North Atlantic Right Whale Consortium
2018 Annual Report Card

Pettis, H.M.[1], Pace, R.M. III[2], Hamilton, P.K.[1]

[1] *Anderson Cabot Center for Ocean Life at the New England Aquarium, Central Wharf, Boston, MA, USA 02110*
[2] *Grizzlywhaler Consulting Services, 137 W. Pelham Road, Shutesbury, MA 10702*

NORTH ATLANTIC RIGHT WHALE CONSORTIUM BACKGROUND

The North Atlantic right whale (*Eubalaena glacialis*) remains one of the most endangered large whales in the world. Over the past two decades, there has been increasing interest in addressing the problems hampering the recovery of North Atlantic right whales by using innovative research techniques, new technologies, analyses of existing databases, and enhanced conservation and education strategies. This increased interest demanded better coordination and collaboration among all stakeholders to ensure that there was improved access to data, research efforts were not duplicative, and that findings were shared with all interested parties. The North Atlantic Right Whale Consortium, initially formed in 1986 by five research institutions to share data among themselves, was expanded in 1997 to address these greater needs. Currently, the Consortium membership is comprised of representatives from more than 100 entities including: research, academic, and conservation organizations; shipping and fishing industries; whale watching companies; technical experts; United States (U.S.) and Canadian Government agencies; and state authorities.

The Consortium membership is committed to long-term research and management efforts, and to coordinating and integrating the wide variety of databases and research efforts related to right whales to provide the relevant management, academic and conservation groups with the best scientific advice and recommendations on right whale conservation. The Consortium is also committed to sharing new and updated methods with its membership, providing up-to-date information on right whale biology and conservation to the public, and maintaining effective communication with U.S. and Canadian Government agencies, state authorities, the Canadian Right Whale Network, the U.S. Southeast Right Whale Implementation Team, the Atlantic Large Whale Take Reduction Team, the Atlantic Scientific Review Group, and members of the U.S. Congress. The Consortium membership supports the maintenance and long-term continuity of the separate research programs under its umbrella, and serves as executor for database archives that include right whale sighting and photo-identification data contributed by private institutions, government scientists and agencies, and individuals. Lastly, the Consortium is interested in maximizing the effectiveness of management measures to protect right whales, including using management models from other fields.

The Consortium is governed by an Executive Committee and Board members who are elected by the general Consortium Membership at the Annual Meeting.

North Atlantic Right Whale Consortium members agreed in 2004 that an annual "report card" on the status of right whales would be useful. This report card includes updates on the status of the cataloged population, mortalities and injury events, and a summary of management and research efforts that have occurred over the previous 12 months. The Board's goal is to make public a summary of current research and management activities, as well as provide detailed recommendations for future activities. The Board views this report as a valuable asset in assessing the effects of research and management over time.

ESSENTIAL POPULATION MONITORING AND PRIORITIES

In the 2009 Report Card to the International Whaling Commission (IWC), the Consortium Board identified key monitoring efforts that must be continued and maintained in order to identify trends in the population, as well as assess the factors behind any changes in these trends (Pettis, 2009). The key efforts are: (1) Photographic identification and cataloging of right whales in historically high-use habitats and migratory corridors, including, but not limited to, the southeast United States, Cape Cod Bay, Great South Channel, Bay of Fundy, Scotian Shelf, and Jeffreys Ledge, (2) Monitoring of scarring and visual health assessment from photographic data, (3) Examination of all mortalities, and (4) Continue using photo-ID and genetic profiling to monitor population structure and how this changes over time.

The Consortium Board regards the Consortium databases as essential to recovery efforts for the North Atlantic right whale population. In a review of the federal recovery program for North Atlantic right whales, the Marine

Mammal Commission agreed with the Board's sentiment, stating that "both databases play critical roles in right whale conservation" and that the Identification Catalog "is the cornerstone of right whale research and monitoring" (Reeves *et al.* 2007). The review went on to recommend that both databases ("both" here and above refers to the Identification and Sightings databases; there are several Consortium databases available) be fully funded on a stable basis.

Over the last several years, right whale distribution and patterns of habitat use have shifted, in some cases dramatically. These shifts have been observed throughout the range of North Atlantic right whales and have direct implications on research and management activities, as well as on each of the key efforts identified above. As such, the Board believes that identifying potential extralimital and new critical habitats and developing alternative survey effort strategies to respond to the distributional changes should be a priority. These strategies should include efforts to not only locate and identify individual right whales, but also to ensure that information critical to important monitoring and management efforts (i.e. health assessment, injury and scarring assessments) is effectively and efficiently collected.

An unprecedented **twenty** North Atlantic right whale mortalities were documented in 2017 (17) and 2018 (3), representing more than 4% of the estimated living population. This, coupled with the decline in reproductive output by 40% between 2010-2016 (Kraus *et al.* 2016) and no documented births in 2018, threatens the very survival of this species. To date, anthropogenic factors, including entanglement in fixed fishing gear and vessel strikes, have been implicated in 10 of the 20 mortalities (the remaining 10 have undetermined cause of death, though two of these are suspected as human impact – one entanglement and one vessel strike). It is clear that current management regulations have not been effective at reducing serious entanglement injuries (Pace *et al.* 2014) and between 2010 - 2016, entanglement related deaths accounted for 85% of diagnosed mortalities. (Kraus *et al.* 2016). Additionally, entanglements reduce survival probability over time for right whales and moderate and severe injuries from entanglement are increasing (Robbins *et al.* 2015; Knowlton *et al.* 2016). Although several large scale management efforts to mitigate vessel strikes have proven to be successful (Laist *et al.* 2014), including shifts in traffic separation schemes in the Bay of Fundy (2003) and Boston (2007), the designation of the Roseway Basin (2007) and Great South Channel as Areas to be Avoided (2009), and the ship speed restriction rule implemented in 2008,), there is still room for improvement. Vessel strikes have been implicated in two mortalities in and around Cape Cod Bay, U.S. since May 2016. These deaths call into question the effectiveness of existing spatial and temporal seasonal management areas in the U.S. Additionally, at least five right whale mortalities in 2017 were attributed to vessel strikes in the Gulf of St. Lawrence, Canada, leading to a call to action for immediate mitigation plans in Canada.

