NORTH ATLANTIC RIGHT WHALE (*Eubalaena glacialis*)

STOCK DEFINITION AND GEOGRAPHIC RANGE

The western North Atlantic right whale population ranges primarily from calving grounds in coastal waters of the southeastern U.S. to feeding grounds in New England waters and the Canadian Bay of Fundy, Scotian Shelf, and Gulf of St. Lawrence (Figure 1). Mellinger et al. (2011) reported acoustic detections of right whales near the 19th-century whaling grounds east of southern Greenland, but the number of whales and their origin is unknown. Knowlton et al. (1992) reported several long-distance movements as far north as Newfoundland, the Labrador Basin, and southeast of Greenland. Resightings of photographically identified individuals have been made off Iceland, in the old Cape Farewell whaling ground east of Greenland (Hamilton et al. 2007), in northern Norway (Jacobsen et al. 2004), in the Azores (Silva et al. 2012), and off Brittany in northwestern France (New England Aquarium unpub. catalog record). These long-range matches indicate an extended range for at least some individuals. Records from the Gulf of Mexico (Moore and Clark 1963; Schmidly et al. 1972; Ward-Geiger et al. 2011; NMFS Southeast Regional Office unpublished data) and a lone calf documented off the Canary Islands in 2020 (North Atlantic Right Whale Catalog, unpublished data) represent individuals beyond the primary calving and wintering ground in the waters of the southeastern U.S. East Coast.

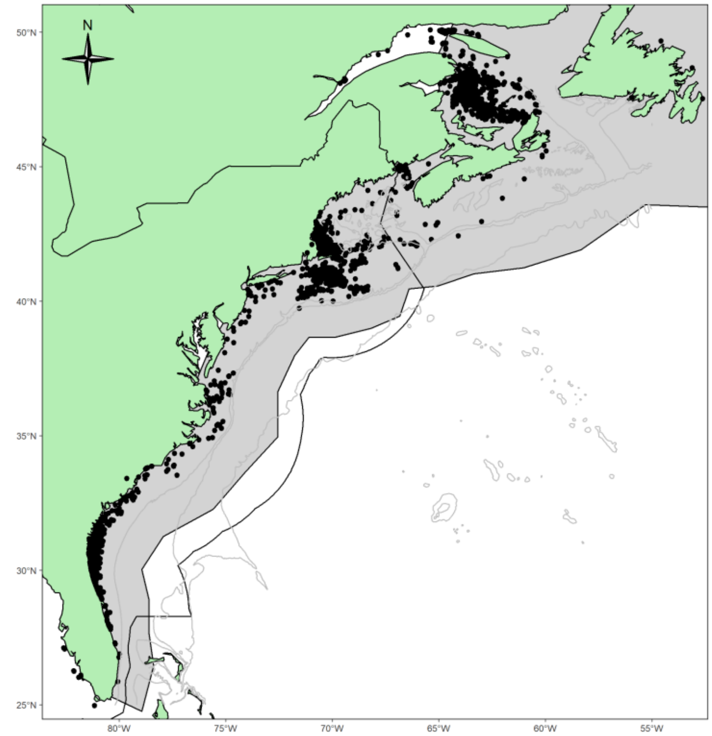


Figure 1. Approximate range (shaded area) and distribution of sightings (dots) of known North Atlantic right whales 2018-2023. Data from North Atlantic Right Whale Consortium database (https://www.narwc.org/narwc-databases.html, accessed 13 September, 2024) and NMFS unpublished data.

Although the location of much of the population is unknown during much of the year, passive acoustic studies have demonstrated year-round presence of right whales on the Scotian Shelf (Durette-Morin et al. 2022), in the Gulf of Maine (Morano et al. 2012; Bort et al. 2015), and off southern New England (Estabrook et al. 2022), New York (Murray et al. 2022), New Jersey (Whitt et al. 2013), and Virginia (Salisbury et al. 2016). Additionally, right whales were acoustically detected off Georgia and North Carolina in 7 of 11 months monitored (Hodge et al. 2015). Davis et al. (2017) pooled together acoustic detections from a large number of passive acoustic recorders and documented broad-scale use of the U.S. eastern seaboard during much of the year, with widespread right whale acoustic occurrence in winter months from Florida to the southern Scotian Shelf. Right whales occurred across the dataset (spanning 2004–2014) from Florida to southern Greenland. Since 2015, acoustic monitoring networks along the East Coast continue to show year round presence from Cape Hatteras, North Carolina to Massachusetts Bay, Massachusetts with a peak in detections south of New England in winter months (Passive Acoustic Cetacean Map (PACM; https://apps-nefsc.fisheries.noaa.gov/pacm/#/narw)). In Canada, large scale passive acoustic studies documented right whales in the Gulf of St. Lawrence (Simard et al. 2019) and Atlantic Canadian waters (Durette-Morin et al. 2022). Right whales were acoustically detected every year in the Gulf of St Lawrence from 2010–2018; the earliest seasonal detections were at the end of April, lasting until mid-January (Simard et al. 2019, Durette-Morin et al. 2022). Among the recorder locations in the Gulf of St. Lawrence, detections occurred in the southern Gulf to the Strait of Belle Isle, and daily detection rates quadrupled at listening stations off the Gaspé

Peninsula beginning in 2015 (Simard et al. 2019, Durette-Morin et al. 2022). Right whales were detected in Atlantic Canadian waters from the Bay of Fundy, to Cabot Strait, to Southern Newfoundland, but were not detected in the Labrador Sea and Newfoundland Shelf during extensive acoustic monitoring throughout the Atlantic Canadian continental shelf between 42°N and 58°N during 2015 through 2017 (Durette-Morin et al. 2022). Recently developed monthly habitat-based density estimates of right whales for U.S. waters and a portion of southern Canadian waters show strong correlation with acoustic detection rates (Roberts et al. 2024).

Individuals' movements within and between habitats across the range are extensive. In 2000, one whale was photographed in Florida waters on 12 January, then again 11 days later (23 January) in Cape Cod Bay, less than a month later off Georgia (16 February), and back in Cape Cod Bay on 23 March, effectively making the round-trip migration to the Southeast and back at least twice during the winter season (Brown and Marx 2000). Results from satellite-tagging studies clearly indicate that sightings separated by a few weeks in the same area should not necessarily be assumed to indicate a stationary or resident animal. Instead, telemetry data have shown lengthy excursions, including into deep water off the continental shelf and along the US east coast, over short timeframes (Mate et al. 1997; Baumgartner and Mate 2005, Aschettino et al. 2022, 2023). The majority of right whale sightings off northeastern Florida and southeastern Georgia were within 90 km of the shoreline, as was most of the survey effort, however, one sighting occurred ~140 km offshore (NMFS unpub. data).

Systematic visual surveys conducted off the coast of North Carolina during the winters of 2001 and 2002 sighted 8 calves, suggesting the calving grounds may extend as far north as Cape Fear (W.A. McLellan, Univ. of North Carolina Wilmington, pers. comm.). Four of those calves were not sighted by surveys conducted farther south. One of the females photographed was new to researchers, having effectively eluded identification over the period of her maturation. An offshore survey in March 2010 observed the birth of a right whale in waters 75 km off Jacksonville, Florida (Foley et al. 2011). In 2016, the Southeastern U.S. Calving Area Critical Habitat was expanded north to Cape Fear, North Carolina (81 FR 4837, 26 February 2016). There is also at least one case of a calf apparently being born in the Gulf of Maine (Patrician et al. 2009) and another calf was detected in Cape Cod Bay in 2012 (Center for Coastal Studies, Provincetown, MA USA, unpub. data).

New England and Canadian waters are important feeding habitats for right whales, where they feed primarily on copepods (largely of the genera *Calanus* and *Pseudocalanus*). Right whales must locate and exploit extremely dense patches of zooplankton to feed efficiently (Mayo and Marx 1990, Sorochan et al. 2021). These dense zooplankton patches are likely a primary characteristic of the spring, summer, and fall right whale habitats (Kenney et al. 1986, 1995). The characteristics of acceptable prey distribution in these areas are summarized in Baumgartner et al. (2003), Baumgartner and Mate (2003), and Ross et al. (2023). In 2016, the Northeastern U.S. Foraging Area Critical Habitat was expanded to include nearly all U.S. waters of the Gulf of Maine (81 FR 4837, 26 February 2016).

Both visual and acoustic monitoring detected an important change in right whales' seasonal residency patterns beginning in 2010, with reduced right whale presence in the Bay of Fundy and Gulf of Maine (Davis et al. 2017; Davies et al. 2019, Meyer-Gutbrod et al. 2021). Between 2012 and 2016, visual surveys in the Great South Channel also saw a sharp decline in right whale sightings (Khan et al. 2018), while the number of individuals using Cape Cod Bay in spring increased (Mayo et al. 2018; Ganley et al. 2019, Meyer-Gutbrod et al. 2023). Right whale aggregations in the central Gulf of Maine in winter (Cole et al. 2013) have also not been detected since 2011 (NMFS unpublished data), although the species is detected acoustically every year in the Gulf of Maine (Davis and Van Parijs 2023; PACM 2024). Additionally, large numbers of right whales have been documented feeding and socializing south of Martha's Vineyard and Nantucket Islands (Leiter et al. 2017; Stone et al. 2017; Quintana-Rizzo et al. 2021; O'Brien et al. 2022), an area outside of the 2016 Northeastern U.S. Foraging Area Critical Habitat. Right whale presence in this area is nearly year round, including in summer months. The highest sighting rates in this area are between December and May, when close to a quarter of the population may be present at any given time. The age and sex of the whales using this area did not vary significantly from that of the population (Quintana-Rizzo et al. 2021). Since 2015, increased acoustic detections and survey effort in the Gulf of St. Lawrence have documented right whale presence there from late spring through the fall (Cole et al. 2016; Simard et al. 2019; DFO 2020). Photographic captures of right whales in the Gulf of St. Lawrence during the summers of 2015–2019 documented 48, 50, 133, 132, and 135 unique individuals using the region, respectively, with a total of 187 unique individuals documented over the five summers (Crowe et al. 2021). Individuals utilizing the Gulf of St. Lawrence foraging habitat exhibit site fidelity (Crowe et al. 2021), and individual variation in the use of this habitat is partially explained by maternal lineage (Bishop et al. 2022).

Genetic analyses based upon direct sequencing of mitochondrial DNA (mtDNA) have identified seven mtDNA haplotypes in the western North Atlantic right whale population, including heteroplasmy that led to the declaration of the seventh haplotype (Malik et al. 1999; McLeod and White 2010). Schaeff et al. (1997) compared the genetic variability of North Atlantic and southern right whales (*E. australis*) and found the former to be significantly less diverse, a finding broadly replicated by Malik et al. (2000). The low diversity in North Atlantic right whales might indicate inbreeding, but no definitive conclusion can be reached using current data. Modern and historic genetic population structures were compared using DNA extracted from museum and archaeological specimens of baleen and bone. This work suggested that the eastern and western North Atlantic populations were not genetically distinct (Rosenbaum et al. 1997, 2000). However, the virtual extirpation of the eastern stock and its lack of recovery in the last hundred years strongly suggest population subdivision over a protracted (but not evolutionary) timescale. Genetic studies concluded that the principal loss of genetic diversity occurred prior to the 18th century (Waldick et al. 2002). However, revised conclusions that nearly all the remains in the North American Basque whaling archaeological sites were bowhead whales (*Balaena mysticetus*) and not right whales (Rastogi et al. 2004; McLeod et al. 2008) contradict the previously held belief that Basque whaling during the 16th and 17th centuries was principally responsible for the loss of genetic diversity.

High-resolution (i.e., using 35 microsatellite loci) genetic profiling improved the understanding of genetic variability, the number of reproductively active individuals, reproductive fitness, parentage, and relatedness of individuals (Frasier et al. 2007, 2009). It has also helped fill gaps in our understanding of the species' age structure, calf development, calf survival, and weaning (Hamilton et al. 2023). Because the callosity patterns used to identify individual right whales take months to develop after a whale's birth, obtaining biopsy samples from calves on the calving grounds provides a means of genetically identifying calves later in life or after death. Between 1990 and 2010, only about 60% of all known calves were seen with their mothers in summering areas when their callosity patterns are stable enough to reliably make a photo-ID match later in life. The remaining 40% were not seen on a known summering ground. Because the calf's genetic profile is the most reliable way to establish parentage, if the calf is not sampled when associated with its mother early on, information such as age and familial relationships may be lost. From 1980 to 2001, there were 64 calves born that were not sighted later with their mothers and thus unavailable to provide age-specific mortality information (Frasier et al. 2007). Hamilton et al. (2022) reported that of the 470 calves observed between 1998 and 2018, 370 (78.7%) were biopsied, 293 as calves and 77 later in life, their identification linked by photographs. Of the 100 calves not biopsied during this period, 32 were sufficiently photographed to allow subsequent identification and aging, but 68 had yet to be identified other than as a unique calf.

