^2. The aerial portion covered 11,782 km of tracklines that were over waters north of New Jersey from the coastline to the 100 m depth contour, throughout the U.S. waters. The shipboard portion covered 4,351 km of tracklines that were in waters offshore of central Virginia to Massachusetts (waters that were deeper than the 100 m depth contour out to beyond the outer limit of the U.S. EEZ). Both sighting platforms used a two-team data collection procedure, which allows estimation of abundance to correct for perception bias of the detected species (Laake and Borchers 2004) using standard mark-recapture distance sampling with covariates to assist in defining the detection function. The estimates were also corrected for availability bias which was estimated from dive patterns recorded from tagged humpbacks. The abundance resulting from the aerial survey in the U.S. portion of the Gulf of Maine was 1,372 (CV=0.70), where the availability bias correction factor was 1.541 (CV=0.185); thus, the uncorrected abundance was 890 (CV=0.68). The abundance resulting from the shipboard survey on the shelf break was 996 (CV=0.59), where the availability bias correction factor was 1.0.

Abundance estimates of 8,439 (CV=0.49) for the Newfoundland/Labrador portion and 1,854 (CV=0.40) for the Bay of Fundy/Scotian Shelf/Gulf of St. Lawrence portion were generated from the Canadian Northwest Atlantic International Sightings Survey (NAISS) survey conducted in August–September 2016. This large-scale aerial survey covered Atlantic Canadian shelf and shelf break habitats from the northern tip of Labrador to the U.S border off southern Nova Scotia (Lawson and Gosselin 2018). Line-transect density and abundance analyses were completed using Distance 7.1 release 1 (Thomas *et al*. 2010).

According to Clapham *et al.* (2003), and as has been done in previous Stock Assessment Reports, the abundance of the Gulf of Maine humpback whale when derived from visual sighting survey data would consist of those from the U.S. waters (2,368 (CV=0.48)) plus 2/3 of the humpback whales in the Canadian Bay of Fundy and Scotian shelf up to about Halifax, Nova Scotia. The Canadian portion of the Gulf of Maine stock has not been estimated, though the number of sightings of Gulf of Maine humpbacks from the Canadian 2016 NAISS survey are approximately 0.6 of the Bay of Fundy/Scotian Shelf/Gulf of St. Lawrence portion of the Canadian 2016 NAISS estimate reported above. Based on this, one might estimate 742 ($\approx$ 1854 * 2/3 * 0.6) for the Canadian portion of the Gulf of Maine humpback population by line transect methodology as a rough number to add to the estimate from U.S. waters.

As an alternative approach to estimating whale abundance, we analyzed the photo-identification database (Robbins and Pace 2018) and applied mark and recapture methods using a state-space model of the sighting histories of individual whales following the methodology described in Pace et al. 2017.

Sightings histories of Gulf of Maine humpback whales were constructed from the photo-ID recapture database as it existed in April 2019. The data were provided by an annual spatially arranged survey dedicated to gathering photo-id data on Gulf of Maine humpbacks. The estimation process was greatly enhanced by using photographic captures from sources other than the primary survey including additional research efforts by the principal survey team but outside of the dedicated survey effort, other cetacean research groups, and cooperating whale watch vessels. These later data were used to inform the known state matrix. All sightings from the primary survey were bounded by the hatched area noted on Figure 2 for capture-mark-recapture (CMR) sampling strata. A hierarchical, state-space Bayesian open population model of these histories produced a median abundance value of 1,396 individuals (95% credible intervals 1363−1429). As with any statistically-based estimation process, uncertainties exist in the estimation of abundance because it is based on a probabilistic model that makes certain assumptions about the data structure. Because the statistically-based uncertainty is asymmetric about N, the credible interval is used above to characterize that uncertainty (as opposed to a CV that may appear in other stock assessment reports).

The CMR estimate of 1,396 stands as the best available estimate for this stock assessment report for several reasons. First it is in agreement with updated line transect survey estimate of 2,368, which has a large CV that ranges from 5,781 to 970. Second, the CMR estimate provides a tighter confidence interval and therefore is more precise. Third, the long term nature of the CMR database enabled the calculation of historical annual population estimates backwards in time through 2000, thus allowing trend analysis. Furthermore, humpback whales meet the key criteria for applying mark and recapture methodology as an animal with an established stock and home-range that is also uniquely identifiable. There is some spatial difference in sampling strata between the CMR and Line transect survey, which result in the CMR estimate better representing the population abundance. The line transect estimate is most accurate when fully sampling the defined seasonal range of the stock. The current estimate includes many sightings from the continental shelf areas east of New York and New Jersey. While, this region is typically included for the Gulf of Maine stock particularly when assigning cases of anthropogenic mortality, further research is required to confirm that surveys south of the Gulf of Maine might detect animals from other stocks using U.S. waters during good forage conditions. At the same time the aerial portion of the line transect estimate did not go into the Canadian waters in the Bay of Fundy region, nor east of the Hague line. The CMR estimate can be generated from a sampling a subregion of a species range, if that region is used by the entire population, as was the case here where sampling of the GOM humpback stock was conducted throughout the Gulf of Maine. CMR estimates are potentially subject to error if there is permanent immigration/emigration into or out of the population. However there is little evidence for this, given a lack of photo ID reports for GOM animals observed permanently relocating to other stock regions which would be indicative of emigration. Similarly there is little evidence for immigration, given the lack of regular 'new entrants' into the population as adults. Temporary emigration (*e.g.* the animal is not observed in the survey area for multiple years) only adds to individual capture heterogeneity, which is accommodated by the model given the longevity of the data sets. Given the efficiency of the method, NMFS should consider investment to ensure the continuation of this data record.