In the spring of 2018, Canada announced new measures to mitigate both entanglements and vessel strikes in areas in which right whales frequent, including vessel speed reductions, temporary and fixed fisheries management areas and closures, and increased reporting requirements for fishing activity, lost gear, and interactions with marine mammal. The detection of no right whale mortalities in Canadian waters in 2018 suggest that these new mitigation efforts have been successful. There were, however, four entanglements detected in Canadian (3) and U.S. (1) waters in 2018 and all three of the 2018 mortalities in the U.S. were attributed to entanglements. Continued timely and effective efforts to reduce both entanglement and vessel strike mortalities must be a priority for both the U.S. and Canada if this species is to survive.

POPULATION STATUS

The ability to monitor North Atlantic right whale vital rates is entirely dependent on the North Atlantic Right Whale Identification Database (Catalog), curated by the Anderson Cabot Center for Ocean Life at the New England Aquarium. As of September 4, 2018, the database consisted of over a million slides, prints, and digital images collected during the 75,142 sightings of 734 individual right whales photographed since 1935. Each year, 2,000 to 5,000 sightings consisting of 20-30,000 images are added to the identification database. Using Catalog data, a number of methods have been employed to estimate the number of North Atlantic right whales alive annually. Due to lag times in data submission to the catalog and data processing, data through 2017 were available for these calculations. Here we describe four different estimate methods and present the Consortium's best estimate for 2017.

Presumed Alive Method

The presumed alive method (PA) counts whales that have been seen at least once in the last six years (Knowlton *et al.* 1994). It is a consistently measureable and easily available value, but it assumes that whales remain alive for six

years after their last sighting (which is often not the case) and the estimates for recent years may be artificially low due to delays in data processing. The PA number for 2017 is 465.

Catalog Method

The Catalog method (formerly referred to as the "Report Card" method) includes a low, middle and high estimate. A table with each of these estimates as well as a full description of the methodology is provided in Appendix 1 of this report card. The values are based upon the number of photographed whales only; they exclude potential unphotographed whales and therefore should not be considered a "population estimate". This estimate has the weakness of utilizing the PA methodology with its assumptions, but it is the only method that incorporates whales that have been photographed but not yet added to the Catalog. The Catalog estimates for 2017 range from a low of 343 to a high of 728 with a middle estimate of 511.

Minimum Number Alive Method

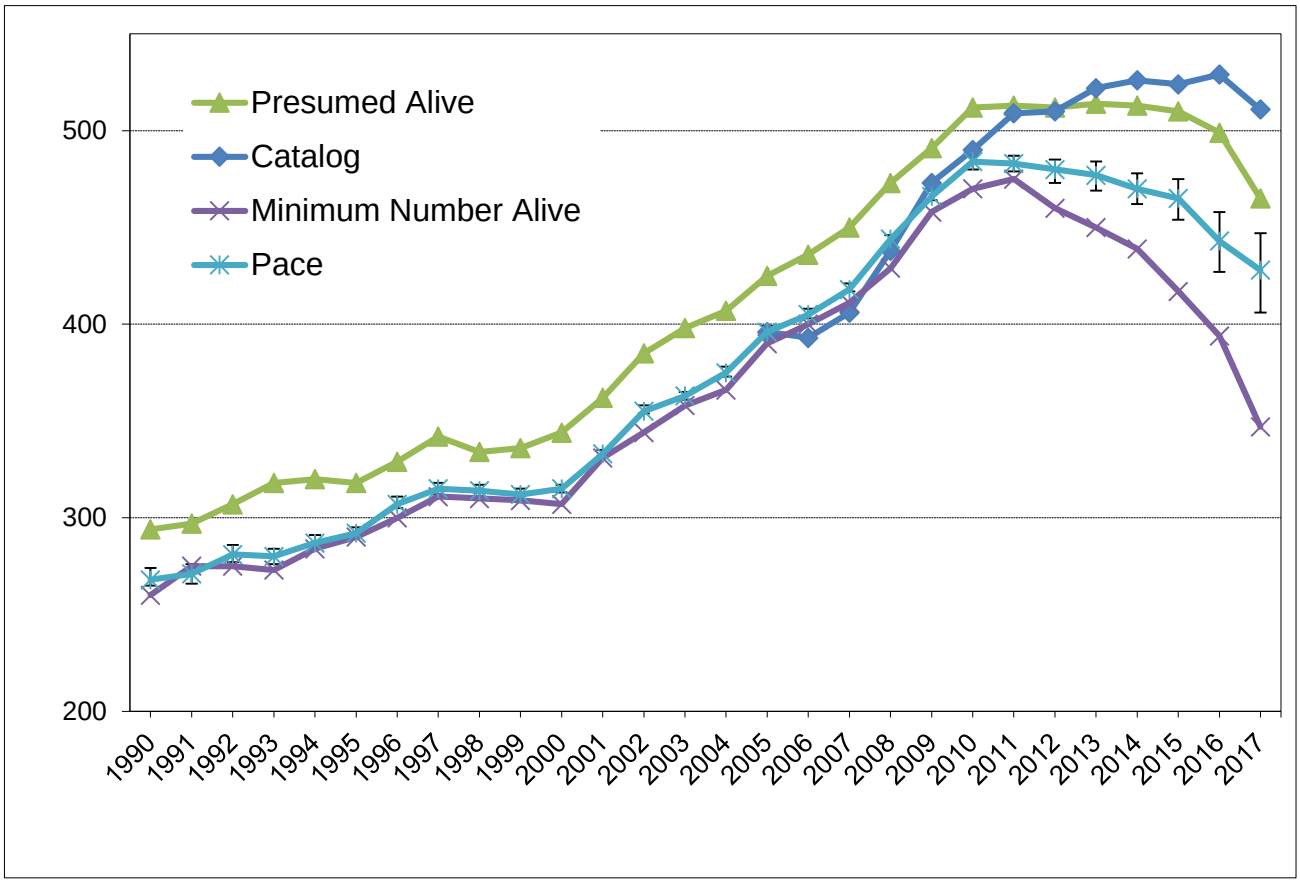
The Minimum Number Alive (MNA) is the number that was historically used in National Marine Fisheries Service stock assessment reports and counts whales seen in a given year, plus any whale not seen that year- but seen both before *and* after (see Hayes *et al.* 2017). The MNA number is more accurate than PA for older years, but is also not accurate for recent years for the same reason as the PA method, plus the fact that there have been fewer "after" years to detect a whale. The MNA number for 2017 is 347.