Frasier (2007b) genetically examined the paternity of 87 calves born between 1980 and 2001. Although genetic profiles were available for 69% of all potential fathers in the population, paternity was assigned to only 51% of the calves, and all the sampled males were excluded as fathers of the remaining calves. The findings suggested that either the unsampled males were particularly successful or that the population of males, and the population as a whole, was larger than suggested by the photo-identification data (Frasier 2007b). However, a study comparing photo-identification and pedigree genetic data for animals known or presumed to be alive during 1980–2016 found that the presumed alive estimate is similar to the actual abundance of this population, which indicates that the majority of the animals have been photo-identified (Fitzgerald 2018).

POPULATION SIZE

Estimation of the western North Atlantic right whale stock size is based on a state-space model of the sighting histories of individual whales identified using photo-identification techniques (Pace et al. 2017; Pace 2021) with an accommodation of potential recruits based on observed calves (Linden 2024a,b). Population size was estimated using sighting histories constructed from the central photo-ID recapture database (curated at the New England Aquarium) as it existed on 13 September 2024, and included photographic information from all dedicated survey teams in the US and Canada up through 30 November 2023. Using a hierarchical, state-space Bayesian open population model of these histories (Linden 2024b) produced a median abundance value (Nest) in 2023 of 372 individuals (95%CI: 360-383; Table 1). Typically this model has relied on individual animals being photographically identifiable from their callosity patterns to be recruited into the population, which are typically not stable until animals are greater than 1 year old. However, a recent model development has directly addressed this challenge and individuals less than 1 year old are now included in the abundance estimate (Linden 2024a). 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 structure of the data. Because the statistically-based uncertainty is asymmetric about N, the credible interval may better characterize that uncertainty (as opposed to a CV that may appear in other stock assessment reports).

Table 1. Best and minimum abundance estimates in 2023 for western North Atlantic right whales (**Eubalaena glacialis*** ***) with Maximum Productivity Rate (R_{max}), Recovery Factor (F_r), and PBR.***

N_{est}	95% Credible Interval	60% Credible Interval	N_{min}	F_r	R_{max}	PBR
372	360–383	367–377	367	0.1	0.04	0.73

Historical Abundance

The total North Atlantic right whale population size pre-whaling is estimated between 9,075 and 21,328 based on extrapolation of spatially explicit models of right whale carrying capacity in the North Pacific (Monserrat et al. 2015). Basque whalers were thought to have taken right whales during the 1500s in the Strait of Belle Isle region (Aguilar 1986); however, genetic analysis has shown that nearly all of the remains found in that area are, in fact, those of bowhead whales (Rastogi et al. 2004; Frasier et al. 2007). This stock of right whales may have already been substantially reduced by the time colonists in Massachusetts started whaling in the 1600s (Reeves et al. 2001, 2007). A modest but persistent whaling effort along the coast of the eastern U.S. lasted three centuries, and the records include one report of 29 whales killed in Cape Cod Bay in a single day in January 1700. Reeves et al. (2007) calculated that a minimum of 5,500 right whales were taken in the western North Atlantic between 1634 and 1950, with nearly 80% taken in a 50-year period between 1680 and 1730. They concluded, “there were at least a few thousand whales present in the mid-1600s.” The authors cautioned, however, that the record of removals is incomplete, the results were preliminary, and refinements are required. Based on back calculations using the present population size and growth rate, the population may have numbered fewer than 100 individuals by 1935 when international protection for right whales came into effect (Hain 1975; Reeves et al. 1992; Kenney et al. 1995). However, little is known about the population dynamics of right whales in the intervening years.

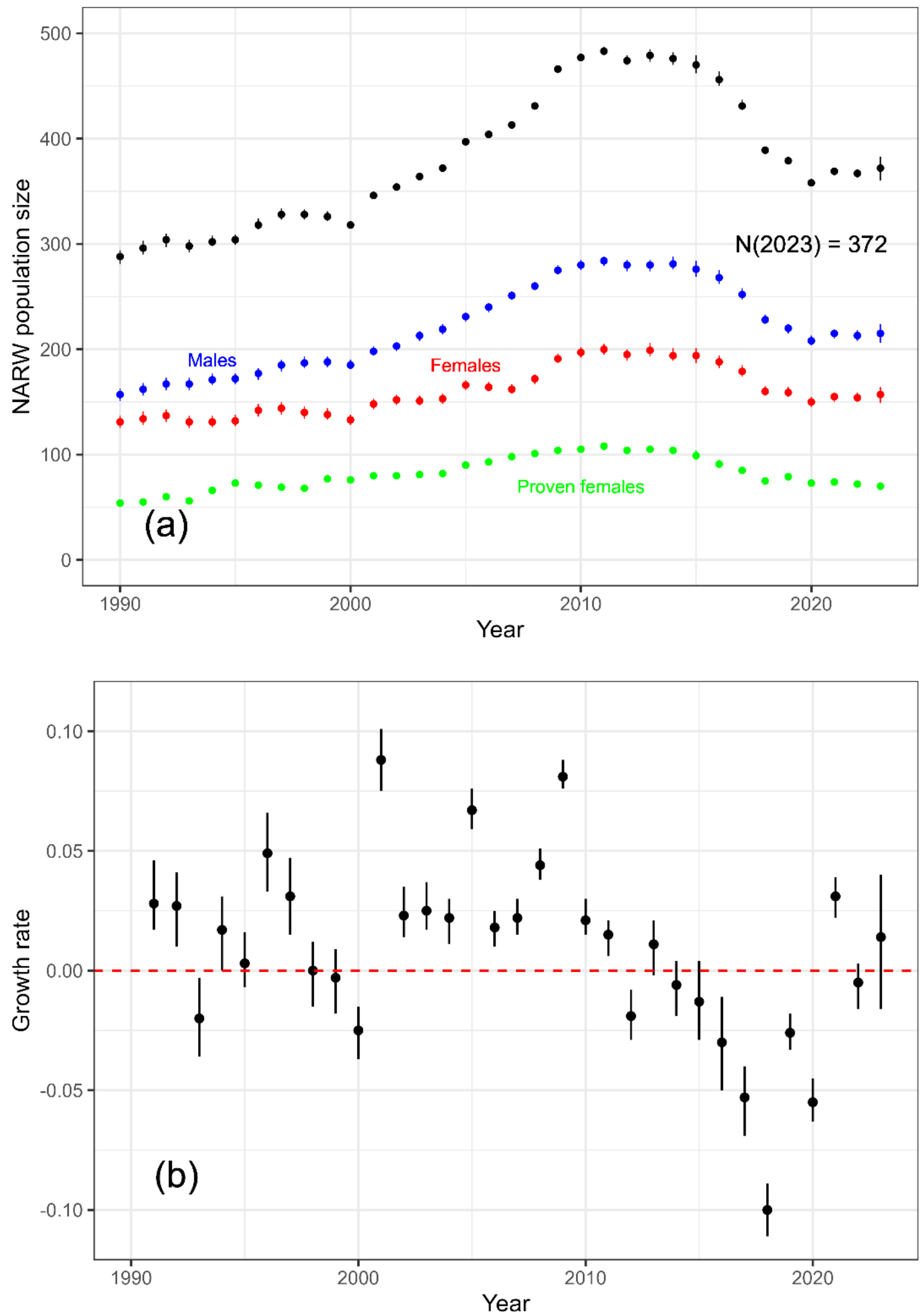
Minimum Population Estimate

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 methods of Pace et al. (2017) and refinements of Pace (2021) and Linden (2024a). This is roughly equivalent to the 20th percentile of the log-normal distribution as specified by Wade and Angliss (1997). The median estimate of abundance for adult and subadult western North Atlantic right whales is 372, and the minimum population estimate is 367 individuals (based on photographic information collected through 30 November 2023; Table 1).

Current Population Trend

The population growth rate reported for the period of 1986–1992 by Knowlton et al. (1994) was 2.5% (CV=0.12), suggesting that the stock was recovering slowly, but that number may have been influenced by the discovery phenomenon as existing whales were recruited to the catalog. Work by Caswell et al. (1999) suggested that crude survival probability declined from about 0.99 in the early 1980s to about 0.94 in the late 1990s. The decline was statistically significant. Additional work conducted in 1999 was reviewed by an IWC workshop on status and trends in this population (IWC 2001); the workshop concluded based on several analytical approaches that survival had indeed declined in the 1990s. Although capture heterogeneity could negatively bias survival estimates, the workshop concluded that this factor could not account for the entire observed decline, which appeared to be particularly marked in adult females. Another workshop was convened by NMFS in September 2002, and it reached similar conclusions regarding the decline in the population (Clapham 2002). At the time, the early part of the recapture series had not been examined for excessive retrospective recaptures which had the potential to positively bias the earliest estimates of survival as the catalog was being developed.

Examination of the abundance estimates for the years 1990–2011 (Figures 2a, 2b) suggests that abundance increased at about 2.6% per annum from posterior median point estimates of 288 individuals in 1990 to 483 in 2011. There was a 100% chance that abundance declined from 2011 to 2020 when the final estimate was 358 individuals. The overall abundance decline between 2011 and 2020 was 26% (derived from 2011 and 2020 median point estimates). There has been a considerable change in right whale habitat-use patterns in areas where most of the population had been observed in previous years (e.g., Davies et al. 2017), exposing the population to new anthropogenic threats (Hayes et al. 2018). Pace (2021) found a significant decrease in mean survival rates since 2010, correlating with the observed change in area-use patterns. This pattern persists in Linden (2024b), though survival has increased since 2020 (Figure 2c). The apparent change in habitat use also had the effect that, despite relatively constant effort to find whales in traditional areas, the chance of photographically capturing individuals decreased in the mid-2010s (Figure 3). However, the methods in Pace et al. (2017) and Linden (2024b) account for changes in capture probability.


500
400
300
200
100
0
NARW population size
N(2023) = 372
Males
Females
Proven females
(a)
1990
2000
2010
2020
Year
0.10
0.05
0.00
-0.05
-0.10
Growth rate
(b)
1990
2000
2010
2020
Year

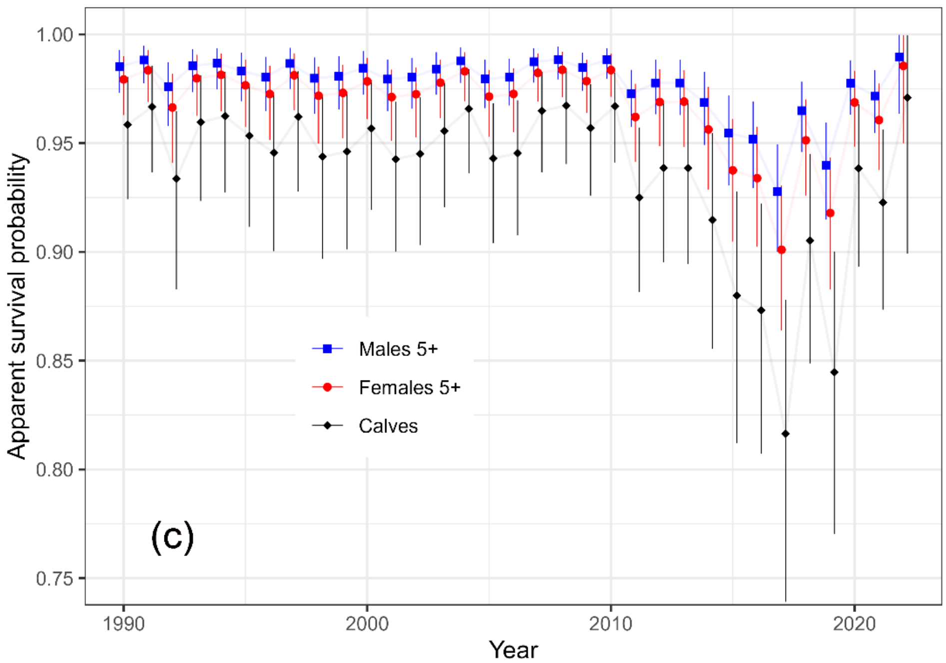


Figure 2. (a) Abundance estimates for North Atlantic right whales. Estimates are the median values of a posterior distribution from modeled capture histories. Also shown are sex-specific abundance estimates, including estimates for both adult females and females of all ages. (b) Annual population growth rates from the abundance values. (c) Sex-specific survival rate estimates. All graphs show associated 95% credible intervals.