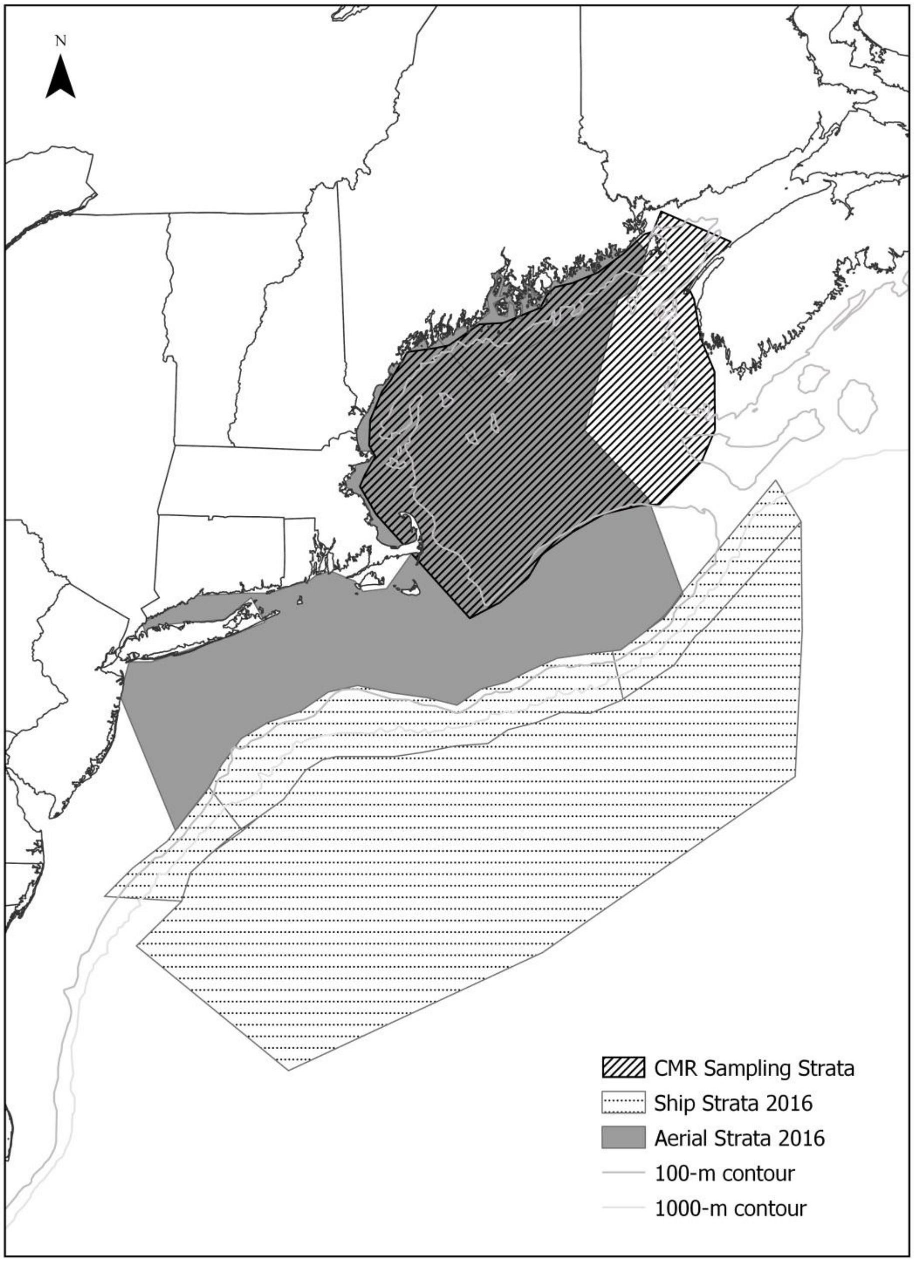

Figure 2. Map of sampling strata for two reported humpback whale population estimation methods. Capture-Mark-Recapture (CMR) strata identifies long term photo ID survey area in Gulf of Maine waters (note, western edge of CMR strata extends to coastline). Line transect strata of 2016 aerial (US waters) and ship-based surveys are also defined.

Minimum Population Estimate

The minimum population estimate is the lower limit of the two-tailed 60% credible interval about the median of the posterior abundance estimates using the CMR methods of Pace *et al.* (2017). This is roughly equivalent to the 20th percentile of the log-normal distribution as specified by Wade and Angliss (1997). The minimum population estimate is 1,380 using the CMR method.

Table 1. Summary of abundance estimates for Gulf of Maine humpback whales with month, year, and area covered during each abundance survey, and resulting abundance estimate (Nbest) and coefficient of variation (CV).

Month/Year	Type	N_{best}	CV
Jun–Aug 2011	Virginia to lower Bay of Fundy	335	0.42
Jun–Oct 2015	Gulf of Maine and Bay of Fundy	896	0
Jun-Sep 2016	Central Virginia to lower Bay of Fundy	2,368	0.48
Mid-summer 2016	State-space mark-recapture estimates	1,396	n/a

Current Population Trend

As detailed below, previous analyses concluded that the Gulf of Maine humpback whale stock is characterized by a positive trend in abundance. This was consistent with an estimated average trend of 3.1% (SE=0.005) in the North Atlantic population overall for the period 1979–1993 (Stevick *et al.* 2003), although there are no feeding-area-specific estimates. An analysis of demographic parameters for the Gulf of Maine (Clapham *et al.* 2003) suggested a lower rate of increase than the 6.5% reported by Barlow and Clapham (1997). Examination of the abundance estimates for the years 2000‒2016 (Figure 3) suggests that abundance increased at about 2.8% per annum (Robbins and Pace 2018).

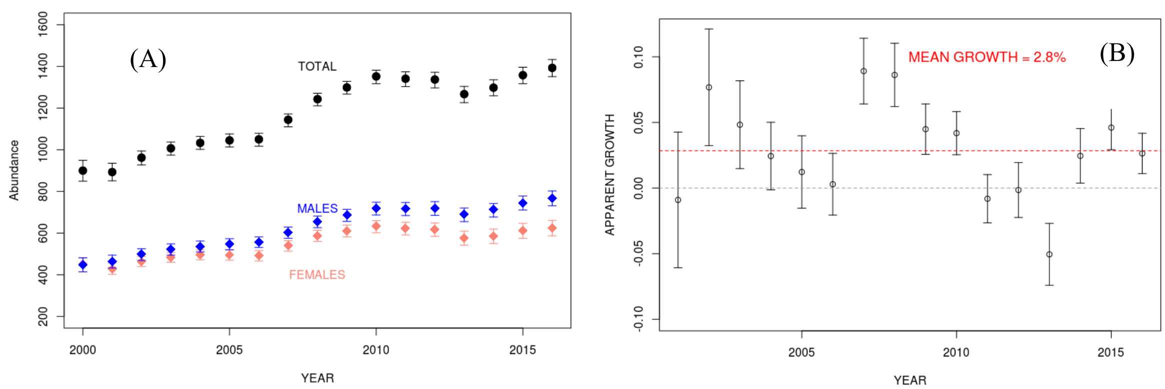

Figure 3. (A) Abundance estimates for Gulf of Maine humpback whales using the methodology described in Pace *et al.* 2017. Estimates are the median values of a posterior distribution from modeled capture histories. Also shown are sex-specific abundance estimates. Cataloged whales may include some but not all calves produced each year. (B) Crude annual growth rates from the abundance values.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