Pace Method

The Pace method analysis was added for the 2016 report card and continued this year. This analysis comes from the Pace *et al.* 2017 model which "adapted a state-space formulation with Jolly-Seber assumptions about population entry (birth and immigration) to individual resighting histories and fit it using empirical Bayes methodology." This model estimate includes whales that have not been photographed. The full methodology is available in the paper. It is important to note that the estimates provided by the Pace *et al.* 2017 methodology represent the estimated abundance at the *start* of the sample period plus all new entries into the population. That number for 2017 is 428. If one wanted an estimate at the end of the interval, one could subtract the number of known dead (or estimated number of dead if a detection rate for carcasses was available).

The full results for all four methods are presented in Figure 1**.** All numbers except the past Catalog method estimates were recalculated using data as of September 4, 2018 and therefore the numbers in this figure will differ from those in past report cards. The PA number is always artificially high as a comparison to the past year's MNA numbers attest. The difference is largely due to whales that have not been seen since before the year in question. For example, the 30+ animals that the PA number included in 1990 and the MNA did not are whales that have not been seen since 1990 and are thus very likely dead. From 1990 to 2010, the average difference between the PA number and the MNA number was 35 animals. If that difference remained consistent into this decade, the adjusted presumed alive number in 2017 would be 430 whales. The Pace method removes assumptions of when a whale is alive and is likely more accurate. The Catalog estimates are always higher than the other two methods for the most recent years. However, the fact that the old Catalog estimates for 2005 to 2009 were close to the eventual MNA numbers suggests that the methodology worked reasonably well through 2009. However, starting in 2010, the two numbers started to diverge. This is partially because fewer whales were seen so the MNA number may be artificially low. But it also appears that the six year assumption for PA whales is increasingly erroneous, whales die sooner than six years after their last sighting. The Catalog estimate does however capture recent increase in calves that have not yet been cataloged. This delay in cataloging is largely due to the right whale distribution shift which has resulted in fewer calves being seen on the feeding grounds with their mothers, and fewer sightings of them as juveniles anywhere- both of which make cataloging recent calves challenging.

Figure 1. Assessments of the North Atlantic right whale population based on four available assessment methods. The Pace method shows a point "estimate" along with error bars which represent 95% of the posteriori probability. That model estimates the number of whale alive *at the start* of each year plus any new whales estimated to enter during that year. Data through 2017 as of September 4, 2018.



Best Right Whale Population Estimate 2017

We believe the Pace Method provides the best estimate for 2017. To get an estimate of whales alive *at the end* of 2017 using this methodology, we take the estimate at the start of 2017 (428, Figure 1) and subtract the observed deaths during 2017 (13 cataloged whales and four unidentified). Therefore, the best estimate for the end of 2017 is **411** right whales (95% confidence range +/- 22 and 19 respectively) using data as of September 4, 2018.

How Well Are We Monitoring?

Below is an annual count of sightings, unique individuals, whales presumed alive, kilometers of effort that have been submitted to the sightings database at the University of Rhode Island, and percent of the population that was identified each year from 2000 onward (Table 1). The shift in whale distribution has reduced both the number of sightings contributed to the Catalog and the percent of the population seen annually since 2011. Data as of September 4, 2018.

Table 1. Annual counts of sightings, unique individuals, presumed living whales, survey effort, and the percentage of the population seen. Survey effort from dedicated surveys only; opportunistic sightings do not record or report effort. None of the numbers for 2017 are final as not all of the data for that year have been submitted or analyzed. Data as of September 4, 2018.

Year	Sightings	Unique IDs	Presumed Living Population	Survey Effort (1,000 km)	% of population seen
2000	3087	236	344	125	69%
2001	3849	282	362	127	78%
2002	2718	303	385	252	79%
2003	2405	314	398	180	79%
2004	1811	286	407	287	70%
2005	3399	353	425	357	84%
2006	2801	347	436	316	80%
2007	3739	379	450	267	84%
2008	4147	390	473	254	83%
2009	4635	422	491	246	86%
2010	3224	421	512	271	82%
2011	3464	437	513	234	85%
2012	2127	375	512	271	73%
2013	1905	296	514	215	58%
2014	2399	369	513	200	72%
2015	1771	262	510	184	51%
2016	2199	319	499	155	64%
2017	3014	343	465	126	74%

Reproduction

There were no documented calves born in 2018 (Table 2).

Table 2. Summary of calving events and associated interval times for North Atlantic right whales from 2009-2018. The number of available cows, defined as females who have given birth to at least one previous calf, were presumed to be alive, and have not given birth in the last two years, are followed by the percentage of available cows to successfully calve.

Year	Calf Count	Available Cows/ % to calve	Average Interval	Median Interval	First time Moms
2009	39	58/67.2%	4.0	4	8
2010	19	45/42.2%	3.3	3	4
2011	22	48/45.8%	3.7	3	3
2012	7	64/10.9%	5.4	4	2
2013	20	83/24.1%	4.6	4	7
2014	11	85/12.9%	4.4	4.5	1
2015	17	80/21.3%	5.5	6	4
2016	14*	81/17.3%	6.6	7	4
2017	5	71/7.04%	10.2	8	0
2018	0	76/0	-	-	-

*There were 14 mothers seen with calves in the 2015/2016 season, however, due to a three-way calf switch that included the presumed loss of one calf that was never photographed, only 13 calves were photographed.

Mortalities

Between 01 January 2018 – 31 December 2018, three right whale mortalities were documented, all in U.S. waters (Table 3). Entanglement was identified as cause of death for all three animals. The Consortium Board recognizes necropsies as significant data collection events that provide valuable information on which management and conservation measures can be (and have been) based. The Board views consistent necropsy response and support (both financial and personnel) as critical to monitor both right whale recovery and the efficacy of management actions.

Live Vessel Strikes, Entanglements, and Entrapments

Vessel Strikes:

There were two non-lethal vessel strike injuries documented between 01 January 2018 – 31 December 2018 (Table 4).