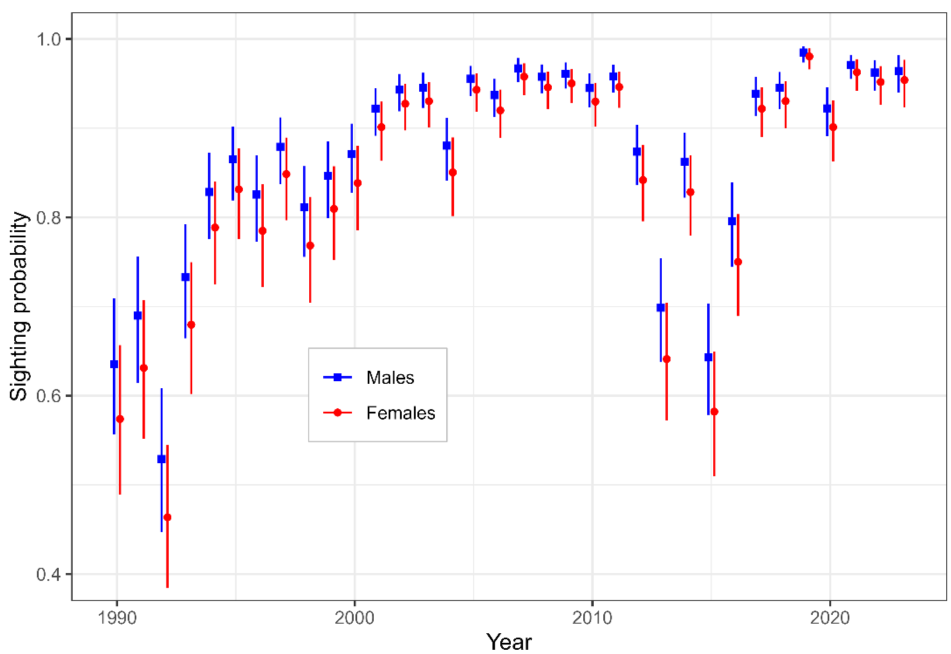


Figure 3. Estimated recapture probability and associated 95% credible intervals of North Atlantic right whales 1990–2023 based on a Bayesian mark-resight/recapture model allowing random fluctuation among years for survival rates, treating capture rates as fixed effects over time, and using both observed and known states as data (from Linden 2024b). Males are shown in blue with squares; females are shown in red with circles.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

Knowlton et al. (1994) reported that during 1980–1992, 145 calves were born to 65 identified females (not including six documented neonate mortalities), and the number of calves born annually ranged from 5 to 17, with a mean of 11.2. The mean calving interval, based on 86 records from 1976-1992, was 3.67 years. There was an indication that calving intervals may have been increasing over time, although the trend was not statistically significant (P=0.083). While the pool of reproductively active females climbed from 1980 to 1986 as photographic effort captured mothers new to the study, it became static at approximately 51 individuals from 1987–1992 (Knowlton et al. 1994). Since 1993, calf production has been more variable than a simple stochastic model would predict.

During 1990–2023, at least 518 calves were born into the population (including neonate mortalities). The number of calves born annually ranged from 0 to 39 with a mean of 14.9 (SD=8.7).

Population productivity is indexed by dividing the number of detected calves by the estimated abundance each year (Apparent Productivity Index [API]). Productivity for this stock has been highly variable over time and has been characterized by periodic swings in per capita birth rates (Figure 4). Notwithstanding the high variability observed, as expected for a small population, productivity in North Atlantic right whales lacks a definitive trend. Corkeron et al. (2018) found that during 1990–2016, calf count rate increased at 1.98% per year with outlying years of very high and low calf production. This rate is approximately a third of that found for three different southern right whale (*Eubalaena australis)* populations during the same time period (5.3–7.2%; Corkeron et al. 2018). Based on the most recent population estimate, the number of females known to have calved that are likely still alive is 70 [95% CI: 62, 78] (Linden 2024b).

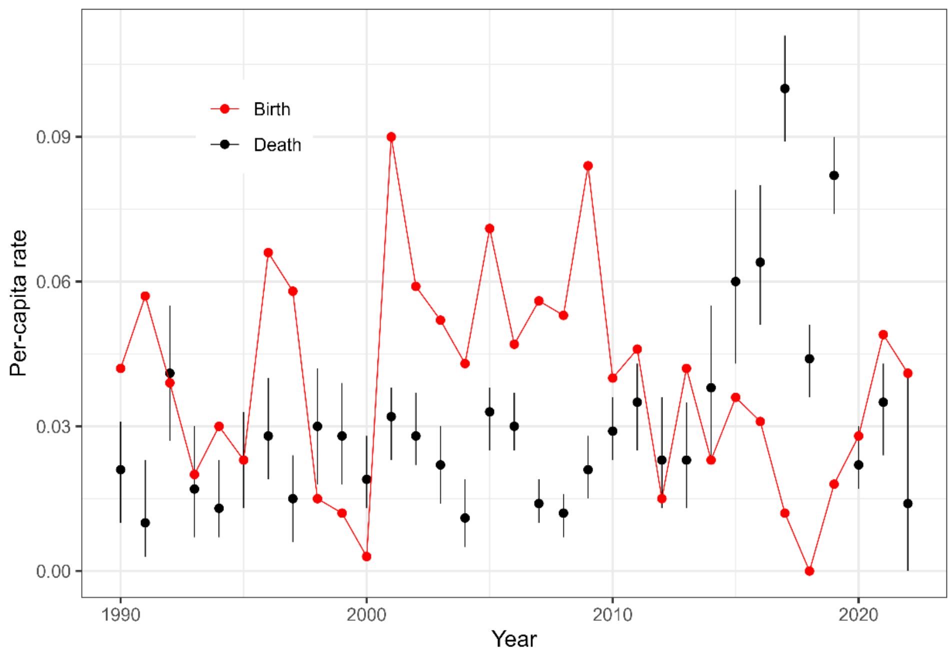


Figure 4. North Atlantic right whale per capita death rate and birth rate (red line, closed circles) with associated 95% credible intervals, 1990–2022.

The available evidence suggests that at least some of the observed variability in the calving rates of North Atlantic right whales is related to variability in nutrition (Fortune et al. 2013; Knowlton et al. 2022). There is also clear evidence that North Atlantic right whales are growing to shorter adult lengths than in earlier decades (Stewart et al. 2021) and are in poor body condition compared to southern right whales (Christiansen et al. 2020, Miller et al. 2011), as well as compared to the population's body condition in the past (Knowlton et al. 2022). Stewart et al. (2022) found that smaller females have longer inter-birth intervals than larger females. All these changes may result from a combination of documented regime shifts in primary feeding habitats (Meyer-Gutbrod and Greene 2014; Meyer-Gutbrod et al. 2021; Meyer-Gutbrod et al. 2022; Record et al. 2019) and increased energy expenditures related to non-lethal entanglements (Rolland et al. 2016; Pettis et al. 2017; van der Hoop et al. 2017). Despite management actions, overall entanglement rates as measured by the rate at which scars are acquired by living North Atlantic right whales (Hamilton et al. 2020; Figure 5) remain high.

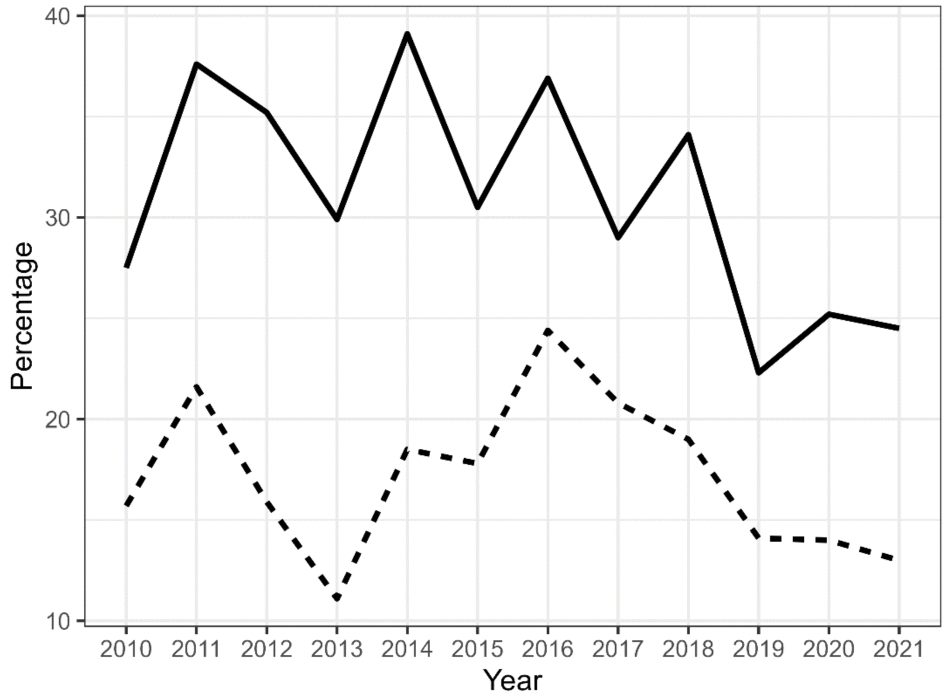


Figure 5. North Atlantic right whale entanglement rates estimated by monitoring scars on living whales. The crude entanglement rate (dashed line) is the proportion of whales seen with newly discovered entanglement scars; the year the scar was detected may not represent the year the entanglement occurred. The annual entanglement rate (solid line) is the minimum rate of entanglement, derived from the proportion of whales with new scars that were adequately photographed in both years of sequential combinations (e.g., 2017/2018; data from Hamilton et al. 2023).

An analysis of the age structure of this population found that it contained a smaller proportion of juvenile whales than expected, only 26–31%, which may reflect lowered recruitment and/or high juvenile mortality (Hamilton et al. 1998; IWC 2001). By 2022, only 14.5% of the whales presumed alive were confirmed juveniles (Hamilton et al. 2023). Calf and perinatal mortality was estimated by Browning et al. (2010) to be between 17 and 45 animals during the period 1989 and 2003. It is possible that the apparently low reproductive rate for this species is due in part to an unstable age structure or to reproductive dysfunction in some females. However, few data are available on either factor, and senescence has not been documented for any baleen whale.

The maximum net productivity rate is unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be the default value of 0.04. This value is based on theoretical modeling showing that cetacean populations may not grow at rates much greater than 4% given the constraints of their reproductive life history (Barlow et al. 1995). Projection models suggest that this rate could be 4% per year if female survival was the highest recorded over the time series from Pace et al. (2017). Reviewing the available literature, Corkeron et al. (2018) showed that female mortality is primarily anthropogenic and concluded that anthropogenic mortality has limited the recovery of North Atlantic right whales. In a similar effort, Kenney (2018) back-projected a series of scenarios that varied entanglement mortality from observed to zero. Using a scenario with zero entanglement mortality, which included 15 "surviving" females, and a five-year calving interval, the projected population size including 26 additional calf births would have been 588 by 2016. Single-year production has exceeded 0.04 in this population several times, but those outputs are not likely sustainable given the 3-year minimum interval required between successful calving events and the small fraction of reproductively active females. This is likely related to synchronous calving that can occur in capital breeders under variable environmental conditions. Hence, uncertainty exists as to whether the default value is representative of maximum net productivity for this stock, but it is unlikely that it is much higher than the default.

POTENTIAL BIOLOGICAL REMOVAL

Potential biological removal (PBR) is the product of minimum population size, one-half the maximum net productivity rate and a recovery factor for endangered, depleted, or threatened stocks, or stocks of unknown status relative to OSP (MMPA Sec. 3. 16 U.S.C. 1362; Wade and Angliss 1997). The recovery factor for right whales is 0.1 because this species is listed as endangered under the Endangered Species Act (ESA). The minimum population size is 367. The maximum productivity rate is 0.04, the default value for cetaceans. PBR for the western North Atlantic stock of the North Atlantic right whale is 0.73 (Table 1).

ANNUAL HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

For the period 2018 through 2022, the annual detected (i.e., observed) human-caused mortality and serious injury to right whales averaged 5.45 individuals per year (Table 2). This is derived from two components: 1) incidental fishery entanglement records at 3.95 per year and 2) vessel strike records averaging 1.5 per year.

Injury determinations are made based upon the best available information; these determinations may change with the availability of new information (Henry et al. 2024). Only records considered to be confirmed human-caused mortalities or serious injuries are reported in the observed mortality and serious injury (M/SI) rows of Table 2.

Annual rates calculated from detected mortalities are a negatively-biased accounting of human-caused mortality; they represent a definitive lower bound. Detections are irregular, incomplete, and not the result of a designed sampling scheme. Research on other cetaceans has shown the actual number of deaths can be several times higher than observed (Wells et al. 2015; Williams et al. 2011). The hierarchical Bayesian, state-space model used to estimate North Atlantic right whale abundance (Pace et al. 2017) can also be used to estimate total mortality for adults and juveniles; the estimates are exclusive to those individuals old enough to enter the sightings catalog (>0.5 years of age). The estimated rate of total non-calf mortality using this modeling approach is 14.8 animals (non-calves) per year, or 74 animals total, for the period 2018–2022 (Linden 2024b). This estimated total mortality accounts for detected mortality and serious injury (injuries likely to lead to death), as well as undetected (cryptic) mortality within the population. Figure 6 shows the estimates of total mortality for 1990–2022 using the state-space model. The model's estimated 14.8 total mortality rate for the 5-year period 2018–2022 is 2.7 times higher than the 5.45 *detected* mortality and serious injury value reported for the same period. An analysis of right whale mortalities between 2003 and 2018 found that of the 33 examined non-calf carcasses for which cause of death could be determined, all mortality was human-caused (Sharp et al. 2019). Based on these findings, 100% of the estimated mortality of 14.8 animals (non-calves) per year is assumed to be human-caused. Sharp et al. (2019) found that 5 of 10 (50%) calf mortalities were from natural causes.