Zerbini *et al.* (2010) reviewed various estimates of maximum productivity rates for humpback whale populations, and, based on simulation studies, they proposed that 11.8% be considered as the maximum rate at which the species could grow. Barlow and Clapham (1997), applying an interbirth interval model to photographic mark-recapture data, estimated the population growth rate of the Gulf of Maine humpback whale stock at 6.5% (CV=0.012). Maximum net productivity is unknown for this population, although a theoretical maximum for any humpback population can be calculated using known values for biological parameters (Brandão *et al.* 2000; Clapham *et al.* 2001). For the Gulf of Maine stock, data supplied by Barlow and Clapham (1997) and Clapham *et al.* (1995) give values of 0.96 for survival rate, 6 years as mean age at first parturition, 0.5 as the proportion of females, and 0.42 for annual pregnancy rate. From this, a maximum population growth rate of 0.072 is obtained according to the method described by Brandão *et al.* (2000). This suggests that the observed rate of 6.5% (Barlow and Clapham 1997) is close to the maximum for this stock.

Clapham *et al.* (2003) updated the Barlow and Clapham (1997) analysis using data from the period 1992 to 2000. The population growth estimate was either 0% (for a calf survival rate of 0.51) or 4.0% (for a calf survival rate of 0.875). Although uncertainty was not strictly characterized by Clapham *et al.* (2003), their work might reflect a decline in population growth rates from the earlier study period. More recent work by Robbins (2007) places apparent survival of calves at 0.664 (95% CI: 0.517-0.784), a value between those used by Barlow and Clapham (1997) and in addition found productivity to be highly variable and well less than maximum.

Despite the uncertainty accompanying the more recent estimates of observed population growth rate for the Gulf of Maine stock, the maximum net productivity rate was assumed to be 6.5% calculated by Barlow and Clapham (1997) because it represents an observation greater than the default of 0.04 for cetaceans (Barlow *et al.* 1995) but is conservative in that it is well below the results of Zerbini *et al.* (2010).

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 Gulf of Maine stock is 1,380 whales. The maximum productivity rate is 0.065 (based on Barlow and Clapham 1997). In the 2015 and prior SARs, the recovery factor was 0.10 because this stock was listed as an endangered species under the Endangered Species Act (ESA). The 2016 revision to the ESA listing of humpback whales concluded that the West Indies Distinct Population Segment (of which the Gulf of Maine stock is a part) did not warrant listing (81 FR 62259, September 8, 2016). Consequently, in the 2016 SAR the recovery factor was revised to 0.5, the default value for stocks of unknown status relative to OSP (Wade and Angliss 1997). PBR for the Gulf of Maine humpback whale stock is 22.

ANNUAL HUMAN-CAUSED SERIOUS INJURY AND MORTALITY

For the period 2013 through 2017, the minimum annual rate of detected human-caused mortality and serious injury to the Gulf of Maine humpback whale stock averaged 12.15 animals per year. This value includes incidental fishery interaction records, 7.75; and records of vessel collisions, 4.4 (Table 2; Henry *et al.* 2020). In addition to the total 60.75 (38.75 entanglement, 22 vessel) anthropogenic mortalities and serious injuries for this time period, 11 carcasses examined found no detected human interaction. In contrast to stock assessment reports before 2007, these averages include humpback mortalities and serious injuries that occurred in the southeastern and mid-Atlantic states that could not be confirmed as involving members of the Gulf of Maine stock. In past reports, only events involving whales confirmed to be members of the Gulf of Maine stock were counted against the PBR. Starting in the 2007 report, we assumed whales were from the Gulf of Maine unless they were identified as members of another stock. At the time of this writing, no whale was identified as a member of another stock. These determinations may change with the availability of new information. Canadian records from the southern side of Nova Scotia were incorporated into the mortality and serious injury rates, to reflect the effective range of this stock as described above. For the purposes of this report, the discussion is primarily limited to those records considered to be confirmed human-caused mortalities or serious injuries.

It is important to stress that serious injury determinations are made based upon the best available information; these determinations may change with the availability of new information (Henry *et al.* 2020). For the purposes of this report, takes against PBR are limited to those records considered confirmed human-caused mortalities or serious injuries. Annual rates calculated from detected mortalities should be considered a low-biased accounting of human-caused mortality; they represent a definitive lower bound. Detections of mortality and serious injury are haphazard, incomplete, and not the result of a designed sampling scheme. A key uncertainty is the fraction of the actual human-caused mortality and serious injury represented by the detected mortalities and serious injuries. Research on small cetaceans has shown the actual number of deaths can be several times higher than that observed (Wells and Allen 2015; Williams *et al.* 2011). Because annual population estimates are now available (Pace *et al*. 2017), it is possible to estimate total annual mortality (and the number of undetected.

$N_{t+1} = N_t + B_t - D_t$

Where N_t is the number of animals in a population in year *t*, N_{t+1} is the number of animals in the population in year *t+1*, B_t is the number of births in the population in year *t*, and D_t is the number of deaths in the population in year *t*.