Entanglement and Entrapments

There were eight active entanglement/entrapment cases reported between 01 January 2018 – 31 December 2018, of which five were new. Table 5 includes newly reported cases as well as pertinent updates to previously reported cases.

Table 3. Documented right whale mortalities 01 January 2018 – 31 December 2018.

Whale #	Date	Location	Sex	Age	Field #	Necropsied?	Cause	Comments
3893	01/22/2018	East of Virginia Beach, VA USA	F	10	VAQS20191005 Eg	Yes	Entanglement	Whale was entangled in gear
Unk	08/25/2015	Martha's Vineyard	M	Unk	IFAW18-224Eg	Yes	Entanglement	
Unk	10/14/2018	120nm east of Wellfleet, MA	Unk	Unk	IFAW18-281Eg	No	Entanglement	Photographed and sampled at sea.

Table 4. Right whale vessel strikes (non-lethal) detected between 01 January 2018 – 31 December 2018.

Whale #	Date of First Injury Sighting	First location	Sex	Age (current)	Comments
4145	03/1/2018	Cape Cod Bay	M	7	Seen injury free 4/28/2017 (CCB). New injury consists of small prop cuts on dorsal left fluke and left trailing edge. Skeg marks on dorsal left fluke and left body. Wounds do not appear to be fresh. There are no visual indicators that the injury has impacted health thus far.
Unk	07/11/2018	Gulf of St. Lawrence	Unk	Unk	Prop marks visible behind and across the blowholes. Condition of whale is poor with grey skin, increased orange cyamid load on body, and compromised body condition visible from air. Whale was resighted in August 2018 in similar condition.

Table 5. Right whale entanglements and status updates 01 January 2018 – 31 December 2018. Newly reported entanglements (carrying gear) and updates to previously reported entanglements are in **bold**. Entangled dead whales are not included here.

Whale #	Date of First Entanglement Sighting	First location	Sex	Age (current)	Comments
1142	04/01/2014	100 miles east of NJ USA	F	Adult, >41	Sighted with rostrum wrap. **Whale was resighted on 4/10/2018 and 4/12/2018 (Stellwagen Bank), still entangled. A disentanglement team was able to partially cut both lines exiting the right side of her mouth. The hope is that the damage to the ropes will deteriorate the strength of the line over time. Whale was re-sighted on 6/19/2018, 7/12/2018, 7/19/2018 and 7/20/2018 in the Gulf of St. Lawrence, still entangled. Her condition deteriorated markedly between June and July.**
4146	04/23/2017	Cape Cod Bay, USA	F	7	Length of yellowish line caught in the left side of the mouth. The line is doubled on itself and trails aft of the flukes by about a body length. There appears to be a jumble of line and/or netting near the end of the trailing gear. Disentanglement response unable to work whale. **Resighted gear free on 4/22/2018 in Cape Cod Bay.**

Table 5 (cont'd). Right whale entanglements and status updates 01 January 2018 – 31 December 2018. Newly reported entanglements (carrying gear) and updates to previously reported entanglements are in **bold**. Entangled dead whales are not included here.

Whale #	Date of First Entanglement Sighting	First location	Sex	Age (current)	Comments
3245	08/28/2017	~20miles east of Perce, Gaspe Peninsula, CANADA	M	16	Whale entangled in what appears to be heavy line. Type unknown. The whale was essentially hogtied, with line through its mouth, leading to wraps of the peduncle. The whereabouts of any bitter ends are unknown but based on behavior and line impressed into the right flank, it appears the line leads to heavy weight. No disentanglement response permitted. **Whale resighted 10/29/2017 in GoSL skim feeding. Remained unclear whether the whale was gear free at this time. It was, however, apparent that if gear was still present, the configuration had changed as there was no obvious line observed over the back or wrapped around the peduncle. Resighted again in Jan-Feb 2018 in Cape Cod Bay. Whale appears to have shed gear.**
4091	**05/12/2018**	**60 miles ESE of Chatham, USA**	**F**	**8**	**The whale has line wrapped around its right flipper, at minimum, with about 50ft green line trailing. What appears to be a red, yellow and green buoy is near the right flipper. Due to weather forecast and distance, the CCS response team could not mount a response. Whale has not been resighted.**
3312	**07/13/2018**	**Gulf of St. Lawrence**	**M**	**15**	**Aerial survey team sighted whale with gear in tow. Whale had been seen by the same team earlier in the day gear free. At minimum, the whale had yellowish line through the mouth and trailing at least a few body lengths behind. One of the trailing lines may sink and the aerial team noticed what may have been floats or tackle subsurface. The whale appeared agitated, and was writhing at the surface and defecating. Raw rope burns were apparent across the back and peduncle. Whale has not been resighted.**
3843	**07/30/2018**	**Bay of Fundy**	**M**	**10**	**Observed entangled in the Bay of Fundy trailing a buoy approx. one body length aft of the flukes. Whale was very thin and had severe wounds and significant aggregations of cyamids around the peduncle. Whale was partially disentangled on 8/5/2018 (including the attached buoy). There is likely some remaining line on the whale that will hopefully shed over time. Resighted on 12/30/2018 southeast of Nantucket. Line remains, exiting left mouth and there may be a rostrum wrap.**
3960	**08/20/2018**	**Gulf of St. Lawrence**	**M**	**9**	**Whale observed with multiple wraps of the rostrum, damaged baleen, and no line trailing, although the sighting team felt that there was likely weight attached. Throughout the sighting the whale was thrashing at the surface and the configuration of the entanglement changed often. This behavior, the condition of the whale and changing entanglement configuration, led the team to believe that it was likely a new entanglement. As the team on scene was consulting and documenting the whale, its entanglement configuration continued to change and the whale picked up speed swimming at ~8kts. After more observations, the team felt that the whale might have shed the entanglement. No additional sightings of this whale have been reported. While observers noted that no gear was visible at the end of the sighting, they could not see all body areas and the whale was relatively distant and therefore the whale is considered still entangled.**
2310	**12/20/2018**	**Southeast of Nantucket**	**M**	**Adult, >24**	**The whale appears to have a short bitter end at the area of its left pectoral flipper that enters its left mouth. The line passes through the mouth and exits out the right side, trailing roughly 1-2 body lengths, at minimum, aft of the flukes. It appears as though the trialing line sinks into the water column due to the nature of the line, no bitter end was observed. There were no significant injuries associated with the entanglement documented. The whale was slightly thin. A response was not mounted. The whale may shed the line on its own.**