There is currently insufficient information to apportion the estimated total right whale mortality to that occurring in U.S. waters. To apportion the estimated total right whale mortality by cause, e.g., entanglement versus vessel collision, we used the proportion of observed mortalities and serious injuries from entanglement compared to those from vessel collision for the period 2018–2022. During this period, 72% of the observed mortality and serious injury was the result of entanglement and 28% was from vessel collisions. Applying these proportions to the estimated total mortality of adults and juveniles provides an estimate of 54 total entanglement deaths and 20 total vessel collision deaths during 2018–2022 (Table 2). These estimates may be biased if there is significant bias in the detection of entanglement versus vessel collision serious injuries. From 1990 to 2017, NMFS determined a total of 62 right whales were seriously injured, and of these, 54 (87%) were due to entanglement. However, during the same period, of the 41 right whale carcasses examined for cause of death, 21 (51%) were attributed to vessel collision and 20 (49%) to entanglement. Moore et al. (2004) and Sharp et al. (2019) theorized that the underrepresentation of entanglement deaths in examined carcasses may be the result of weight loss in chronically entangled whales, who can become negatively buoyant and sink at the time of death, whereas whales killed instantly by vessel collision may remain available for detection for a longer period and are more likely to be recovered for examination. However, floating carcasses of whales, which move only by wind and currents, may not be carried into areas where detection is likely, whereas entangled whales may continue to swim and carry gear for days to years (see van der Hoop et al. 2017) and move into areas patrolled by survey teams. Based on records of mortalities and serious injuries maintained by the NMFS Greater Atlantic and Southeast Regional Offices between 2001–2020, 59% of all right whale serious injuries were first documented by survey teams, whereas only 19% of right whale carcasses were first discovered by survey teams. The visibility of some entanglements may add to the likelihood of serious injury detection, whereas blunt trauma from a vessel collision may not be externally detectable. Both Pace et al. (2021) and Moore et al. (2020) recommend continued research into the potential mechanisms creating the disparity between apparent causes of serious injuries and necropsy results.

Table 2. Annual estimated and observed human-caused mortality and serious injury for the North Atlantic right whale (*Eubalaena glacialis*). Estimated total mortality is derived from annual population estimates for adults and juveniles from 2018–2022 (Linden 2024b). Observed values are from confirmed interactions from 2018–2022.

Years	Source	Total	Annual Average
2018–2022	**Estimated total adult and juvenile mortality**	**74**	**14.8**
	Estimated adult and juvenile incidental fishery-related mortality	**54**	**10.8**
	Estimated adult and juvenile vessel collision mortality	**20**	**4.0**
2018–2022	Detected total human-caused M/SI[a]	27.25	5.45
	Detected incidental fishery-related M/SI[a,b]	19.75	3.95
	Detected vessel collision M/SI[a]	7.5	1.5
	Fishery-related SI prevented[c]	2	0.4

a. Observed serious injury events with decimal values were counted as 1 for this comparison.
b. The observed incidental fishery interaction count does not include fishery-related serious injuries that were prevented by disentanglement.
c. Fishery-related serious injuries prevented are a result of successful disentanglement efforts.

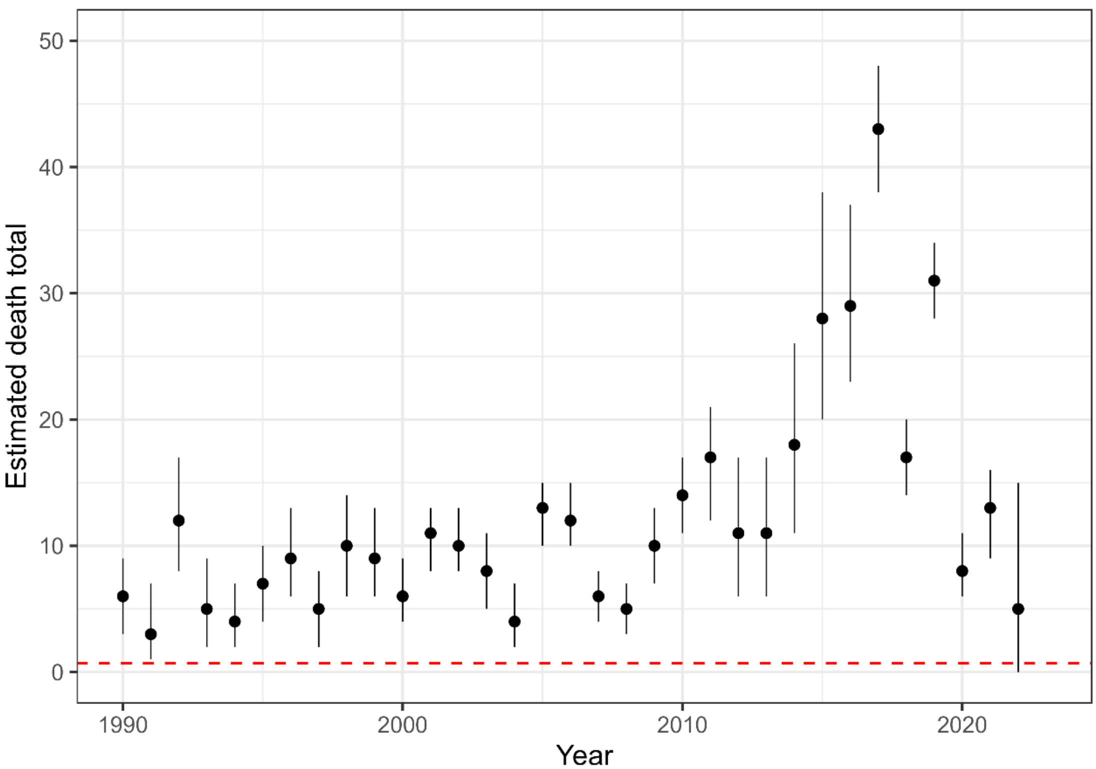


Figure 6. Time series of estimated total right whale mortalities, 1990–2022. Red dashed line indicates Potential Biological Removal (PBR) level.

The small population size and low annual reproductive rate of right whales suggest that human sources of mortality have a greater effect relative to population growth rates than for other whale species (Corkeron et al. 2018). The principal factors preventing growth and recovery of the population are entanglement and vessel strikes. Between 1970 and 2018, 124 right whale mortalities were recorded (Knowlton and Kraus 2001; Moore et al. 2005; Sharp et al. 2019). Of these, 18 (14.5%) were calves that were believed to have died from perinatal complications or other natural causes. Of the remainder, 26 (21.0%) resulted from vessel strikes, 26 (21.0%) were related to entanglement in fishing gear, and 54 (43.5%) were of unknown cause. At a minimum, therefore, 42% of the observed total for the period and 43% of the 102 non-calf deaths were attributable to human impacts (calves accounted for six deaths from vessel strikes and two from entanglements). However, when considering only those cases where cause of death could be determined, 100% of non-calf mortality was human-caused.

The details of a particular mortality or serious injury record often require a degree of interpretation (Moore et al. 2005; Sharp et al. 2019). The cause of death is based on analysis of the available data; additional information may result in revisions. When reviewing Table 3 below, several factors should be considered: 1) a vessel strike or entanglement may have occurred at some distance from the location where the animal is detected/reported; 2) the mortality or injury may involve multiple factors (e.g., whales that have been both vessel struck and entangled are not uncommon); 3) the actual vessel or gear type/source is often uncertain; and 4) entanglements may involve several types of gear. Beginning with the 2001 Stock Assessment Report, Canadian records have been incorporated into the mortality and serious injury rates to reflect the effective range of this stock. However, because whales have been known to carry gear for long periods of time and travel great distances before being detected (see van der Hoop et al. 2017; Morin et al. 2020), and recovered gear is often not adequately marked, it is difficult to assign most entanglements to the country of origin. It is not known how the disruption of survey efforts by COVID-19 virus precautions may have impacted the detection of serious injuries or mortalities in 2020 and 2021.

It should be noted that entanglement and vessel collisions may not seriously injure or kill an animal directly but may weaken or otherwise affect a whale's reproductive success (van der Hoop et al. 2017; Corkeron et al. 2018; Christiansen et al. 2020; Stewart et al. 2021). The NMFS serious injury determinations for large whales commonly include animals carrying gear when these entanglements are constricting or are determined to interfere with foraging (Henry et al. 2024). Successful disentanglement and subsequent resightings of these individuals in apparent good health are criteria for downgrading an injury to non-serious. However, these and other non-serious injury determinations should be considered to fully understand anthropogenic impacts to the population, especially in cases where females' fecundity may be affected.

Fishery-Related Mortality and Serious Injury

Not all mortalities are detected, but reports of known mortality and serious injury relative to PBR, as well as total human impacts, are contained in the records maintained by the New England Aquarium and the NMFS Greater Atlantic and Southeast Regional Offices. These records were reviewed, and those determined to be human-caused are detailed in Table 3. Information from an entanglement event often does not include the detail necessary to assign the entanglements to a particular fishery or location.

Although disentanglement is often unsuccessful or not possible for many cases, there are several documented cases of entanglements for which the intervention by disentanglement teams averted a likely serious-injury determination. See Table 2 for the annual average of serious injuries prevented by disentanglement.

Whales often free themselves of gear following an entanglement event, and as such, scarring may be a better indicator of fisheries interaction rates than entanglement records. Scarring rates suggest that entanglements occur at about an order of magnitude more often than detected from observations of whales with gear on them. Knowlton et al. (2012) reviewed scarring on identified individual right whales over a period of 30 years (1980–2009), documenting 1,032 definite, unique entanglement events on the 626 individual whales. Most individual whales (83%) were entangled at least once, and over half of them (59%) were entangled more than once. About a quarter of the individuals identified in each year (26%) were entangled in that year. Juveniles and calves were entangled at higher rates than were adults. Moore et al. (2021) reported that between 1980 and 2017, 86.1% (642 of 746) individual whales identified had evidence of entanglement interactions. Analysis of whales carrying entangling gear also suggest that entanglement wounds have become more severe since 1990, possibly due to increased use of stronger lines in fixed fishing gear (Knowlton et al. 2016).

Analyses of entanglement trends indicate that mitigation measures implemented prior to 2010 had not been effective at reducing large whale mortality. Knowlton et al. (2012) concluded from their analysis of right whale entanglement scarring rates from 1980–2009 that management efforts of the prior decade had not reduced right whale encounters with gear, and that the rate of serious entanglements (whales bearing gear or with a cut deeper than 8cm) had increased. Using observed mortalities of eight large whale species from 1970–2009, van der Hoop et al. (2013) found an increasing trend in entanglement mortality despite regulatory efforts. Pace et al. (2014), analyzing entanglement rates and serious injuries due to entanglement of four large whale species during 1999–2009, found an increase in annual entanglement rates but no significant trend in entanglement-related mortality, indicating that mitigation measures implemented prior to 2009 had not been effective at reducing large whale mortality due to commercial fishing. Since 2009, new entanglement mitigation measures (72 FR 193, 05 October 2007; 79 FR 124, 27 June 2014; 86 FR 51970, 17 September 2021; 87 FR 11590, 02 March 2022) have been implemented as part of the Atlantic Large Whale Take Reduction Plan, but their effectiveness has yet to be formally evaluated. One difficulty in assessing mitigation measures is the need for a statistically significant time series to determine effectiveness.

Other Mortality

Vessel strikes are a major cause of mortality and injury to right whales (Kraus 1990; Knowlton and Kraus 2001, van der Hoop et al. 2012). Records of vessel strike mortality and serious injury to right whales from 2017 through 2021 are summarized in Table 3. Researchers have identified increasing vessel speed as a factor in lethal vessel strike events involving whales (Vanderlaan and Taggart 2007) and inferred a strong relationship between vessel speed and the likelihood of interactions (Conn and Silber, 2013). Using simple biophysical models, Kelley et al. (2020) determined that whales can be seriously injured or killed by vessels of all sizes and that a collision with a 50-ton vessel transiting at seven knots has a probability of lethality greater than 50%.

In 2008, NOAA Fisheries implemented the North Atlantic right whale vessel speed regulations (50 CFR 224.105) in an effort to reduce vessel strike mortality. Since this rule was established, there have been several evaluations of vessel compliance with the rule and its effectiveness at reducing vessel strikes of right whales (Silber and Bettridge 2012, Laist et al. 2014, van der Hoop et al. 2015, Hayes et al., 2018). Most recently, NMFS (2020) found that vessel compliance with the speed rule varied across Seasonal Management Areas with apparent compliance during the 2018-2019 season reaching 81% coastwide. In August 2022, NMFS proposed substantial changes to the speed rule to further reduce ongoing lethal vessel strikes of right whales in U.S. waters, which was supported by a coast wide vessel strike risk assessment (Garrison et al. 2022).

An Unusual Mortality Event was established for North Atlantic right whales in June 2017 due to elevated strandings along the Northwest Atlantic Ocean coast, especially in the Gulf of St. Lawrence region of Canada. There were 34 dead whales documented through December 2022: 11 vessel strike, 9 entanglement, 1 perinatal, 3 unknown, and 10 unexamined. Additionally, 30 free-swimming whales were documented as being seriously injured (2 vessel strike, 27 entanglement, and 1 abandoned dependent calf) and 45 morbidity cases were documented with sublethal injuries and/or illness (3 vessel strike, 35 entanglement, 2 unknown injury, and 5 poor body condition). The UME entanglement serious injury tallies include events where serious injury was averted by disentanglement and abandoned dependent calves Therefore, some of the serious injuries listed in the UME are not captured in Table 3. The latest UME updates are available at (https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2024-north-atlantic-right-whale-unusual-mortality-event).