Solving for D_t yields: $D_t = N_t + B_t - N_{t+1}$ which can then be used to estimate undetected mortality as: D_t- observed deaths= undetected deaths

The total mortality estimated described above is based on the assumption that all animals that exit from the population in the model are actual deaths and that all entries into the population are births. If immigration were occurring, new mature animals would be documented and captured in the estimate of B_t. The total mortality estimate assumes all departures from the population are deaths, given the lack of any evidence for emigration from the population. Temporary emigration (*e.g.* the animal is not observed in the survey area for multiple years) only adds to individual capture heterogeneity, which is accommodated by the model given the longevity of the data sets. Importantly, these assumptions are not novel to the total mortality estimate, but a core part of the published Pace *et al*. (2017) method. A method to assign cause to these undetected mortalities is currently under development; as such these additional mortalities are not counted towards PBR at this time. Regardless, these estimates exceed or equal the number of detected serious injuries and mortalities (Figure 4) and currently roughly 20% of mortalities since 2000 are estimated to have been observed. For all the mortality observed in humpbacks, the current minimum fraction of anthropogenic mortality is 0.85. If this proportion were assigned to all unseen mortalities, the estimated annual anthropogenic mortality for this time period would be 53 and exceed PBR. While NMFS will be working to publish methodology for apportioning unseen mortality, it is worth noting that anthropogenic mortality in humpbacks would still exceed PBR if only 0.37 of unseen mortality were attributed to anthropogenic causes and it is very likely that is has exceeded PBR for the past several years (Figure 4).

There is mounting evidence that humpback whales have been over PBR for some time, and likely will be formally determined to be so in a future report. This is further supported by the NMFS declaration of Unusual Mortality Event No. 63.7 which includes cases from 2016 to the time of this writing in 2019 (https://www.fisheries.noaa.gov/national/marine-life-distress/2016-2019-humpback-whale-unusual-mortality-event-along-atlantic-coast).The literature and review of records described here suggest that there are significant human impacts beyond those recorded in the data assessed for serious injury and mortality. For example, a study of entanglement-related scarring on the caudal peduncle of 134 individual humpback whales in the Gulf of Maine suggested that between 48% and 65% had experienced entanglements (Robbins and Mattila 2001) and that 12-16% encounter gear annually (Robbins 2012).

To better assess human impacts (both vessel collision and commercial fishery mortality and serious injury) there needs to be greater emphasis on the timely recovery of carcasses and complete necropsies. Decomposed and/or unexamined animals (e.g., carcasses reported but not retrieved or no necropsy performed) represent 'lost data', some of which may relate to human impacts.

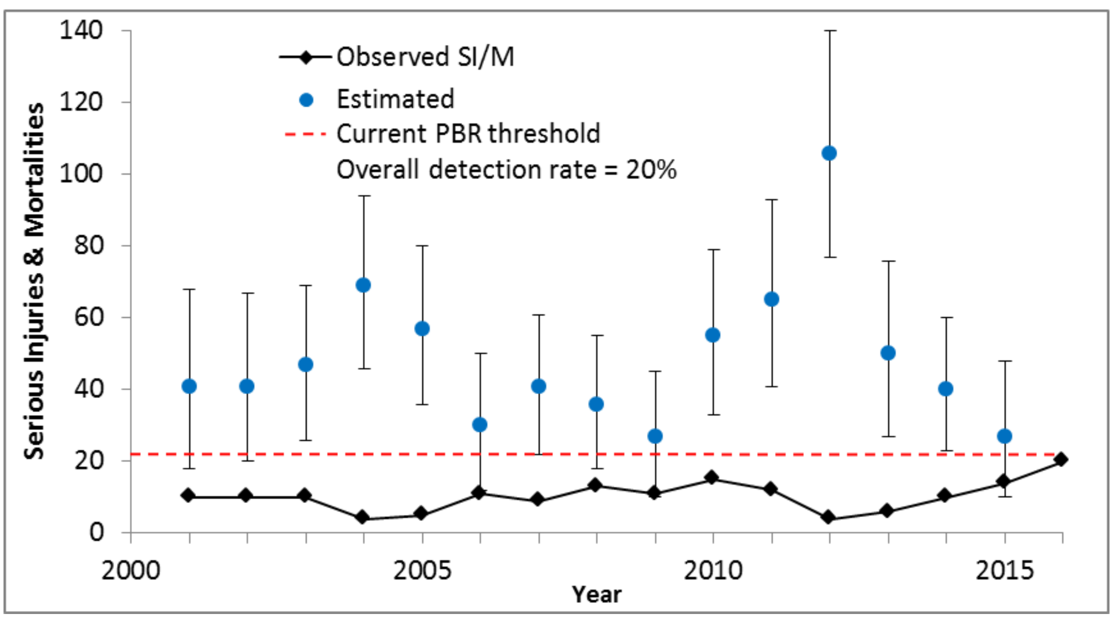

Figure 4. Time series of observed annual total serious injuries and mortalities (SI/M; bottom black line) observed versus total annual estimated mortalities (blue circles with associated error bars).Dashed line indicates current PBR threshold of 22.

Background

As with right whales, human impacts (vessel collisions and entanglements) may be slowing recovery of the humpback whale population. Van der Hoop *et al.* (2013) reviewed 1,762 mortalities and serious injuries recorded for 8 species of large whales in the Northwest Atlantic for the 40 years 1970–2009. Of 473 records of humpback whales, cause of death could be attributed for 203. Of the 203, 116 (57%) mortalities were caused by entanglements in fishing gear, and 31 (15%) were attributable to vessel strikes.

Inferences made from scar prevalence and multistate models of GOM humpback whales report that (1) younger animals are more likely to become entangled than adults, (2less than 10% of humpback entanglements are ever reported, and (3) 3% of the population may be dying annually as the result of entanglements (Robbins 2009, 2010, 2011, 2012). Humpback whale entanglements also occur in relatively high numbers in Canadian waters. Reports of interactions with fixed fishing gear set for groundfish around Newfoundland averaged 365 annually from 1979 to 1987 (range 174–813). An average of 50 humpback whale entanglements (range 26–66) was reported annually between 1979 and 1988, and 12 of 66 humpback whales entangled in 1988 died (Lien *et al.* 1988). A total of 965 humpbacks was reported entangled in fishing gear in Newfoundland and Labrador from 1979 to 2008 (Benjamins *et al.* 2012). Volgenau *et al.* (1995) reported that gillnets were the primary cause of entanglements and entanglement mortalities (20%) of humpbacks in the Gulf of Maine between 1975 and 1990. More recently, Johnson *et al*. (2005) found that 40% of humpback entanglements were in trap/pot gear and 50% were in gillnets, but sample sizes were small and much uncertainty still exists about the frequency of certain gear types involved in entanglement. A recent review (Cassoff *et al*. 2011) describes in detail the types of injuries that baleen whales, including humpbacks, suffer as a result of entanglement in fishing gear.