Monitoring Health of Injured Right Whales

Efforts to better track and monitor the health of North Atlantic right whales with anthropogenic injuries were initiated in January 2013. These efforts aim to support annually mandated human induced serious injury and mortality determinations, to reduce the likelihood of undetected and unreported events, and to better assess both short and long term impacts of injury on right whale health. Previously and newly injured right whales with vessel strikes, attached fixed gear, or with moderate to severe entanglement injuries in the absence of attached gear (see Knowlton *et al.* 2016 for review of injury types) are flagged for monitoring biannually. Each whale's pre- and post-injury health conditions are evaluated using the visual health assessment technique (Pettis *et al.* 2004) and a determination of the impact of injury on health is made. Based on the available sighting and health information, whales are assigned to one of four categories: 1) Evidence of declining health coinciding with injury; 2) Inconclusive (this determination was assigned to animals when a: evidence of declining health exists but it was unclear whether or not it was linked to injury and/or b: images/information were inadequate to fully assess health condition visually; and/or c: condition has improved but remains compromised; 3) No indication of declining health caused by injury based on available images/information (these are removed from the monitoring list should subsequent sightings also show no impact of injury on health); and 4) Extended Monitor - no indication of declining health or whale's condition has improved but whale will remain on monitoring list because of injury severity and/or is still carrying gear. This last category was created to capture whales without current health impacts related to injury, but with injuries that have the potential to negatively impact future health condition (e.g. some severe vessel strikes, whales carrying gear, etc.).

Between 01 January and 31 December 2018, 17 new injury of interest events were documented, 15 of which were entanglement related and two were vessel strikes. Of these 17, four exhibited declining condition coinciding with injury. The impact of injury on the health of nine whales was inconclusive. There were no visual indicators of injury impact on health condition for the remaining four newly injured whales. Fourteen whales previously on the monitoring list were removed, including five who became presumed dead and nine who exhibited stable health. As of 31 December 2018, the Serious Injury/Human Impact list includes 70 whales with 79 injuries documented from 17 March 2004 through 31 December 2018 (Table 6). The majority of the injuries are entanglement related (67/79, 84.8%) followed by vessel strikes (10/79, 12.7%). There are two whales on the list with injuries of unknown origin (Table 7).

Table 6. Since the inception of the injured right whale monitoring protocol, the number of injured whales and newly reported injuries has varied by year. The number of whales included on the injured whale list is given for each biannual report and is followed parenthetically by how many of those were newly detected injuries. There are currently nine whales on the injured list with multiple injuries.

Year	June	December
2013	**33***	**32 (2)**
2014	**45 (16)**	**50 (6)**
2015	**51 (4)**	**59 (9)**
2016	**60 (4)**	**63(8)**
2017	**61 (4)**	**70 (10)**
2018	**74 (9)**	**70 (8)**

*The first injured whale monitoring report was distributed in June 2013 and therefore does not include a comparative number of newly reported injuries.

Table 7. Impact of anthropogenic injury on right whale visual health by injury type based on assessments of photographs pre- and post-injury for all North Atlantic right whales on the Serious Injury/Human Impact list as of 31 December 2018.

	Entanglement		Vessel Strike	Other	Total
	Gear Present	No Gear Present			
Decline in Condition	7	13	2	1	23
Inconclusive	14	12	2	1	29
No Decline in Condition	2	11	2	0	15
Extended Monitor	1	1	1	0	3
Total	24	37	7	2	70*

*This represents the number of whales on the monitoring list. Nine of these whales have each had second injuries documented since their initial injury sighting. For purposes of this report, whales are included under the category representing their most recent injury.

Aerial and Vessel-based Sighting Summary: 2017

Prior to the 2017 Report Card, sighting information was reported for the time period following the previous NARWC Annual Meeting. However, that reporting included the current year for which not all data has necessarily been received and/or processed. Therefore, beginning with the 2017 Report Card, sighting summaries will be presented for the previous calendar year. Cataloged sighting information for the year 2017 (analysed 04 September 2018) is summarized below and includes survey, research, and opportunistic sightings. Months with sightings and major contributing organizations (>10% total sightings for region) are listed after total number of sightings. Summaries of survey types (if available) are listed below each region.

Major Contributing Organizations

BHC: Boston Harbor Cruises
CAWW: Cape Ann Whale Watch
CCS: Center for Coastal Studies
CWI: Canadian Whale Institute
DFO: Fisheries and Oceans Canada
FWRI: Florida Fish and Wildlife Research Institute
GDNR: Georgia Department of Natural Resources
MICS: Mingan Island Cetacean Studies
NEAq: New England Aquarium
NEFSC: Northeast Fisheries Science Center
QLM: Quoddy Link Marine
S2S: Sea to Shore Alliance
TC: Transport Canada
WHOI: Woods Hole Oceanographic Institution

Southeast United States (sightings: 54, January – Feb; FWRI, GDNR, S2S, WHOI)

- Aerial and vessel surveys, biopsy darting, drone

Mid-Atlantic (includes south of Cape Cod) (sightings: 289, February - December; NEAq, NEFSC)

- Aerial surveys and vessel surveys

Great South Channel (sightings: 137, February, April - July; NEFSC, CCS)

- Aerial and vessel surveys

New England (Massachusetts Bay/Cape Cod Bay) (sightings: 1757, January – May, December; CCS, WHOI)

- Aerial and vessel surveys, habitat sampling, drone based photogrammetry, opportunistic

Gulf of Maine (sightings: 10, May, August, October; CCS, NEFSC)

- Aerial surveys

Bay of Fundy (sightings: 68, July - September; NEAq, QLM)

- Vessel surveys

Roseway Basin (sightings: 1, July; NEFSC)

- Aerial surveys

North (Gulf of St. Lawrence) (sightings: 694, May - October; CWI, DFO, MICS, NEFSC, TC)

- Vessel and aerial surveys

Jeffreys Ledge (sightings: 6, May – July; BHC, CAWW)

- Whale Watch, Opportunistic

Management and Mitigation Activities

United States

- In 2018, NMFS conducted a number of management activities under the Endangered Species Act (ESA) related to recovery plan implementation specific to Section 4(f). this included:
    - convening a new Northeast U.S. Implementation Team (NEIT)
    - forming a U.S. North Atlantic Right Whale Implementation Team (RWIT; composed of the NEIT and Southeast Implementation Team (SEIT))
    - establishing a RWIT Population Evaluation Tool Subgroup.
- NOAA called for 15 Dynamic Management Area (DMA) voluntary speed reduction zones between 01 January 2018 and 31 December 2018 (Table 8)

Table 8. Dynamic Management Area (DMA) voluntary speed reduction zones posted by NOAA between 01 January 2018 and 31 December 2018.