Table 3. Observed human-caused mortality and serious injury records of right whales: 2018–2022[a]

Date[b]	Fate	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
01/22/2018	Mortality	3893	off Virginia Beach, VA	EN	1	CN	PT	Extensive, severe constricting entanglement including partial amputation of right pectoral accompanied by severe proliferative bone growth. COD - chronic entanglement. Gear consistent with a portion of a Canadian snow crab set.
02/15/2018	Serious Injury	3296	off Jekyll Island, GA	EN	1	XU	NP	No gear present, but extensive recent injuries consistent with constricting gear on right flipper, peduncle, and leading fluke edges. Large portion of right lip missing. Extremely poor condition - emaciated with heavy cyamid load. No resights.
07/13/2018	Prorated Injury	3312	Gulf of St Lawrence, QC	EN	0.75	CN	NR	Free swimming with line through mouth and trailing both sides. Full configuration unknown - unable to confirm extent of flipper involvement. No resights. Entangled in Canadian gear of unknown origin.

Date[b]	Fate	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
07/30/2018	Prorated Injury	3843	off Grand Manan, NB	EN	0.75	XC	GU	Free-swimming with buoy trailing 70 ft behind whale. Attachment point(s) unknown. Severe, deep, raw injuries on peduncle & head. Partial disentanglement. Resighted with line exiting left mouth and no trailing gear. Possible rostrum and left pectoral wraps, but unable to confirm. Improved health, but final configuration unclear. No additional resights.
08/25/2018	Mortality	4505	Martha's Vineyard, MA	EN	1	XU	NP	No gear present. Evidence of constricting pectoral wraps with associated hemorrhaging. COD - acute entanglement
10/14/2018	Mortality	3515	off Nantucket, MA	EN	1	XU	NP	No gear present, but evidence of constricting wraps across ventral surface and at pectorals. COD - acute, severe entanglement.
12/1/2018	Serious Injury	3208	off Nantucket, MA	EN	1	XU	NP	No gear present. Evidence of new, healed, constricting body wrap. Health decline evident - gray, lesions, thin. Previously reported as 24Dec2018
12/20/2018	Prorated Injury	2310	off Nantucket, MA	EN	0.75	XU	NR	Free-swimming with open bridle through mouth. Resight in Apr2019 shows configuration changed, but unable to determine full configuration. Health appears stable. No additional resights
6/4/2019	Mortality	4023	Gulf of St Lawrence, QC	VS	1	CN	-	Abrasion, blubber hemorrhage, and muscle contusion caudal to blowholes consistent with pre-mortem vessel strike
6/20/2019	Mortality	1281	Gulf of St Lawrence, QC	VS	1	CN	-	Sharp trauma penetrating body cavity consistent with vessel strike. Vessel >65 ft based on laceration dimensions.
6/25/2019	Mortality	1514	Gulf of St Lawrence, QC	VS	1	CN	-	Fractured ear bones, skull hemorrhaging, and jaw contusion consistent with blunt trauma from vessel strike.
6/27/2019	Mortality	3450	Gulf of St Lawrence, QC	VS	1	CN	-	Hemothorax consistent with blunt force trauma.
7/4/2019	Serious Injury	3125	Gulf of St Lawrence, QC	EN	1	CN	PT	Free-swimming with extensive entanglement involving embedded head wraps, flipper wraps, and trailing gear. Baleen damaged and protruding from mouth. Partially disentangled: 200-300 ft of line removed. Embedded rostrum and blowhole wraps remain, but now able to open mouth. Significant health decline. No resights. Gear consistent with a portion of a Canadian snow crab set.

Date[b]	Fate	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
8/6/2019	Mortality	1226	Gulf of St Lawrence, QC	EN	1	CN	NR	Constricting rostrum wraps, in anchored or weighted gear. Carcass found with no gear present but evidence of extensive constricting entanglement involving rostrum, gape, both flippers. COD - probable acute entanglement. Entangled in line of Canadian origin.
1/8/2020	Serious Injury	5010	off Altamaha Sound, GA	VS	1	US	-	Dependent calf with deep lacerations to head and lips, exposing bone. No resights post 15Jan2020.
2/24/2020	Serious Injury	3180	off Nantucket, MA	EN	1	XU	NR	Free-swimming with bullet buoy lodged in right mouthline, far forward. Line seen exiting left gape. No trailing gear visible. Poor condition - emaciated with heavy cyamid load. No resights.
3/16/2020	Prorated Injury	-	Georges Bank, US EEZ	EN	0.75	XU	NR	Free-swimming with 2 polyballs trailing approximately 30 ft aft of flukes. Attachment point(s) and full configuration unknown. No resights
6/24/2020	Mortality	5060	off Elberon, NJ	VS	1	US	-	Dependent calf with deep lacerations along head and peduncle from 2 separate vessel strikes. Head lacerations were chronic and debilitating while the laceration to peduncle was acutely fatal. Proximate COD - sharp and blunt vessel trauma. Ultimate COD - hemorrhage and paralysis.
10/11/2020	Serious Injury	4680	2.7 nm E off Sea Bright, NJ	EN	1	XU	NR	Free-swimming with 2 lines embedded in rostrum, remaining configuration unknown. Extremely poor condition - emaciated with greying skin. Large, open lesion on left side of head. No resights.
10/19/2020	Mortality	3920	off Nantucket, MA	EN	1	CN	PT	Free-swimming with deeply embedded rostrum wrap. Partial disentanglement - removed 100 ft of trailing line and attached telemetry. Health deteriorated over subsequent sightings - emaciation, increased cyamid load, sloughing skin. Carcass documented on 27Feb2021 off Florida. No necropsy conducted but COD from chronic entanglement most parsimonious. Gear consistent with Canadian snow crab.
1/11/2021	Serious Injury	1803	off Fernandina Beach, FL	EN	1	XU	NR	Free-swimming with constricting wraps at peduncle and fluke insertion and around left fluke blade. No resights post 12Jan2021.
2/12/2021	Mortality	5130	St. Augustine, FL	VS	1	US	-	Dependent calf. 54 ft vessel traveling at 21 kts self-reported strike. Calf stranded on 13Feb2021. Deep lacerations across back and head with associated fractured ribs and skull.

Date[b]	Fate	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
2/12/2021	Prorated Injury	3230	St. Augustine, FL	VS	.52	US	-	54 ft vessel traveling at 21 kts self-reported strike. Lactating female with lacerations of unknown depth resighted on 16Feb2021. Dependent calf died from injuries received (see 12Feb2021 mortality event). No additional resights.
3/10/2021	Serious Injury	3560	off Sandwich, MA	EN	1	CN	GU	Free-swimming with constricting rostrum wrap and trailing gear 300 ft. Partial disentanglements on 3 separate occasions removed sections of trailing gear. Successful calving event in Dec2021. Stable health until 23Jul2022 when appeared thinner, increased lesions & cyamids, and discolored rostrum. Dependent calf (see 02Dec2021 event) last sighted on 26Apr2022, not present at 23Jul2022 or 22Sep2022 sightings. (Carrying new entanglement and in significant health decline at 22Sep2022 sighting.) No additional resights. Gear consistent with rope from Canadian trap gear.
7/13/2021	Serious Injury	4615	Gulf of St Lawrence, QC	EN	1	CN	NR	Recent (within hours) entanglement - Line through mouth and over rostrum leading down towards right flipper and back towards flukes. Constricting line over peduncle and down to weighted gear. Resighted on 14Jul2021 with rostrum wrap leading down to weighted gear, no gear on fluke or peduncle area. No additional resights. Entangled in rope of Canadian origin.
12/2/2021	Serious Injury	2022 calf of 3560	off Cumberland Island, GA	EN	1	CN	-	Dependent calf of seriously injured lactating female (see 10Mar2021 event). No resights post 26Apr2022.
5/19/2022	Prorated Injury	3823	Gulf of St. Lawrence, QC	EN	0.75	XC	NR	Free-swimming with line through mouth, possible bridling under chin, and trailing with one line ending hundreds of feet and the other descends to depth. Full configuration unknown. No resights.
6/30/2022	Serious Injury	1403	Gulf of St Lawrence, QC	EN	1	XC	NR	Free-swimming with tight body wrap. Attachment point(s) unknown. No resights post 07Jul2022.
8/20/2022	Mortality	5120	Gulf of St Lawrence, QC	EN	1	US	PT	Free-swimming with at least 4 constricting peduncle wraps and 1 fluke blade wrap. Resights through 12Jun2023 show deterioration in health - skin sloughing and increased cyamid load. Carcass found on 28Jan2024. Embedded in peduncle with associated hemorrhaging, thin body condition consistent with chronic entanglement. Entangled in a buoy line with markings consistent with Maine state waters trap gear.

Date[b]	Fate	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
9/21/2022	Serious Injury	3560	off Nantucket, MA	EN	1[f]	XU	NR	Free-swimming with line through mouth and trailing to weighted gear. Possible flipper involvement. Heavy cyamid load. Still carrying constricting rostrum wrap from previous entanglement (see 10Mar2021 event). No resights

Assigned Cause	Observed five-year mean (US/CN/XU/XC)
Vessel strike	1.5 (0.7/0.8/0/0)
Entanglement	3.95 (0.2/1.55/1.7/0. 50)

a. For more details on events, see Henry et al. 2024. For full gear analysis, see https://www.fisheries.noaa.gov/new-england-mid-atlantic/marine-mammal-protection/atlantic-large-whale-take-reduction-plan.
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, NP=none present, NR=none recovered/received, PT=pot/trap, WE=weir.
f. Individual with 2 separate serious injury entanglement events. Only one is counted against PBR.

STATUS OF STOCK

This is a strategic stock because the average annual human-related mortality and serious injury exceeds PBR, and also because the North Atlantic right whale is listed as an endangered species under the ESA. The size of this stock is extremely low relative to OSP and, until recently, had been declining (Figure 2a). The North Atlantic right whale is considered one of the most critically endangered populations of large whales in the world (Clapham et al. 1999; NMFS 2017; IUCN 2020). The observed (and clearly biased low, Pace et al. 2021) human-caused mortality and serious injury was 7.1 right whales per year from 2018 through 2022. Using the refined methods in Linden (2024b), the estimated annual rate of total mortality of adults and juveniles for the period 2018–2022 was 14.8, which is 2.7 times larger than the 5.45 total derived from reported mortality and serious injury for the same period. Given that PBR has been calculated as 0.73, human-caused mortality or serious injury for this stock must be considered significant.

OTHER FACTORS THAT MAY BE AFFECTING THE STOCK

Habitat Issues

Beyond human-caused mortality and serious injury, there are other factors that may be causing a decline or impeding right whale recovery, or may become factors in the future. These include potential effects of climate change and impacts of emerging industries such as offshore wind energy and aquaculture development.

Baumgartner et al. (2017) discussed that ongoing and future environmental and ecosystem changes may displace *C. finmarchicus* or disrupt the mechanisms that create very dense copepod patches upon which right whales depend. Ocean warming in the Gulf of Maine has altered the availability of late stage *C. finmarchicus* to right whales, resulting in a sharp decline in sightings in the Bay of Fundy and Great South Channel over the last decade (Record et al. 2019; Davies et al. 2019; Meyer-Gutbrod et al. 2021) and an increase in sightings in Cape Cod Bay (Mayo et al. 2018; Ganley et al. 2019).

Climate change is also affecting the seasonal timing of the whales' presence in traditional habitats, leading to a mismatch with static management measures designed to reduce anthropogenic threats (Ganley et al. 2022; Pendleton et al. 2022). The Gulf of St. Lawrence has become an important habitat for a large portion of the population since at least 2015 (Simard et al. 2019; Crowe et al. 2021; Durette-Morin et al. 2022), which resulted in a substantial increase in anthropogenic mortality before management measures could be implemented (Davies and Brillant 2019). An Unusual Mortality Event was declared for the species as a result (https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2024-north-atlantic-right-whale-unusual-mortality-event). Gavrilchuk et al. (2021) suggested that ocean warming in the Gulf of St. Lawrence may eventually compromise the suitability of this foraging area for right whales, potentially displacing them further to the shelf waters east of Newfoundland and Labrador in search of dense *Calanus* patches.

Food limitation may contribute to a decline in the population's health and reproduction. Meyer-Gutbrod et al. (2022) found that the right whales' increased use of the Gulf of St. Lawrence over the last 10 years was driven by a decline in prey in the Gulf of Maine, and not an increase in prey in Canada. Knowlton et al. (2022) found that the apparent health of all whales in the population had declined significantly since the 1980s, including those not documented as injured.

Declining body sizes are a potential contributor to low birth rates over the past decade. Stewart et al. (2022) found that larger whales had shorter inter-birth intervals and produced more calves per potential reproductive year. A whale born in 2019 is now expected to reach a body length 1 m shorter than a whale born in 1981. Smaller whales may be the result of poor nutrition or sublethal injury, either to the whale or to their mother (Stewart et al. 2021). Reed et al. (2022) show that it is both the failure of the pre-breeding females to transition to reproducing females, as smaller whales have less capacity to gain sufficient condition to calve than larger females (Christiansen et al. 2020), as well as the mortality of reproducing females, that has contributed to the recent right whale population decline.