More than 2 decades ago, Wiley *et al.* (1995) reported that serious injuries attributable to ship strikes were more common and probably more serious than those from entanglements, but this claim is not supported by more recent analysis. Non-lethal interactions with gear and vessels are common (see Robbins 2010, 2011, 2012; Hill *et al* 2017), but recent analysis suggests entanglement serious injuries and mortalities are more common than ship strikes (van der Hoop *et al.* 2013). Furthermore, in the NMFS records for 2013 through 2017, there are only 23 reports of serious injuries and mortalities as a result of collision with a vessel and 56 records of injuries (prorated or serious) and mortalities attributed to entanglement. Similarly, a recent analysis of the past 20 years of mortalities in North Atlantic right whales, which have considerable overlap in distribution, shows a steady increase in the rate of entanglement (Hayes *et al.* 2019- this SAR report). Because it has never been shown that serious injuries and mortalities related to ships or to fisheries interactions are equally detectable, it is unclear as to which human source of mortality is more prevalent. A major aspect of vessel collision that will be cryptic as a serious injury is blunt trauma; when lethal it is usually undetectable from an external exam (Moore *et al.* 2013). No whale involved in the recorded vessel collisions had been identified as a member of a stock other than the Gulf of Maine stock at the time of drafting this report.

Fishery-Related Serious Injuries and Mortalities

A description of fisheries is provided in Appendix III. See Appendix V for more information on historical takes.

Confirmed human-caused mortalities and serious injuries from the last five years reported to the NMFS Greater Atlantic and Southeast regional offices and to Atlantic Canadian Maritime stranding networks (Henry *et al*. 2020) are listed in Table 2. When there was no evidence to the contrary, events were assumed to involve members of the Gulf of Maine stock. While these records are not statistically quantifiable in the same way as observer fishery records, they provide some indication of the minimum frequency of entanglements. Specifically to this stock, if the calculations of Robbins (2011, 2012) are reasonable then the 3% mortality due to entanglement that she calculates equates to a minimum average rate of 25.

Although disentanglement is often unsuccessful or not possible for many cases, there are several documented cases of entanglements for which the intervention of disentanglement teams averted a likely serious-injury determination. Twenty-four serious injuries were prevented by intervention during 2013–2017 (Henry *et al.* 2020).

Table 2. Confirmed human-caused mortality and serious injury records of humpback whales (Megaptera novaeangliae) where the cause was assigned as either an entanglement (EN) or a vessel strike (VS): 2013–2017 [a]

Date[b]	**Injury Determination**	**ID**	**Location[b]**	**Assigned Cause**	**Value against PBR[c]**	**Country[d]**	**Gear Type[e]**	**Description**
3-Apr-13	Mortality	-	off Ft Story, VA	VS	1	US	-	Fractured orbitals & ribs w/ associated bruising
13-Sep-13	Mortality	-	York River, VA	VS	1	US	-	6 lacerations penetrate into muscle w/ associated hemorrhaging
16-Sep-13	Prorated Injury	-	off Chatham, MA	EN	0.75	XU	NR	Partial disentanglement; original & final configurations unknown
28-Sep-13	Mortality	-	off Saltaire, NY	EN	1	XU	GN	Embedded line in mouth w/ associated hemorrhaging & necrosis; evidence of constriction at pectorals, peduncle & fluke w/ associated hemorrhaging; emaciated. Previously reported as GU.
1-Oct-13	Mortality	-	Buzzards Bay, MA	EN	1	US	NP	Evidence of underwater entrapment & subsequent drowning.
4-Oct-13	Serious Injury	-	off Chatham, MA	EN	1	XU	NR	Full configuration unknown, but evidence of health decline: emaciation & pale skin
02-Jun-14	Prorated Injury	-	15 mi E of Monomoy Island, MA	EN	0.75	XU	NR	Free-swimming with buoy and highflier trailing 100ft aft of flukes. Attachment point(s) unknown. Unable to confirm if resighted on 21Jun2014.

Date[b]	Injury Determination	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
21-Jun-14	Prorated Injury	-	5 mi E of Gloucester, MA	EN	0.75	XU	NR	Free-swimming trailing a buoy and possibly another buoy/highflier aft. Attachment point(s) unknown. Unable to confirm if this is a resight of 02Jun2014.
18-Jul-14	Serious Injury	-	Provincetown Harbor, MA	EN	1	XU	NR	Free-swimming, trailing short amount of line from left side of mouth. No other gear noted, but evidence of previously more complicated, constricting entanglement. Current configuration deemed non-life threatening. Unsuccessful disentanglement attempt. In poor condition - emaciated with some cyamids. No resights
03-Sep-14	Prorated Injury		off Long Island Beach, NJ	EN	.75	XU	NE	Full/final config. unknown. Seen with new vessel strike lacerations on 14Aug2014. No resights. Previously reported as gear unknown and being gear free (SI value=0) but gear status determined to be unconfirmed.

Date[b]	Injury Determination	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
11-Sep-14	Mortality	Spinnaker	10 nm SE of Frenchboro, ME	EN	1	XU	GN	Free-swimming with gillnet gear. Found anchored on 12Sep2014. Gillnet panel lodged in mouth and tightly wrapping forward part of body. Panel entangled in pots with 20+ wraps of pot lines around flukes and peduncle. Mostly disentangled--left with short section of gillnet in mouth expecting to shed. Animal entangled again (14May2015 - anchored and disentangled). Carcass found 11Jun2015. Necropsy revealed gillnet from 2014 entanglement embedded deep into the maxilla and through the vomer. Bone had started to grow around the line. Gillnet is unknown origin. Pot/trap is US gear.
20-Sep-14	Prorated Injury	NYC0010	off Rockaway Beach, Long Island, NY	EN	.75	US	GN	Free-swimming with netting and rope with floats wrapping flukes. Entanglement noticed during photo processing. Full configuration unknown. No resights. Previously reported as gear unknown.
01-Oct-14	Prorated Injury	-	15 mi E of Metompkin Inlet, VA	EN	.75	XU	NR	Free-swimming whale with line &/or netting on left fluke blade. Gear appeared heavy. Full configuration unknown. No resights.