Trigger Date (date of RW sightings)	**# Right Whales**	**Sightings Source**	**General Location**	**Boundaries**
1/21/2018	22	Aerial Survey	30 nautical Miles south of Nantucket	41.15N 40.22N 070.51W 069.37W
1/23/2018	4	U.S. Military Vessel	86 nautical Miles east-southeast of Virginia Beach, Virginia	36 54N 36 12N 074 47W 073 55W
1/26/2018	3	Aerial Survey	54 nautical Miles east-southeast of Virginia Beach Virginia	36 53N 36 14N 075 18W 074 29W
3/20/2018	6	Aerial Survey	11 nautical Miles southwest of Nantucket	41 28N 40 47N 070 45W 069 46W
3/29/2018	8	Aerial Survey	20 nautical Miles south-southwest of Nantucket, MA	41 28N 40 47N 070 45W 069 46W
4/9/2018	5	Aerial Survey	69 nautical miles northeast of Virginia Beach, VA	37 41N 36 58N 075 06W 074 13W
4/18/2018	5	Whale Watch Boat	12 nautical Miles east of Boston, MA	42 43 N 42 00 N 071 17W 070 20W
4/24/2018	3	Trained observers aboard the R/V Kommander Iona	19 Nautical Miles south of Martha's Vineyard	41 25 N 40 46 N 070 58 W 070 06 W
5/1/2018	3	Aerial Survey	27 nautical miles east of Boston	42 32 N 41 53 N 070 57 W 070 04 W
5/2/2018	12	Beachgoer and Photo ID	21 nautical miles northeast of Boston	42 59 N 42 10 N 071 16 W 070 10 W
5/5/2018	3	Aerial Survey	8nm east of Race Pt. Provincetown MA	42 22 N 41 44N 070 27W 069 36W
6/30/2018	4	Aerial Survey	2 nautical miles south of Nantucket, MA	41 32 N 40 54 N 070 29 W 069 34 W
12/11/20018	6	Aerial Survey	Cape Cod Bay, MA	42 07 N 41 28 N 070 45 W 069 54 W
12/14/2018	4	Shipboard; Trained protected species observers	12 nautical miles southeast of Atlantic City, NJ	39 33 N 38 52 N 074 42 W 073 49 W
12/15/2018	33	Aerial Survey	26 nautical miles south of Nantucket, MA	41 17 N 40 24 N 070 37 W 069 25 W

Canada

- In 2018, Fisheries and Oceans Canada (DFO) and Transport Canada (TC) implemented a series of measures to reduce risk to right whales in Canada waters. These include:
  - Static and dynamic vessel speed restriction zones in the Gulf of St. Lawrence;
  - Static and dynamic fishery closure zones in non-tended fixed gear fisheries, in the Gulf of St. Lawrence and in right whale critical habitat areas;
  - An investment of $1 million in annual support for marine mammal response organizations; and
  - Investments in science to better understand threats to right whales, and to inform future management measures.
- The Government of Canada has been consulting with fishing and shipping industry representatives, Indigenous groups and other partners, for feedback on 2018 measures and to support the development of measures for 2019.
- Canada's National Marine Mammal Peer Review Committee will meet in November 2018 to review data and address question related to right whale distribution, habitat use, and risk of interactions with fishing gear and collision with vessels in Canadian waters.
- Extensive surveillance of Atlantic Canadian waters for North Atlantic right whales was achieved using aircraft, vessels, and passive acoustic technology including hydrophones and gliders. DFO, TC and partners are preparing plans for survey and surveillance efforts in 2019.
- DFO has supported a number of fishing gear innovation trials undertaken by industry, in different areas and fisheries in Atlantic Canada. These include "ropeless" fishing systems and gear modifications to reduce the risk of entanglement for whales.
- DFO held a meeting with Marine Mammal Response Program partners on October 24 and 25 to review the 2018 season, as well as discuss capacity building for response moving forward.
- Large vessel speed restrictions were in force in the Gulf of St. Lawrence from April 28, 2018, and will continue until November 15. The dates may change depending on the migration of the North Atlantic right whales.

Right Whale Project Requests for NARWC Data Use in 2018

- Create an inventory of cetacean species using the Northeast Canyons National Marine Monument waters and examine distribution and relative abundance
- Right whale international signal flag project
- Increasing Northeast US Marine Aquaculture production by pre-permitting Federal Ocean Space
- geographic based risk assessment for North Atlantic Right Whale mortalities in traffic dense regions off the east coast of United States
- Distribution of the Giant Oceanic Manta Ray (*Manta birostris*) in the southeastern United States
- Cetacean presence in the Fundian Channel/Brown's Bank area to inform protected area planning
- Investigating hormones in individual right whale baleen
- Gross and histopathological findings from North Atlantic right whale (*Eubalaena glacialis*) mortalities between 2003 and 2017
- Block Island SMA Modification to Protect Right Whales in the Providence/Quonset Port Area
- Growth of North Atlantic Right Whales (*Eubalaena glacialis*) revisited
- Right whale international signal flag project
- Integration of Sightings database in SLGO's web application *Marine Conditions*
- North Atlantic right whale habitat use in the Gulf of St. Lawrence
- Vessel strike risk to North Atlantic right whales in the Gulf of St. Lawrence and comparison of strike risk between right whale habitats of eastern Canada
- Calvin Family Tree
- Computer vision for conservation
- Climate Change and the Conservation Oceanography of the North Atlantic Right Whale Population
- How and why is the timing and occurrence of seasonal migrants in the Gulf of Maine changing due to climate?
- Interactive online platform for studying right whale distribution in Canadian waters

- A bi-hemispheric comparison of right whale body condition reveals poor nutritional state of the North Atlantic right whale
- Assessment of LIMPET tagged whales
- What if there were no fishing? North Atlantic right whale population trajectories without entanglement mortality.
- Using Multispectral Satellite Imagery and Deep Learning to Automatically Detect Marine Mammals from Orbit

2018 North Atlantic Right Whale Publications/Reports

Reports and publications that utilized NARWC databases in 2018 and/or those of general interest to the right whale community are listed and hyperlinked below.