Offshore wind energy development along the east coast of the U.S. will introduce additional stressors to North Atlantic right whales and their habitat, such as noise and/or pressure, entanglement hazards, vessel traffic, and changes in oceanographic conditions. Potential impacts to North Atlantic right whales, depending on the stressors, include: hearing impairment; behavioral disturbance; avoidance of wind areas; injury and mortality (i.e., from entanglement or vessel strike); and changes in quality and availability of prey that may lead to reduced fitness (decreased survival and reproduction, Bailey et al. 2014; Barkaszi et al. 2021; Carpenter et al. 2016; Dorrell et al. 2022; Leiter et al. 2017; Maxwell et al. 2022; Quintana-Rizzo et al. 2021). While only a few projects in U.S. water are currently fully approved and under development, should the proposed development go forward as planned, the extensive overlap with their range would mean that in the future, any individual right whale may be exposed to multiple projects.

Expansions to the aquaculture industry, both inshore and offshore, may also affect North Atlantic right whales. Lines in the water for various types of aquaculture increase the potential for entanglement, both directly through whale interactions with aquaculture gear or secondarily through the entanglement of trailing gear on a whale with fixed aquaculture gear (Price et al. 2017). Increased vessel traffic in and around aquaculture farms will increase ambient noise levels and the risk of vessel strikes (Price et al. 2017). There may also be oceanographic changes to areas used for aquaculture that could affect the physical environment or create changes to prey availability.

REFERENCES CITED

Aguilar, A. 1986. A review of old Basque whaling and its effect on the right whales of the North Atlantic. Rep. Int. Whal. Comm. (Special Issue) 10:191–199.

Aschettino, J.M., D. Engelhaupt, A. Engelhaupt, M. Richlen, and M. Cotter. 2022. Mid-Atlantic baleen whale monitoring, Virginia Beach, Virginia: 2020/21 Annual Progress Report. U.S. Fleet Forces Command contract N62470-20-0016.

Aschettino, J.M., D. Engelhaupt, and A. Engelhaupt. 2023. Mid-Atlantic nearshore and mid-shelf baleen whale monitoring, Virginia Beach, Virginia: 2021/22 Annual Progress Report. U.S. Fleet Forces Command contract N62470-20-0016.

Bailey, H., K.L. Brookes and P.M. Thompson. 2014. Assessing environmental impacts of offshore wind farms: lessons learned and recommendations for the future. Squat. Biosyst. 10.

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

Barkaszi, M., M. Fonseca, T. Foster, A. Malhotra and K. Olsen. 2021. Risk assessment to model encounter rates between large whales and sea turtles and vessel traffic from offshore wind energy on the Atlantic OCS. Bureau of Ocean Management (BOEM). OCS Study. BOEM 2021-034. 85 pp.

Baumgartner, M.F. and B.R. Mate. 2005. Summer and fall habitat of North Atlantic right whales (*Eubalaena glacialis*) inferred from satellite telemetry. Can. J. Fish. Aq. Sci. 62:527–543.

Bishop, A.L., L.M. Crowe, P.K. Hamilton, and E.L. Meyer-Gutbrod. 2022. Maternal lineage and habitat use patterns explain variation in the fecundity of a critically endangered baleen whale. Front. Mar. Sci. 9:880910.DOI: 10.3389/fmars.2022.880910.

Bort, J., S. Van Parijs, P. Stevick, E. Summers and S. Todd. 2015. North Atlantic right whale *Eubalaena glacialis* vocalization patterns in the central Gulf of Maine from October 2009 through October 2010. Endanger. Spec. Res. 26:271–280.

Brown, M.W. and M.K. Marx. 2000. Surveillance, monitoring and management of North Atlantic right whales, *Eubalaena glacialis*, in Cape Cod Bay, Massachusetts: January to mid-May, 2000. Final report. Division of Marine Fisheries, Boston, Massachusetts. 52pp. http://www.mass.gov/eea/docs/dfg/dmf/programsandprojects/rwhale00.pdf

Browning, C.L., R.M. Rolland and S.D. Kraus. 2010. Estimated calf and perinatal mortality in western North Atlantic right whales (*Eubalaena glacialis*). Mar. Mamm. Sci. 26:648–662.

Carpenter, J.R., L. Merckelbach, U. Callies, S. Clark, L. Gaslikova and B. Baschek. 2016. Potential impacts of offshore wind farms on North Sea stratification. PLoS One 11:e0160830.

Caswell, H., S. Brault and M. Fujiwara. 1999. Declining survival probability threatens the North Atlantic right whale. Proc. Natl. Acad. Sci. USA 96:3308–3313.

Christiansen, F., S.M. Dawson, J.W. Durban, H. Fearnbach, C.A. Miller, L. Bejder, M. Uhart, M. Sironi, P. Corkeron, W. Rayment, E. Leunissen, E. Haria, R. Ward, H.A. Warick, I. Kerr, M.S. Lynn, H.M. Pettis, and M. J. Moore. 2020. Population comparison of right whale body condition reveals poor state of the North Atlantic right whale. Mar. Ecol. Prog. Ser. 640:1–16.

Clapham, P.J. (ed). 2002. Report of the working group on survival estimation for North Atlantic right whales. Available from the Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543.

Cole, T.V.N., P. Hamilton, A.G. Henry, P. Duley, R.M. Pace III, B.N. White and T. Frasier. 2013. Evidence of a North Atlantic right whale *Eubalaena glacialis* mating ground. Endang. Species Res. 21:55–64.

Cole, T.V.N., P. Duley, M. Foster, A. Henry and D.D. Morin. 2016. 2015 Right Whale aerial surveys of the Scotian Shelf and Gulf of St. Lawrence. Northeast Fish. Sci. Cent. Ref. Doc. 16-02. 14pp.

Conn, P.B., and G.K. Silber. 2013. Vessel speed restrictions reduce risk of collision-related mortality for North Atlantic right whales. Ecosphere 4:1-16.

Corkeron, P., P. Hamilton, J. Bannister, P. Best, C. Charlton, K.R. Groch, K. Findlay, V. Rowntree, E. Vermeulen and R.M. Pace. 2018. The recovery of North Atlantic right whales, *Eubalaena glacialis*, has been constrained by human-caused mortality. R. Soc. Open Sci. 5:180892.

Crowe, L.M., M.W. Brown, P.J. Corkeron, P.K. Hamilton, C. Ramp, S. Ratelle, A.S.M. Vanderlaan and T.V. N. Cole. 2021. In plane sight: A mark-recapture analysis of North Atlantic right whales in the Gulf of St. Lawrence. Endang. Species Res. 46:227–251.

Davies, T.A., and S.W. Brillant. 2019. Mass human-caused mortality spurs federal action to protect endangered North Atlantic right whales in Canada. Marine Policy 104:157-162.

Davies, K.T.A., M.W. Brown, P.K. Hamilton, A.R Knowlton, C.T. Taggart, A.S.M. Vanderlaan. 2019. Variation in North Atlantic right whale (*Eubalaena glacialis*) occurrence in the Bay of Fundy, Canada, over three decades. Endang. Species Res. 39:159–171.

Davis, G.E., M.F. Baumgartner, J.M. Bonnell, J. Bell, C. Berchok, J.B. Thornton, S. Brault, G. Buchanan, R.A. Charif, D. Cholewiak, C.W. Clark, P. Corkeron, J. Delarue, K. Dudzinski, L. Hatch, J. Hildebrand, L. Hodge, H. Klinck, S. Kraus, B. Martin, D.K. Mellinger, H. Moors-Murphy, S. Nieukirk, D.P. Nowacek, S. Parks, A.J. Read, A.N. Rice, D. Risch, A. Širović, M. Soldevilla, K. Stafford, J.E. Stanistreet, E. Summers, S. Todd, A. Warde and S.M. Van Parijs. 2017. Long-term passive acoustic recordings track the changing distribution of North Atlantic right whales (*Eubalaena glacialis*) from 2004 to 2014. Sci. Rep. 7:13460.

Davis, G.E., S. Van Parijs. 2023. North Atlantic Right Whale Passive Acoustic Detections Report: January 2020 - June 2022. Northeast Fisheries Science Center reference document 23-07. doi.org/10.25923/daev-8a42.

Daoust, P.-Y., E.L. Couture, T. Wimmer and L. Bourque. 2017. Incident Report: North Atlantic right whale mortality event in the Gulf of St. Lawrence, 2017. Collaborative report produced *by:* Canadian Wildlife Health Cooperative, Marine Animal Response Society, and Fisheries and Oceans Canada. 256pp.

DFO [Department of Fisheries and Oceans Canada]. 2020. Updated information on the distribution of North Atlantic right whale in Canadian waters. DFO Can Sci Advis Sec Sci Advis Rep 2020/037.

Dorrell, R.M., C.J Lloyd, B.J. Lincoln, T.P. Rippeth, J.R. Taylor, C.P. Caulfield, J. Sharples, J.A. Polton, B.D. Scannell, D.M. Greaves, et al. 2022. Anthropogenic mixing in seasonally stratified shelf seas by offshore wind farm infrastructure. Front. Mar. Sci. 9:830927.

Durette-Morin, D., C. Evers, H.D. Johnson, K. Kowarski, J. Delarue, H. Moors-Murphy, E. Maxner, J.W. Lawson, Jack W., and K.T.A. Davies. 2022. The distribution of North Atlantic right whales in Canadian waters from 2015-2017 revealed by passive acoustic monitoring. Front. Mar. Sci. 9:976044.

Estabrook, B.J., J.T. Tielens, A. Rahaman, D.W. Ponirakis, C.W. Clark, A.N. Rice. 2022. Dynamic spatiotemporal acoustic occurrence of North Atlantic right whales in the offshore Rhode Island and Massachusetts Wind Energy Areas. Endang. Species Res. 49:115-133. https://doi.org/10.3354/esr01206

Fitzgerald, Kayla. 2018. Combining genetic and photo-identification data to improve abundance estimates for the North Atlantic right whale. Master's Thesis. Saint Mary's University, Halifax, Nova Scotia. 32pp.

Foley, H.J., R.C. Holt, R.E. Hardee, P.B. Nilsson, K.A. Jackson, A.J. Read, D.A. Pabst and W.A. McLellan. 2011. Observations of a western North Atlantic right whale (*Eubalaena glacialis*) birth offshore of the protected southeast U.S. critical habitat. Mar. Mamm. Sci. 27:234–240.

Fortune, S.M.E., A.W. Trites, C.A. Mayo, D.A.S. Rosen and P.K. Hamilton. 2013. Energetic requirements of North Atlantic right whales and the implications for species recovery. Mar. Ecol. Prog. Ser. 478:253–272.

Frasier, T.R., B.A. McLeod, R.M. Gillett, M.W. Brown and B.N. White. 2007a. Right whales past and present as revealed by their genes. Pages 200–231 *in*: S.D. Kraus and R.M. Rolland (eds). The urban whale: North Atlantic right whales at the crossroads. Harvard University Press, Cambridge, Massachusetts.

Frasier, T.R., P.K. Hamilton, M.W. Brown, L.A. Conger, A.R. Knowlton, M.K. Marx, C.K. Slay, S.D. Kraus and B.N. White. 2007b. Patterns of male reproductive success in a highly promiscuous whale species: The endangered North Atlantic right whale. Mol. Ecol. 16:5277–5293.

S.D. Kraus, T.R. Frasier, P.K. Hamilton, M.W. Brown, S.D. Kraus and B.N. White. 2009. Sources and rates of errors in methods of individual identification for North Atlantic right whales. J. Mamm. 90(5):1246–1255.

Ganley, L.C., S. Brault and C.A. Mayo. 2019 What we see is not what there is: Estimating North Atlantic right whale *Eubalaena glacialis* local abundance. Endang. Species Res. 38:101–113.

Ganley, L.C., J. Byrnes, D.E. Pendleton, C.A. Mayo, K.D. Friedland, J.V. Redfern, J.T. Turner and S. Brault. 2022. Effects of changing teperature phenology on the abundance of a critically endangered baleen whale. Glob. Ecol. Conserv. 38: e02193. https://doi.org/10.1016/j.gecco.2022.e02193.

Garrison, L.P., J. Adams, E.M. Patterson and C.P. Good. 2022. Assessing the risk of vessel strike mortality in North Atlantic right whales along the U.S East Coast. NOAA Technical Memorandum NOAA NMFS-SEFSC-757: 42 p.

Gavrilchuk, K., V. Lesage, S.M.E. Fortune, A.W. Trites and S. Plourde S. 2021. Foraging habitat of North Atlantic right whales has declined in the Gulf of St. Lawrence, Canada, and may be insufficient for successful reproduction. Endang. Species Res. 44:113–136.

Hain, J.H.W. 1975. The international regulation of whaling. Marine Affairs J. 3:28–48.

Hamilton, P.K., A.R. Knowlton and M.K. Marx. 2007. Right whales tell their own stories: The photo-identification catalog. Pages 75–104 *in*: S.D. Kraus and R.M. Rolland (eds). The urban whale: North Atlantic right whales at the crossroads. Harvard University Press, Cambridge, Massachusetts.

Hamilton, P.K., A.R. Knowlton, M.K. Marx and S.D. Kraus. 1998. Age structure and longevity in North Atlantic right whales *Eubalaena glacialis* and their relation to reproduction. Mar. Ecol. Prog. Ser. 171:285–292.