Date[b]	Injury Determinat ion	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
15-Dec-14	Prorated Injury	-	8.5 nm S of Grand Manan, NB	EN	.75	CN	PT	Fisherman found animal entangled in trawl. Grappled line, animal dove. Upon surfacing, appeared free of gear, but unable to confirm gear free. Original and final configuration unknown. Previously reported as XC.
25-Dec-14	Mortality	Triomphe	Little Cranberry Island, ME	EN	1	XU	NP	Fresh carcass with evidence of extensive constricting entanglement. No necropsy, but robust body condition and histopathology results of samples support EN as COD.
01-Feb-15	Serious Injury	-	off Beaufort, NC	EN	1	XU	NE	Constricting wrap at fluke insertion with line and monofilament netting trailing from flukes. Partial disentanglement by fisherman. Left with embedded gear and at least 40 ft of trailing line and netting. Unknown if there are additional attachment points. No resights. Gear previously reported as NR.
03-Feb-15	Mortality	-	Corolla, NC	EN	1	US	NP	Fresh carcass with injuries consistent with constricting gear. No gear present. Full stomach indicating fed recently. COD likely peracute under water entrapment.

Date[b]	Injury Determination	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
13-Apr-15	Mortality	-	off Fire Island, NY	VS	1	US	-	Extensive bruising and hemorrhaging at left gape and pectoral, throat, and right and left lateral thorax.
18-Apr-15	Mortality	-	Smith Point, NY	VS	1	US	-	Multifocal hemorrhage and edema in right lateral abdomen.
29-Jun-15	Mortality	-	Fire Island, NY	VS	1	US	-	Extensive fracturing of cranial bones with associated bruising. Additional extensive bruising along dorsal and right lateral body.
09-Jul-15	Prorated Injury	-	off Sandy Hook, NJ	EN	0.75	XU	NR	High flier trailing 30 ft aft of flukes. Attachment point(s) and configuration unknown. No resights.

Date[b]	Injury Determination	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
02-Aug-15	Serious Injury	-	off Race Point, Provincetown, MA	EN	1	XU	GN	Free-swimming with two sets of gear through its mouth: Primary gear=a closed bridle of gillnet joining mid-belly and trailing just past flukes and restricting movement; Secondary gear=an open bridle with one end leading to a buoy and the other to a pot. Disentangled from both sets of gear. Left with very short amount of gillnet through mouth that is expected to shed. Emaciated. No resights. Gillnet is primary cause of injury and of unknown origin. Pot/trap is US gear.
02-Aug-15	Prorated Injury	-	off Chatham, MA	EN	0.75	XU	NR	Calf with line around tail leading to buoys 4 ft aft of flukes. Full configuration unknown. No resights post 22Aug2015.
07-Sep-15	Prorated Injury	-	off Race Point, Provincetown, MA	EN	0.75	XU	MF	Monofilament line trailing from flukes. Attachment point(s) and configuration unknown. No resights.

Date[b]	Injury Determination	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
24-Sep-15	Prorated Injury	-	off Hampton, NH	EN	0.75	US	Anchor system	Became entangled in anchor line of fishing vessel during the night. Believed to be towing the entire system--45 lb anchor, 20 ft of chain, 350 ft of anchor line, 150 ft of float line, polyball and acorn buoy--in an unknown configuration. No resights.
25-Sep-15	Serious Injury	-	off Menemsha Harbor, MA	EN	1	XU	NR	Evidence of constricting body wrap, unable to confirm if gear embedded. Trailing 10 ft of line from flukes, full configuration unknown. Animal emaciated with heavy cyamids. No resights.
17-Oct-15	Mortality	-	Lloyd Neck Harbor, NY	VS	1	US	-	Extensive bruising and edema around right cranial and pectoral.
04-Dec-15	Prorated Injury	-	off Brier Island, NS	EN	0.75	CN	PT	Likely anchored in gear. Partially disentangled by fishermen. Left free-swimming with a body wrap aft of blowholes and 2 balloon floats close to body. Final configuration unknown. No resights.

Date[b]	Injury Determination	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
15-Dec-15	Prorated Injury	-	off North East Harbour, NS	EN	0.75	CN	PT	Likely anchored in gear. Partially disentangled by fishermen. Left free-swimming with buoy and lines around front of whale and lines on the peduncle. Attachment point(s) and final configuration unknown. No resights.
07-Jan-16	Prorated Injury	--	off Greenwich, CT	EN	0.75	US	PT	Anchored in gear with line through mouth and around tail. Partially disentangled - all gear removed from mouth and some from tail. Post intervention whale was using pectorals to swim and tail was down, but unable to confirm if any gear remained and in what configuration. No resights.
09-Jan-16	Serious Injury	MAHWC-254	off Fort Story, VA	VS	1	US	-	Deep laceration across back - penetrating into muscle and impacting ability to dive. No resights.
03-Mar-16	Serious Injury	MAHWC-251	off Virginia Beach, VA	VS	1	US	-	Deep laceration on left fluke blade, near insertion. Fluke blade necrotic. No resights.

Date[b]	Injury Determination	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
24-Apr-16	Prorated Injury	-	off Race Point, Provincetown, MA	EN	0.75	XU	NR	Free-swimming with 2 buoys - submerged orange at 5 ft and white bullet at 10 ft - trailing behind flukes. Line appears to wrap flukes. Subsequent sighting only reported white buoy, but only one surfacing and no photos. Attachment point(s) and configuration unknown. No resights.
25-Apr-16	Mortality	-	Marshfield, MA	VS	1	US	-	Bruising deep to muscle and fascia by right pectoral and mandible at the base of the skull. Limited necropsy but depth and area of bruising consistent with blunt trauma from vessel strike.
25-Apr-16	Mortality	-	Napreague Bay, NY	VS	1	XU	-	Extensive bruising to ventral thoracic region along with fractured ribs.