Publications

Bogucki, R., M. Cygan, C. B. Khan, M. Klimek, J. K. Milczek, and M. Mucha. 2018. Applying deep learning to right whale photo identification. *Conservation Biology*

Burgess, E.A., Hunt, K.E., Kraus, S.D. and Rolland, R.M., 2018. Quantifying hormones in exhaled breath for physiological assessment of large whales at sea. *Scientific reports*, *8*(1), p.10031.

Cholewiak, D., Clark, C.W., Ponirakis, D., Frankel, A., Hatch, L.T., Risch, D., Stanistreet, J.E., Thompson, M., Vu, E., Van Parijs, S.M. 2018. Communicating amidst the noise: modeling the aggregate influence of ambient and vessel noise on baleen whale communication space in a national marine sanctuary. Endang Species Res 36:59-75

Convertino, M., Valverde, L.J. 2018. Probabilistic Analysis of the Impact of Vessel Speed Restrictions on Navigational Safety: Accounting for the Right Whale Rule. *The Journal of Navigation*, *71*(1), 65-82.

Corkeron, P., Hamilton, P., Bannister, J., Best, P., Charlton, C., Groch, K.R., Findlay, K., Rowntree, V., Vermeulen, E., Pace, R.M. 2018. The recovery of North Atlantic right whales, *Eubalaena glacialis*, has been constrained by human-caused mortality. *Royal Society Open Science*, *5*(11), 180892.

Fernández Ajó, A.A., Hunt, K.E., Uhart, M., Rowntree, V., Sironi, M., Marón, C.F., Di Martino, M., Buck, C.L. 2018 Lifetime glucocorticoid profiles in baleen of right whale calves: potential relationships to chronic stress of repeated wounding by Kelp Gulls. Conserv Physiol 6(1): coy045; doi:10.1093/conphys/coy045.

Hayes, S.A., Gardner, S., Garrison, L., Henry, A., Leandro, L. North Atlantic Right Whales - Evaluating Their Recovery Challenges in 2018. 2018. NOAA Technical Memorandum NMFS-NE-247. 30pp.

Howle, L.E., Kraus, S.D., Werner, T B., Nowacek, D.P. 2018. Simulation of the entanglement of a North Atlantic right whale (*Eubalaena glacialis*) with fixed fishing gear. *Marine Mammal Science*.

Hunt, K.E., Lysiak, N.S.J., Matthews, C.J.D., Lowe, C., Fernández, Ajó A., Dillon, D., Willing, C., Heide-Jørgensen, M.P., Ferguson, S.H., Moore, M.J., Buck, C.L. 2018 Multi-year patterns in testosterone, cortisol and corticosterone in baleen from adult males of three whale species. Conserv Physiol 6(1): coy049; doi:10.1093/conphys/coy049.

Kenney, R.D. 2018. What if there were no fishing? North Atlantic right whale population trajectories without entanglement mortality. Endangered Species Research 37:233-237. https://doi.org/10.3354/esr00926

Krzystan, A.M., Gowan, T.A., Kendall, W.L., Martin, J., Ortega-Ortiz, J.G., Jackson, K., Knowlton, A.R., Naessig, P., Zani, M., Schulte, D.W., Taylor, C.R.. 2018. Characterizing residence patterns of North Atlantic right whales in the southeastern USA with a multistate open robust design model. Endang Species Res 36:279-295. https://doi.org/10.3354/esr00902.

Lysiak, N.S., Trumble, S.J., Knowlton, A.R., & Moore, M.J. 2018. Characterizing the Duration and Severity of Fishing Gear Entanglement on a North Atlantic Right Whale (Eubalaena glacialis) Using Stable Isotopes, Steroid

and Thyroid Hormones in Baleen. *Frontiers in Marine Science*, *5*, 168.

Mayo, C.A., Ganley, L., Hudak, C.A., Brault, S., Marx, M.K., Burke, E., Brown, M.W. Distribution, demography, and behavior of North Atlantic right whales (Eubalaena glacialis) in Cape Cod Bay, Massachusetts, 1998–2013. 2018. *Mar Mamm Sci*.

Meyer-Gutbrod, E.L., Greene, C.H. 2018. Uncertain recovery of the North Atlantic right whale in a changing ocean. *Global change biology*, *24*(1), 455-464.

Meyer-Gutbrod, E.L., C.H. Greene, and K.T.A. Davies. 2018. Marine species range shifts necessitate advanced policy planning: The case of the North Atlantic right whale. *Oceanography* 31(2)
Montes, N., Swett, R., Jacobson, S.K., & Sidman, C. 2018. Factors Influencing Recreational Boaters' Intentions to Comply with Right Whale Regulations in the Southeastern United States. *Society & Natural Resources*, *31*(4), 473-488.

Peel, D., Smith, J.N., Childerhouse, S. 2018. Vessel Strike of Whales in Australia: The Challenges of Analysis of Historical Incident Data. *Front. Mar. Sci*. 5:69. doi: 10.3389/fmars.2018.00069

Root-Gutteridge, H., Cusano, D.A., Shiu, Y., Nowacek, D.P., Van Parijs, S.M., Parks, S.E.
2018. A lifetime of changing calls: North Atlantic right whales, *Eubalaena glacialis*, refine call production as they age. Animal Behaviour, 137, 21-34.

Wright D.L., Berchok C.L., Crance J.L., Clapham PJ. 2018. Acoustic detection of the North Pacific right whale in the northern Bering Sea. *Mar Mamm Sci*.