Hamilton, P.K., A.R. Knowlton, K.R. Howe, M.K. Marx, K.D. McPherson, H.M. Pettis, A.M. Warren, S.L. Vance, and M.A. Zani. 2023. Maintenance of the North Atlantic right whale catalog, whale scarring and visual health databases, anthropogenic injury case studies, and near real-time matching for biopsy efforts, entangled, injured, sick, or dead right whales. Contract report no. 1305M2-18-P-NFFM-0108 to the NMFS Northeast Fisheries Science Center. Anderson Cabot Center for Ocean Life, New England Aquarium, Boston, MA. https://www.narwc.org/narw-catalog-reports.html

Hamilton, P.K., B.A. Frasier, L.A. Conger, R.C. George, K.A. Jackson and T.R. Frasier. 2022. Genetic identifications challenge our assumptions of physical development and mother–calf associations and separation times: a case study of the North Atlantic right whale (Eubalaena glacialis). Mamm. Biol. https://doi.org/10.1007/s42991-021-00177-4.

Hayes, S.A., S. Gardner, L. Garrison, A. Henry and L. Leandro. 2018. North Atlantic Right Whales – Evaluating their recovery challenges in 2018. NOAA Tech Memo NMFS-NE 247. 24p.

Henry, A.G., M. Garron, D. Morin, A. Smith, A. Reid, W. Ledwell, T.V.N. Cole. 2024. Mortality and serious injury determinations for baleen whale stocks along the Gulf of Mexico, United States East Coast and Atlantic Canadian Provinces, 2018–2022. Northeast Fisheries Science Center reference document 24-10. 60 pp. DOI: 10.25923/6xja-rh04

Hodge, K., C. Muirhead, J. Morano, C. Clark and A. Rice. 2015. North Atlantic right whale occurrence near wind energy areas along the mid-Atlantic US coast: Implications for management. Endang. Species Res. 28:225–234.

IUCN [International Union for Conservation of Nature]. 2020. Almost a third of lemurs and North Atlantic right whale now critically endangered – IUCN Red List. International Union for Conservation of Nature, Gland, Switzerland. https://www.iucn.org/news/species/202007/almost-a-third-lemurs-and-north-atlantic-right-whale-now-critically-endangered-iucn-red-list.

IWC [International Whaling Commission]. 2001. Report of the workshop on the comprehensive assessment of right whales: A worldwide comparison. J. Cetacean Res. Manage. (Special Issue) 2:1–60.

Jacobsen, K., M. Marx and N. Øien. 2004. Two-way trans-Atlantic migration of a North Atlantic right whale (*Eubalaena glacialis*). Mar. Mamm. Sci. 20:161–166.

Johnson, A., G. Salvador, J. Kenney, J. Robbins, S. Kraus, S. Landry and P. Clapham. 2005. Fishing gear involved in entanglements of right and humpback whales. Mar. Mamm. Sci. 21:635–645.

Kelley, D.E., J.P. Vlasic and S.W. Brillant. 2020. Assessing the lethality of ship strikes on whales using simple biophysical models. Mar. Mam. Sci. 37: 251-267.
Kenney, R.D. 2018. What if there were no fishing? North Atlantic right whale population trajectories without entanglement mortality. Endanger. Species Res. 37:233–237.
Kenney, R.D., M.A.M. Hyman, R.E. Owen, G.P. Scott and H.E. Winn. 1986. Estimation of prey densities required by western North Atlantic right whales. Mar. Mamm. Sci. 2:1–13.
Kenney, R.D., H.E. Winn and M.C. Macaulay. 1995. Cetaceans in the Great South Channel, 1979–1989: Right whale (*Eubalaena glacialis*). Cont. Shelf Res. 15:385–414.
Khan, C.B., A.G. Henry, P.A.Duley, J. Gatzke, L.M. Crowe and T.V.N. Cole. 2018. North Atlantic Right Whale Sighting Survey (NARWSS) and Right Whale Sighting Advisory System (RWSAS) 2016 Results Summary. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 18-01; 13 pp.
Knowlton, A.R. and S.D. Kraus. 2001. Mortality and serious injury of North Atlantic right whales (*Eubalaena glacialis*) in the North Atlantic Ocean. J. Cetacean Res. Manage. (Special Issue) 2:193–208.
Knowlton, A.R., S.D. Kraus and R.D. Kenney. 1994. Reproduction in North Atlantic right whales (*Eubalaena glacialis*). Can. J. Zool. 72:1297–1305.
Knowlton, A.R., J. Sigurjonsson, J.N. Ciano and S.D. Kraus. 1992. Long-distance movements of North Atlantic right whales (*Eubalaena glacialis*). Mar. Mamm. Sci. 8:397–405.
Knowlton, A.R., P.K. Hamilton, M.K. Marx, H.M. Pettis and S.D. Kraus. 2012. Monitoring North Atlantic right whale *Eubalaena glacialis* entanglement rates: A 30 year retrospective. Mar. Ecol. Prog. Ser. 466:293–302.
Knowlton, A.R., J. Robbins, S. Landry, H.A. McKenna, S.D. Kraus and T.B. Werner. 2016. Effects of fishing rope strength on the severity of large whale entanglements. Conserv. Biol. 30:318–328. DOI: 10.1111/cobi.12590
Knowlton, A.R., J.S. Clark, P.K. Hamilton, S.D. Kraus, H.M. Pettis, R.M. Rolland, and R.S. Schick. 2022. Fishing gear entanglement threatens recovery of critically endangered North Atlantic right whales. Conserv. Sci. Pract. 4(8), e12736.
Kraus, S.D. 1990. Rates and potential causes of mortality in North Atlantic right whales (*Eubalaena glacialis*). Mar. Mamm. Sci. 6:278–291.
Laist, D.W., A.R. Knowlton and D. Pendleton. 2014. Effectiveness of mandatory vessel speed limits for protecting North Atlantic Right Whales. Endang. Species Res. 23:133–147.
Leiter, S.M, K.M. Stone, J.L. Thompson, C.M. Accardo, B.C. Wikgren, M.A. Zani, T.V.N. Cole, R.D. Kenney, C.A. Mayo and S.D. Kraus. 2017. North Atlantic right whale *Eubalaena glacialis* occurrence in offshore wind energy areas near Massachusetts and Rhode Island, USA. Endang. Species Res. 34:45–59.
Linden, D.W. 2024a. Using known births to account for delayed marking in population estimation of North Atlantic right whales. bioRxiv. https://doi.org/10.1101/2024.10.11.617830
Linden, D.W. 2024b. Population size estimation of North Atlantic right whales from 1990-2023. NOAA Tech Memo NMFS-NE 324. 20pp.
Malik, S., M.W. Brown, S.D. Kraus, A. Knowlton, P. Hamilton and B.N. White. 1999. Assessment of genetic structuring and habitat philopatry in the North Atlantic right whale (*Eubalaena glacialis*). Can. J. Zool. 77:1217–1222.
Malik, S., M.W. Brown, S.D. Kraus and B.N. White. 2000. Analysis of mitochondrial DNA diversity within and between North and South Atlantic right whales. Mar. Mamm. Sci. 16:545–558.
Mate, B.M., S.L. Nieukirk and S.D. Kraus. 1997. Satellite-monitored movements of the northern right whale. J. Wildl. Manage. 61:1393–1405.
Maxwell, S.M., F. Kershaw, C. C. Locke, M. G. Conners, C. Dawson, S. Aylesworth, R. Loomis, A. F. Johnson. 2022. Potential impacts of floating wind turbine technology for marine species and habitats. J. of Env. Manag., 307. https://doi.org/10.1016/j.jenvman.2022.114577
Mayo, C.A. and M.K. Marx. 1990. Surface foraging behaviour of the North Atlantic right whale, *Eubalaena glacialis*, and associated zooplankton characteristics. Can. J. Zool. 68:2214–2220.
Mayo, C.A., L. Ganley, C.A. Hudak, S. Brault, M.K. Marx, E. Burke and M.W. Brown. 2018. Distribution, demography, and behavior of North Atlantic right whales (*Eubalaena glacialis*) in Cape Cod Bay, Massachusetts, 1998–2013. Mar. Mam. Sci. 34(4):979–996.
McLeod, B., M. Brown, M. Moore, W. Stevens, S. H. Barkham, M. Barkham and B. White. 2008. Bowhead whales, and not right whales, were the primary target of 16th- to 17th-century Basque whalers in the western North Atlantic. Arctic. 61:61–75.
McLeod, B.A. and B.N. White. 2010. Tracking mtDNA heteroplasmy through multiple generations in the North Atlantic right whale (*Eubalaena glacialis*). J. Hered. 101:235–239.
Mellinger, D.K, S.L. Nieukirk, K. Klink, H. Klink, R.P. Dziak, P.J. Clapham and B Brandsdóttir. 2011. Confirmation of right whales near a nineteenth-century whaling ground east of southern Greenland. Biol. Lettr. 7:411–413.

Meyer-Gutbrod, E.L., and C.H. Greene. 2014. Climate-associated regime shifts drive decadal scale variability in recovery of North Atlantic right whale population. Oceanography 27(3):148–153.

Meyer-Gutbrod, E.L., C.H. Greene, K.T.A. Davies and D.G. Johns. 2021. Ocean Regime Shift is Driving Collapse of the North Atlantic Right Whale Population. Oceanography. 34. 22-31.

Meyer-Gutbrod, E.L., K.T.A. Davies, C.L. Johnson, S. Plourde, K.A. Sorochan, R.D. Kenney, C. Ramp, J.F. Gosselin, J.W. Lawson, C.H. Greene. 2023. Redfining North Atlantic right whale habitat-use patterns under climate change. Limnol. Oceanogr. 68: S71-S86. DOI: 10.1002/lno.12242

Miller, C., D. Reeb, P. Best, A. Knowlton, M. Brown and M. Moore. 2011. Blubber thickness in right whales *Eubalaena glacialis* and *Eubalaena australis* related with reproduction, life history status and prey abundance. Mar. Ecol. Prog. Ser. 438:267–283.

Monserrat, S., M.G. Pennino, T.D. Smith, R.R. Reeves, C.N. Meynard, D.M. Kaplan and A.S.L. Rodrigues. 2015 A spatially explicit estimate of the prewhaling abundance of the endangered North Atlantic right whale. Cons. Biol. 30:783–791.

Moore, J.C. and E. Clark. 1963. Discovery of right whales in the Gulf of Mexico. Science. 141:269.

Moore, M.J., A.R. Knowlton, S.D. Kraus, W.A. Mc Lellan and R.K. Bonde. 2005. Morphometry, gross morphology and available histopathology in North Atlantic right whale (*Eubalaena glacialis*) mortalities. J. Cetacean Res. Manage. 6:199–214.

Moore, M. J., G.H. Mitchell, T.K. Rowles, and G. Early. 2020. Dead cetacean? Beach, bloat, float, sink. Front. Mar. Sci. 7:333.

Morano, J.L., A.N. Rice, J.T. Tielens, B.J. Estabrook, A. Murray, B.L. Roberts and C.W. Clark. 2012. Acoustically detected year-round presence of right whales in an urbanized migration corridor. Conserv. Biol. 26:698–707.

Morin, D., M. Moise, M. Minton, and J. Higgins. 2020. Atlantic Large Whale Entanglement Report (2017). Greater Atlantic Region Policy Series [20-02]. NOAA Fisheries Greater Atlantic Regional Fisheries Office. https://www.greateratlantic.fisheries.noaa.gov/policyseries/index.php/GARPS/issue/view/15. 103p.

Murray, A., M.L. Rekdahl, M.F. Baumgartner, and H.C. Rosenbaum. 2022. Acoustic presence and vocal activity of North Atlantic right whales in the New York Bight: Implications for protecting a critically endangered species in a human-dominated environment. Conserv. Sci. Pract. 4(11), e12798. https://doi.org/10.1111/csp2.12798

NMFS [National Marine Fisheries Service]. 2015. Critical Habitat for Endangered North Atlantic right whale. Federal Register. 80:9314–9345.

NMFS [National Marine Fisheries Service]. 2017. North Atlantic right whale (*Eubalaena glacialis*) 5-year review: Summary and evaluation. NMFS Greater Atlantic Regional Fisheries Office, Gloucester, Massachusetts. 34pp. https://www.greateratlantic.fisheries.noaa.gov/protected/final_narw_5-year_review_2017.pdf

NMFS [National Marine Fisheries Service]. 2020. North Atlantic right whale (Eubalaena glacialis) vessel speed rule assessment. NMFS Office of Protected Resources, Silver Spring, MD. 53pp. https://media.fisheries.noaa.gov/2021-01/FINAL_NARW_Vessel_Speed_Rule_Report_Jun_2020.pdf.

Pace, R.M., III. 2021. Revisions and further evaluations of the right whale abundance model: Improvements for hypothesis testing. NOAA Tech Memo NMFS-NE 269. 54pp.

Pace, R.M., III, T.V.N. Cole and A.G. Henry. 2015. Incremental fishing gear modifications fail to significantly reduce large whale serious injury rates. Endang. Species. Res. 26:115–126.