Date[b]	Injury Determination	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
18-May-16	Serious Injury	Foggy	off Gloucester, MA	EN	1	XU	GU	Anchored with lines through mouth and 2 embedded body wraps with large float alonside by right body. Entangling gear fouled in 2 other sets of gear. Animal in emaciated. Partial disentanglement - left with an open bridle of 2 lines through the mouth. Subsequent sightings show lines had relooped into a closed bridle and health continued to decline. No resights post July 2016.
21-May-16	Prorated Injury	-	off Mantoloking, NJ	EN	0.75	XU	GN	Full configuration unknown, but minimally wrapped in gear from head to dorsal. Unknown amount of gear removed by public. Unable to confirm if gear free. No resights.
15-Jun-16	Mortality	-	off Fenwick Island, DE	VS	1	US	-	Large area of hemorrhaging around neck and head. Organs displaced forward in body cavity. Full stomach.
24-Jun-16	Mortality	-	off Shinnecock Inlet, NY	VS	1	US	-	Extensive bruising to connective tissue and muscles of the left side, back, and right peduncle.
26-Jun-16	Mortality	Snowplow	off Rockport, MA	VS	1	US	-	Limited necropsy, but significant evidence of blunt trauma to left head and pectoral consistent with vessel strike.

Date[b]	Injury Determination	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
05-Jul-16	Serious Injury	-	off Chatham, MA	EN	1	XU	GU	Free-swimming with embedded wraps at base of flukes and buoy trailing 50 ft. Partially disentangled. Peduncle wraps loosened and expect to shed. Pronosis poor - flukes compromised and deteriorating. Animal swimming with flippers. No resights.
02-Sep-16	Prorated Injury	-	off Gloucester, MA	EN	0.75	XU	NR	Free-swimming and trailing red buoy. Attachment point(s) and configuration unknown. No resights.
10-Sep-16	Mortality	-	Martha's Vineyard, MA	EN	1	XU	NP	No gear present, but evidence of constricting entanglement with associated reactive tissue at fluke insertions. State of decomposition at time of exam precluded COD determination, but injuries and thin blubber layer are consistent with chronic entanglement.
16-Oct-16	Mortality	GOM-1626	off Ipswich, MA	EN	1	US	PT	No necropsy, but extensive entanglement. Line through mouth with constricting wraps on both flippers, body, and peduncle. Entanglement as COD most parsimonious. Confirmed as same individual released from weir on 27Sep2016.

Date[b]	Injury Determination	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
13-Nov-16	Prorated Injury	NYC0052	off Belmar, NJ	EN	0.75	XU	MF	Free-swimming with monofilament over peduncle and trailing from flukes. Attachment point(s) and configuration unknown. No resights.
14-Nov-16	Prorated Injury	-	off Stone Harbor, NJ	EN	0.75	XUS	PT	Free-swimming with line wrapping left flipper and flukes and trailing. Full configuration unclear. No resights. Previously reported as XC, gear not recovered.
04-Dec-16	Prorated Injury	-	off Quogue, NY	EN	0.75	XU	NR	Free-swimming with high flier near flukes. Attachment point(s) and configuration unknown. No resights.
16-Dec-16	Mortality	HDRVA078	off Dam Neck, VA	EN	1	US	NP	No gear present, but evidence of extensive constricting entanglement. Fresh carcass with digestive system full of fish. COD dry drowning due to entanglement.
19-Dec-16	Prorated Injury	-	off Tiverton, NS	EN	0.75	Sure!XC	NR	Free-swimming with line around tail and buoy trailing. Full configuration unknown. No resights.

Date[b]	Injury Determination	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
02-Feb-17	Mortality	-	Chesapeake Bay, VA	VS	1	US	-	Four lacerations that penetrated body cavity. Robust condition with full stomach. COD exsanguination and asphyxia from sharp trauma consistent with vessel strike.
05-Feb-17	Mortality	-	Chesapeake Bay, VA	VS	1	US	-	Extensive skeletal fracturing with associated hemorrhaging consistent with blunt trauma from vessel strike.
11-Feb-17	Mortality	-	Fort Story, VA	VS	1	US	-	Three lacerations that penetrated body cavity. Robust condition with full stomach. COD exsanguination from sharp trauma consistent with vessel strike.
14-Feb-17	Serious Injury	-	Virginia Beach, VA	VS	1	US	-	Two new, deep lacerations fore and aft of dorsal fin. No resights.
03-Apr-17	Mortality	-	Rockaway, NY	VS	1	US	-	Extensive hemorrhage and edema along back and side consistent with blunt trauma from vessel strike.
04-May-17	Mortality	-	Rehobeth Beach, DE	VS	1	US	-	Disarticulated left jaw and cervical vertebrae with associated hemorrhaging. Limited necropsy but injuries consistent with blunt trauma from vessel strike.
15-Jun-17	Mortality	-	Jamestown, RI	VS	1	US	-	Muscle contusions and associated cranial fractures consistent with blunt trauma from vessel strike.

Date[b]	Injury Determination	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
18-Jun-17	Mortality	GOM-1625	Chatham, MA	EN	1	XU	NP	No gear present, but evidence of constricting entanglement with associated hemorrhaging at insertion of pectorals and fluke. Poor health condition.
15-Jul-17	Prorated Injury	2016 Calf of Thumper	off Race Point, Provincetown, MA	EN	.75	US	NR	Free-swimming with hook and monofilament trailing from right fluke blade. Attachment point(s) and full configuration unknown. No resights.
01-Aug-17	Mortality	2017 Calf of Cajun	off Gloucester, MA	EN	1	US	GN	Dependent calf with gillnet exiting right side of mouth. Evidence of unwitnessed extensive ent. Carcass found on 24Feb2018, not recovered for necropsy. Prox. COD = ent., Ultimate COD = unk.
19-Aug-17	Prorated Injury	-	off Long Island, NY	EN	.75	XU	NR	Free-swimming with buoy trailing aft of flukes. Attachment point(s) and configuration unknown. No resights post 11Sep2017.
18-Sep-17	Prorated Injury	-	off Jonesport, ME	EN	.75	CN	PT	Anchored in gear. Fisher responded later, animal not relocated and gear missing section of pots and line. Final configuration unknown. No resights.