Reports

Surrey-Marsden, Claire, K. Howe, M. White, C. George, T. Gowan, P. Hamilton, K. Jackson, J. Jakush, T. Pitchford, C. Taylor, L. Ward, and Zoodsma, B. 2017. North Atlantic Right Whale Calving Area Surveys: 2015/2016 Results. U.S. Dept. of Commerce, NOAA. NOAA Technical Memorandum NMFS-SER-6, 13 p

Baumgartner, M., Moore, M., Kraus, S., Knowlton, A., Werner, T. 2018. Overcoming Development, Regulatory and Funding Challenges for Ropeless Fishing to Reduce Whale Entanglement in the U.S. and Canada.

Khan, C. B., Henry, A., Crowe, L., Duley, P., Gatzke, J., & Cole, T. V. 2018. North Atlantic Right Whale Sighting Survey (NARWSS) and Right Whale Sighting Advisory System (RWSAS) 2016 Results Summary.

REFERENCES

Hayes S.A., Josephson E., Maze-Foley K., Rosel, P.E., editors. (2017). US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments -- 2016. NOAA Tech Memo NMFS NE 241; 274 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at /publications/doi:10.7289/V5/TM-NEFSC-241

Knowlton, A.R., Kraus, S.D., Kenney, R.D. (1994). Reproduction in North Atlantic right whales *(Eubalaena glacialis)*. *Can J Zool* Vol. 72:1297-1305.

Knowlton, A.R., Robbins, J., Landry, S., McKenna, H., Kraus, S.D., Werner, T.B. (2016). Effects of fishing gear strength on the severity of large whale entanglements. *Conserv Bio.* 30: 318-328.

Kraus S.D., Kenney R.D., Mayo C.A., McLellan W.A., Moore M.J., Nowacek D.P. (2016). Recent scientific publications cast doubt on North Atlantic right whale future. *Front Mar Sci* 3:137. doi: 10.3389/fmars.2016.00137

Laist, D. W., Knowlton, A. R., Pendleton, D. (2014). Effectiveness of mandatory vessel speed limits for protecting North Atlantic right whales. *Endang Spec Res 23*(2), 133-147.

Pace, R. M., Cole, T. V. N., Henry, A. G. (2014). Incremental fishing gear modifications fail to significantly reduce large whale serious injury rates. *Endang Spec Res* 26, 115–126. doi: 10.3354/esr00635

Pace, R.M., Corkeron, P.J., Kraus, S.D. (2017). State–space mark–recapture estimates reveal a recent decline in abundance of North Atlantic right whales. *Ecol Evo.* 1-12.

Pettis H.M., Rolland R.M., Hamilton P.K., Brault S., Knowlton A.R., Kraus S.D. (2004). Visual health assessment of North Atlantic right whales (*Eubalaena glacialis*) using photographs. *Can J Zool* 82:8-19

Pettis, H.M. (2009). North Atlantic Right Whale Consortium Annual Report Card (01 November 2007 – 30 April 2009). International Whaling Commission Annual Meeting, May 2009. Reference Document *SC/61/BRG1*.

Reeves, R.R., Read, A.J., Lowry, L., Katona, S.K., Bonnes, D.J. (2007). Report of the North Atlantic Right Whale Program Review. Marine Mammal Commission. Bethesda, Maryland.

Robbins, J., Knowlton, A.R., Landry, S. (2015). Apparent survival of North Atlantic right whales after entanglement in fishing gear. *Biol Conserv* 191: 421-427.

Appendix 1

Catalog Assessment Method

We have developed standardized criteria that can be applied each year to get a low, middle (best estimate) and upper number of whales in the population as determined from Catalog data. One term needs to be explained to understand these numbers. Whales are given temporary intermatch codes if 1) two or more sightings match each other, and 2) neither have been matched to a catalog whale. Some of these whales will eventually be matched to existing cataloged whales and others will be determined to be "new" to the Catalog and assigned a number. Once an intermatch whale is given a Catalog number, or matched to another intermatch code whale, the intermatch code is made inactive. The results for 2017 are provided below in Table 1.

LOWER

To determine the lower bound, we simply count the number of unique cataloged whales identified the year before. Because of delays in processing data, this number is lower than the eventual total number of whales seen alive in that year.

MIDDLE

The middle bound is determined by summing three categories:

1) All whales presumed to be alive in that year (i.e. seen in the last six years),
2) Intermatch whales that are likely to be added to the Catalog. This is calculated by first finding all intermatch codes that span two or more years (both those that are active and those that were matched and made inactive), removing all calves and any SEUS whales whose sightings span two years only because they are seen in December and January of the same field season. Then, we determine which of those intermatch whales have Catalog numbers and what percent of those were new to the catalog (i.e. had not been matched to an existing cataloged whale). The remaining, unidentified intermatch whales are then multiplied by that fraction to determine how many are likely new to the Catalog (e.g. if only 20% of the matched intermatch whales were new, then 20% of the unmatched intermatch whales are likely new). That number is then added to the count of calves born more than two years earlier that are unmatched with active intermatch codes (indicating there is enough information to potentially match them in the future). Process changed Oct. 2009.
3) Calves from the last two years that have not been cataloged. We make an assessment of whether there is enough photographic information to likely be able to match them to future sightings and thus eventually assign them a Catalog number. We then sum those that will likely be cataloged.

UPPER

The upper bound is also the sum of three categories:

1) All Cataloged whales minus those whose carcasses were identified. Even whales missing for 30 years included.
2) All active intermatch whales minus calves from the last two years.
3) All calves from the last two years minus those known to be dead.

Appendix 1 (cont.)

Table 1. The Catalog method of estimating the population represents an assessment of the number of photographed whales in the North Atlantic Right Whale Identification Database. Analysis completed 9/4/18.

Low: 343 individuals	
343	Cataloged whales seen in 2017
Middle: 511 individuals	
465	Cataloged whales presumed alive in 2017
34	Intermatch whales likely to be added to Catalog
12	Calves from 2016 and 2017 likely to be added to Catalog
High: 728 individuals	
676	All Cataloged whales in 2017 minus those known dead
38	All active intermatch codes without 2016 & 2017 calves
14	All uncataloged 2016 and 2017 calves minus dead