Pace, R.M., III, P.J. Corkeron and S.D. Kraus. 2017. State-space mark-recapture estimates reveal a recent decline in abundance of North Atlantic right whales. Ecol. and Evol. 7:8730–8741. DOI: 10.1002/ece3.3406

Pace, RM, III, R. Williams, S.D. Kraus, A.R. Knowlton and H.M. Pettis. 2021. Cryptic mortality of North Atlantic right whales. Conservation Science and Practice. https://doi.org/10.1111/csp2.346

Patrician, M.R., I.S. Biedron, H.C. Esch, F.W. Wenzel, L.A. Cooper, P.K. Hamilton, A.H. Glass and M.F. Baumgartner. 2009. Evidence of a North Atlantic right whale calf (*Eubalaena glacialis*) born in northeastern U.S. waters. Mar. Mamm. Sci. 25:462–477.

PACM (Passive Acoustic Cetacean Map. 2024. Woods Hole (MA): NOAA Northeast Fisheries Science Center v1.1.8 [accessed February 28, 2024]. https://apps-nefsc.fisheries.noaa.gov/pacm).

Pendleton, D.E., M.W. Tingley, L.C. Ganley, K.D. Friedland, C.A. Mayo, M.W. Brown, B.E. McKenna, A. Lordaan and M.D. Staudinger. 2022 Decadal-scale phenology and seasonal climate drivers of migratory baleen whales in a rapidly warming marine ecosystem. Glob. Chang. Biol. 28:4989-5005.

Pettis, H.M., R.M. Rolland, P.K. Hamilton, A.R. Knowlton, E.A. Burgess and S.D. Kraus. 2017. Body condition changes arising from natural factors and fishing gear entanglements in North Atlantic right whales *Eubalaena glacialis*. Endang. Species Res. 32:237–249.

Pettis, H.M., R.M. Pace and P.K. Hamilton P.K. 2022. North Atlantic Right Whale Consortium: 2021 annual report card. Report to the North Atlantic Right Whale Consortium. www.narwc.org

Price, C.S., E. Keane, D. Morin, C. Vaccaro, D. Bean and J.A. Morris Jr.. 2017. Protected Species & Marine Aquaculture Interactions. NOAA Technical Memorandum NOS NCCOS 211. 85 pp

Quintana-Rizzo, E., S. Leiter, T.V.N. Cole, M.N. Hagbloom, A.R. Knowlton, P. Nagelkirk, O. O'Brien, C.B. Khan, A.G. Henry, P.A. Duley, L.M. Crowe, C.A. Mayo and S.D. Kraus. 2021. Residency, demographics, and movement patterns of North Atlantic right whales Eubalaena glacialis in an offshore wind energy development area in southern New England, USA. Endang. Species Res. 45:251–268.

Rastogi, T., M.W. Brown, B.A. McLeod, T.R. Frasier, R. Grenier, S.L. Cumbaa, J. Nadarajah and B.N. White. 2004. Genetic analysis of 16th-century whale bones prompts a revision of the impact of Basque whaling on right and bowhead whales in the western North Atlantic. Can. J. Zool. 82:1647–1654.

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

Record, N.R., J.A. Runge, D.E. Pendleton, W.M. Balch, K.T.A. Davies, A.J. Pershing, C.L. Johnson, K. Stamieszkin, R. Ji, Z. Feng, S.D. Kraus, R.D. Kenney, C.A. Hudak, C.A. Mayo, C. Chen, J.E. Salisbury and C.R.S. Thompson. 2019. Rapid climate-driven circulation changes threaten conservation of endangered North Atlantic right whales. Oceanography. 32(2):162–169. https://doi.org/ 10.5670/oceanog.2019.201

Reed, J., L. New, P. Corkeron, and R. Harcourt. 2022. Multi-event modeling of true reproductive states of individual female right whales provides new insights into their decline. Front. Mar. Sci. 9:994481. doi: 10.3389/fmars.2022.994481

Reeves, R.R., J.M. Breiwick and E. Mitchell. 1992. Pre-exploitation abundance of right whales off the eastern United States. Pages 5-7 *in*: J. Hain (ed) The right whale in the western North Atlantic: A science and management workshop, 14–15 April 1992, Silver Spring, Maryland. Northeast Fish. Sci. Cent. Ref. Doc. 92-05.

Reeves, R.R., R. Rolland and P. Clapham (eds). 2001. Report of the workshop on the causes of reproductive failure in North Atlantic right whales: New avenues of research. Northeast Fish. Sci. Cent. Ref. Doc. 01-16. 46pp.

Reeves, R.R., T. Smith and E. Josephson. 2007. Near-annihilation of a species: Right whaling in the North Atlantic. Pages 39–74 *in*: S.D. Kraus and R. M. Rolland (eds). The urban whale: North Atlantic right whales at the crossroads. Harvard University Press, Cambridge, MA.

Roberts J.J., T.M. Yack, E. Fujioka, P.N. Halpin, M.F. Baumgartner, O. Boisseau, S. Chavez-Rosales, T.V.N. Cole, M.P. Cotter, G.E. Davis, R.A. DiGiovanni, Jr., L.C. Ganley, L.P. Garrison, C.P. Good, T.A. Gowan, K.A. Jackson, R.D. Kenney, C.B. Khan, A.R. Knowlton, S.D. Kraus, G.G. Lockhart, K.S. Lomac-MacNair, C.A. Mayo, B.E. McKenna, W.A. McLellan, D.P. Nowacek, O.O'Brien, D.A. Pabst, D.L. Palka, E.M. Patterson, D.E. Pendleton, E. Quintana-Rizzo, N.R. Record, J.V. Redfern, M.E. Rickard, M. White, A.D. Whitt and A.M. Zoidis. 2024. North Atlantic right whale density surface model for the U.S. Atlantic evaluated with passive acoustic monitoring. Mar. Ecol. Prog. Ser. 732:167-192. DOI: 10.3354/meps14547

Rolland, R.M., R.S. Schick, H.M. Pettis, A.R. Knowlton, P.K. Hamilton, J.S. Clark and S.D. Krauss. 2016. Health of North Atlantic right whales *Eubalaena glacialis* over three decades: From individual health to demographic and population health trends. Mar. Ecol. Prog. Series. 542:265–282.

Rosenbaum, H.C., M.S. Egan, P.J. Clapham, R.L. Brownell, Jr. and R. DeSalle. 1997. An effective method for isolating DNA from non-conventional museum specimens. Mol. Ecol. 6:677–681.

Rosenbaum, H.C., M.S. Egan, P.J. Clapham, R.L. Brownell, Jr., S. Malik, M.W. Brown, B.N. White, P. Walsh and R. DeSalle. 2000. Utility of North Atlantic right whale museum specimens for assessing changes in genetic diversity. Conserv. Biol. 14:1837–1842.

Ross, C.H., J.A. Runge, J.J. Roberts, D.C. Brady, B. Tupper, and N.R. Record. 2023. Estimating North Atlantic right whale prey based on *Calanus finmarchicus* thresholds. Mar. Ecol. Prog. Ser. 703:1-16. DOI: 10.3354/meps14204

Salisbury, D., C.W. Clark, and A.N. Rice. 2016. Right whale occurrence in Virginia coastal waters: Implications of endangered species presence in a rapidly developing energy market. Mar. Mamm. Sci. 32:508–519. DOI: 10.1111/mms.12276

Schaeff, C.M., S.D. Kraus, M.W. Brown, J. Perkins, R. Payne and B.N. White. 1997. Comparison of genetic variability of North and South Atlantic right whales (*Eubalaena*) using DNA fingerprinting. Can. J. Zool. 75:1073–1080.

Schmidly, D.J., C.O. Martin and G.F. Collins. 1972. First occurrence of a black right whale (*Balaena glacialis*) along the Texas coast. Southw. Nat. 17:214–215.

Sharp, S.M., W.A. McLellan, D.S. Rotstein, A.M Costidis, S.G. Barco, K. Durham, T.D. Pitchford, K.A. Jackson, P.-Y. Daoust, T. Wimmer, E.L. Couture, L. Bourque, T. Frasier, D. Fauquier, T.K. Rowles, P.K. Hamilton, H. Pettis and M.J. Moore. 2019. Gross and histopathologic diagnoses from North Atlantic right whale *Eubalaena glacialis* mortalities between 2003 and 2018. Dis. Aquat. Org. 135(1):1–31.

Silber, G. K. and S. Bettridge. 2012. An assessment of the final rule to implement vessel speed restrictions to reduce the threat of vessel collisions with North Atlantic right whales. NOAA Tech. Memo. NMFS-OPR-48. 114pp.

Silva, M.A., L. Steiner, I. Cascão, M.J. Cruz, R. Prieto, T. Cole, P.K. Hamilton and M.F. Baumgartner. 2012. Winter sighting of a known western North Atlantic right whale in the Azores. J. Cetacean Res. Manage. 12:65–69.

Simard, Y., N. Roy, S. Giard and F. Aulanier. 2019. North Atlantic right whale shift to the Gulf of St. Lawrence in 2015, revealed by long-term passive acoustics. Endang. Species Res. 40:271–284.

Sorochan, K.A., S. Plourde, M.F. Baumgartner, and C.L. Johnson. 2021. Availability, supply, and aggregation of prey (Calanus spp.) in foraging areas of the North Atlantic right whale (*Eubalaena glacialis*). ICES Journal of Marine Science, 78(10):3498-3520. DOI: 10.1093/icesjms/fsab200.

Stöber, U. and F. Thomsen 2021 How could operational underwater sound from future offshore wind turbines impact marine life? J. Acoust. Soc. Am. 149 (3).

Stewart, J.D., J.W. Durban, A.R. Knowlton, M.S. Lynn, H. Fearnbach, J. Barbaro, W.L. Perryman, C.A. Miller, and M.J. Moore. 2021. Decreasing body lengths in North Atlantic right whales. Current Biology 31:3174–3179.

Stewart , J.D., J.W. Durban, H. Europe, H. Fernbach, P.K. Hamilton, A.R. Knowlton, M.S. Lynn, C.A. Miller, W.L. Perryman, B.W.H. Tao, and M.J. Moore. 2022. Larger females have more calves: influence of maternal body length on fecundity in North Atlantic right whales. Mar. Ecol. Prog. Ser. 689:179-189..

Stone, K.M., S.M. Leiter, R.D. Kenney, B.C. Wikgren, J.L. Thompson, J.K.D. Taylor and S.D. Kraus. 2017. Distribution and abundance of cetaceans in a wind energy development area offshore of Massachusetts and Rhode Island. J. Coast. Conserv. 21:527–543.

van der Hoop, J.M.**,** M.J. Moore, S.G. Barco, T.V. Cole, P.Y. Daoust, A.G. Henry, D.F. McAlpine, W.A. McLellan, T. Wimmer and A.R. Solow. 2013. Assessment of management to mitigate anthropogenic effects on large whales. Conserv. Biol. 27:121–133.

van der Hoop, J.M., A.S.M. Vanderlaan, T.V.N. Cole, A.G. Henry, L. Hall, B. Mase-Guthrie, T. Wimmer and M.J. Moore. 2015. Vessel strikes to large whales before and after the 2008 Ship Strike Rule. Conserv. Lett. 8:24–32.

van der Hoop, J.M., P. Corkeron and M.J. Moore. 2017. Entanglement is a costly life-history stage in large whales. Ecol. and Evol. 7:92–106. DOI: 10.1002/ece3.2615

Vanderlann, A.S.M, and C.T. Taggart. 2007. Vessel collisions with whales: the probability of lethal injury based on vessel speed. Mar. Mam. Sci. 23:144-156.

Wade, P.R. and R.P. Angliss. 1997. Guidelines for assessing marine mammal stocks: Report of the GAMMS Workshop April 3–5, 1996, Seattle, Washington. NOAA Tech. Memo. NMFS-OPR-12. 93pp. https://repository.library.noaa.gov/view/noaa/15963

Wells, R.S., J.B. Allen, G. Lovewell, J. Gorzelany, R.E. Delynn, D.A. Fauquier and N.B. Barros. 2015 Carcass-recovery rates for resident bottlenose dolphins in Sarasota Bay, Florida. Mar. Mamm. Sci. 31:355–368.

Waldick, R.C., S.D. Kraus, M. Brown and B.N. White. 2002. Evaluating the effects of historic bottleneck events: An assessment of microsatellite variability in the endangered North Atlantic right whale. Mol. Ecol. 11:2241–2250.

Ward-Geiger, L.I., A.R. Knowlton, A.F. Amos, T.D. Pitchford, B. Mase-Guthrie and B.J. Zoodsma. 2011. Recent sightings of the North Atlantic right whale in the Gulf of Mexico. Gulf Mex. Sci. 29:74–78.

Whitt, A.D., K. Dudzinski and J.R. Laliberté. 2013. North Atlantic right whale distribution and seasonal occurrence in nearshore waters off New Jersey, USA, and implications for management. Endanger. Species Res. 20:59–69.

Williams, R., S. Gero, L. Bejder, J. Calambokidis, S.D. Kraus, D. Lusseau, A.J. Read and J. Robbins. 2011. Underestimating the damage: Interpreting cetacean carcass recoveries in the context of the *Deepwater Horizon*/BP incident. Conserv. Lett. 4:228–233.

Williams, B.K., J.D. Nichols and M.J. Conroy. 2002. Analysis of Animal Populations, Modeling, Estimation and Decision Making. Academic Press. San Diego, California.