Date[b]	Injury Determination	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
01-Oct-17	Mortality	-	off Narragansett, RI	VS	1	XU	-	Hemorrhaging along dorsal and left side consistent with blunt trauma from vessel strike.
10-Oct-17	Prorated Injury	-	off Gloucester, MA	EN	.75	US	PT	Anchored in gear. Partially disentangled. Unable to confirm gear free. Final configuration unknown. No resights.
14-Oct-17	Prorated Injury	-	off Race Point, Provincetown, MA	EN	.75	XU	NR	Free-swimming with buoy along right flank. Attachment point(s) and full configuration unknown. No resights.
21-Oct-17	Prorated Injury	GOM-1747	off Long Island, NY	EN	.75	XU	NR	Free-swimming with buoy in tow. Attachment point(s) and full configuration unknown. No resights.
12-Nov-17	Prorated Injury	-	off Atlantic Beach, NY	EN	.75	US	MF	Free-swimming with monofilament trailing from right fluke. Attachment point(s) and full configuration unknown. No resights.
30-Nov-17	Prorated Injury	-	off Grand Manan, NB	EN	.75	CN	PT	Anchored at tail area, partially disentangled. Unable to confirm gear free or that all gear recovered. Final configuration unknown. No resights.
26-Dec-17	Mortality	-	East Atlantic Beach, NY	VS	1	US	-	Extensive bruising and edema on both sides of body consistent with blunt trauma from vessel strike.

Assigned Cause	Five-year mean (US/CN/XU/XC)
Vessel strike	4.4 (4.0/ 0.00/ 0.40/ 0.00)
Entanglement	7.75 (2.05/ 0.75/ 4.8/ 0.15

a. For more details on events please see Henry *et al.* 2020.
b. The date sighted and location provided in the table are not necessarily when or where the serious injury or mortality occurred; rather, this information indicates when and where the whale was first reported beached, entangled, or injured.
c. Mortality events are counted as 1 against PBR. Serious injury events have been evaluated using NMFS guidelines (NOAA 2012).
d. CN=Canada, US=United States, XC=Unassigned 1st sight in CN, XU=Unassigned 1st sight in US.
e. H=hook, GN=gillnet, GU=gear unidentifiable, MF=monofilament, NE=netting, NP=none present, NR=none recovered/received, PT=pot/trap, WE=weir.

Other Mortality

Between November 1987 and January 1988, at least 14 humpback whales died after consuming Atlantic mackerel containing a dinoflagellate saxitoxin (Geraci *et al.* 1989). The whales subsequently stranded or were recovered in the vicinity of Cape Cod Bay and Nantucket Sound, and it is highly likely that other unrecorded mortalities occurred during this event. During the first six months of 1990, seven dead juvenile (7.6 to 9.1 m long) humpback whales stranded between North Carolina and New Jersey. The significance of these strandings is unknown.

Between July and September 2003, an Unusual Mortality Event (UME) that included 16 humpback whales was invoked in offshore waters of coastal New England and the Gulf of Maine. Biotoxin analyses of samples taken from some of these whales found saxitoxin at very low/questionable levels and domoic acid at low levels, but neither were adequately documented and therefore no definitive conclusions could be drawn. Seven humpback whales were considered part of a large whale UME in New England in 2005. Twenty-one dead humpback whales found between 10 July and 31 December 2006 triggered a humpback whale UME declaration. Additionally, in January 2016 a humpback whale UME was declared for the U.S. Atlantic coast due to elevated numbers of mortalities (a total of 88 strandings in 2016–2018; https://www.fisheries.noaa.gov/national/marine-life-distress/2016-2018-humpback-whale-unusual-mortality-event-along-atlantic-coast). This most recent UME is ongoing.

HABITAT ISSUES

Climate-related changes in spatial distribution and abundance, including poleward and depth shifts, have been documented in and predicted for a range of plankton species and commercially important fish stocks (Head *et al*. 2010; Grieve *et al.* 2017; Nye *et al*. 2009; Pinsky *et al*. 2013; Hare *et al*. 2016). There is uncertainty in how, if at all, the distribution and population size of this species will respond to these changes and how the ecological shifts will affect human impacts.

STATUS OF STOCK

NMFS conducted a global status review of humpback whales (Bettridge *et al*. 2015) and recently revised the ESA listing of the species (81 FR 62259, September 8, 2016). The Distinct Population Segments (DPSs) that occur in waters under U.S. jurisdiction, as established in the Final Rule, do not necessarily equate to the existing MMPA stocks. NMFS is evaluating the stock structure of humpback whales under the MMPA, but no changes to current stock structure are proposed at this time. As noted within the humpback whale ESA-listing Final Rule, in the case of a species or stock that achieved its depleted status solely on the basis of its ESA status, such as the humpback whale, the species or stock would cease to qualify as depleted under the terms of the definition set forth in MMPA Section 3(1) if the species or stock is no longer listed as threatened or endangered. The final rule indicated that until the stock delineations are reviewed in light of the DPS designations, NMFS would consider stocks that do not fully or partially coincide with a listed DPS as not depleted for management purposes. Therefore, the Gulf of Maine stock is considered not depleted because it does not coincide with any ESA-listed DPS. The detected level of U.S. fishery-caused mortality and serious injury derived from the available records, (average of 12.5 for 2013–2017) does not exceed the calculated PBR of 22 and, therefore, this is not a strategic stock if the recovery factor is set at 0.5. Because the observed mortality is estimated to be only 20% of all mortality (Figure 4), total annual mortality may be 60-70 animals in this stock. If anthropogenic causes are responsible for as little as 31% of potential total mortality, this stock could be over PBR. While detected mortalities yield an estimated minimum fraction of anthropogenic mortality as 0.85, additional research is being done before apportioning mortality to anthropogenic versus natural causes for undetected mortalities. Therefore, the accounting of human caused mortality is biased low and the uncertainties associated with this assessment may have produced an incorrect determination of strategic status.

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