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

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Contents

Executive Summary

This report combines several North Atlantic Right Whale Catalog related tasks into one, comprehensive report. Each of these tasks reports on a slightly different time period. Catalog maintenance (Task 1) reports primarily on Catalog data through 2019 using data as of September 1, 2020. The entanglement scar coding (Task 2) reports on data for 2018 and compares 2018 findings to previous years. Anthropogenic case study reports (Task 3) describe cases first documented in 2018. The near-real-time matching (Task 4) reports on matching efforts from September 1, 2019 to August 31, 2020. Finally, the visual health coding (Task 5) reports on data through 2018, with some 2019 data and newly added data prior to 2018 included. Combined, these tasks provide an excellent example of the amount of research that can be leveraged by maintaining a time series of images and data on identified individuals.

One factor that affects our ability to perform all these tasks is the continued change in right whale distribution patterns which began in 2010/2011. This shift initially resulted in fewer sightings contributed to the Catalog, but as the research community adjusted where they surveyed in response to the new distribution, the number of sightings has increased and, at 4,396 in 2019, has now surpassed the number contributed annually in 19 of the last 20 years. However, even with the increase in sightings, some segments of the population are seen less frequently than before, and the level of shipboard surveys remains low. Both these changes have made photographically identifying and cataloging calves from recent years, and collecting genetic samples from them later as juveniles, difficult and make the assessment of survival, entanglement rates, scarring rates, and visual health more challenging. It is particularly important that the genetic sampling work on the calving ground continue in order to link calves to post-calf sightings and thus maintain data on age, parentage and juvenile survival. Calves that have not yet been cataloged may be cataloged years later using genetics or more recent photographs. This past year, we cataloged one calf born in 2011 and one in 2013- a far greater delay than was the case in the previous decades. We continue to work closely with the right whale geneticists at St. Mary's University: we confirm that all samples that were collected are sent to the lab, that those samples are correctly linked to the Catalog database, and help make and disseminate genetic identifications when possible.

Even though there were disruptions caused by the COIVD-19 pandemic, we processed more data than we have in years. Since the last catalog report, 4,764 sightings were added to the Catalog, 4,487 identifications confirmed, and 15 new whales added. In addition, 11 whales became presumed dead and one was resurrected. The last three years have had the highest number of presumed deaths on record. There are currently 761 cataloged whales, 458 of which are presumed to be alive- a decrease of four from last year's report. In 2019, there were 10 dead whales documented compared to the three recorded in 2018. With the change in right whale distribution patterns, there have been increasing numbers of sightings reported opportunistically: 32 of the 69 contributing individuals/organizations in 2019 do not normally collect and submit right whale images and they provided over 100 sightings. Tracking down the data and images from many of these sources has proven to be challenging and time consuming- especially those only found on social media.

We accomplished several Catalog-related projects as well. Working with the geneticists at St. Mary's University in Halifax, we identified three calves from past years and added them to the

Catalog, as well as closed the case on two dead whales that definitely did not match any samples in the genetics database. With funds from a private foundation, we overhauled the Catalog public website, improving the image viewer and whale search capabilities, as well as the educational material linked to the site. The website now links directly to the FlukeBook automated matching portal. This past year, we also exported another 62,000+ images of recently identified whales to compliment the 400,000 images exported to FlukeBook the previous year. As the excitement over this new matching tool grows, it is important to clarify where it will fit into the Catalog process. It will speed up matching for many aerial sightings and eventually may help us match shipboard photographs to other shipboard photographs. It is unlikely that it will be able to compare aerials to shipboards and vice versa. In short, it will help with some identifications, but identifications are only one small component of the Catalog work. The Catalog has to be maintained in such a way to allow for assessments of health, anthropogenic scarring, behaviors, and associations. To accomplish this, the Catalog staff have to import and review all the images, code the sightings for what the whale looks like, code the images for view direction and body part, review images for behaviors and associations, select images for deleting when there are hundreds per sighting, and code sighting batches for heath and anthropogenic scarring. The staff will also continue to match all shipboard images, catalog new animals, track links to the genetics database, and confirm each automated match is correct *and* that all the images in that sighting are the same whale (particularly important with social groups). The coding of images and sightings is also what enables us to identify dead whales floating belly-up using obscure marks. In short, maintaining the high-level of detail in the Catalog data allows us to monitor many metrics for this population, including changes in anthropogenic impacts, which in turn inform management efforts.

Scarring data for 2018 indicate a continued high level of entanglement of right whales in fixed fishing gear with a crude entanglement rate (newly discovered entanglement scars as a proportion of whales seen) of 17.0% and an annual entanglement rate (proportion of adequately photographed whales with new scars) of 30.3%. These rates exceed the average crude entanglement rate of 15.5% and the 25% annual entanglement rate documented by Knowlton et al. (2012) for 1980-2009. The proportion of the population with one or more entanglements remains high at 86.5%. In 2018, there were 59 entanglement events, including 15 serious entanglements, a continued high proportion of moderate and severe injuries (37%), and a continuing decline in the juvenile population (down to 16%). At 4.3% of all sightings, the 15 serious injuries represent the highest documented serious entanglement rate in 39 years with 2017 holding the previous record at 3.9%.

Anthropogenic case studies were developed for three new vessel strike cases and six new entanglement cases documented in 2018. These case studies include photographs and life history data, and, for the entanglement cases, rope polymer information where available. The vessel strike cases have a drawing depicting the location of the wounds.

Through near-real time matching, we were able to support the team on the calving ground with up-to-date list of whales needing to be darted and mothers considered available to calve, as well as provide matching support for their 25 whales. Due to cancellations in field work due to the COVID-19 pandemic, our usual near-real time matching support for the biopsy effort in Cape Cod Bay and the Gulf of St. Lawrence was not required in 2020. Instead, we assisted Nick

Hawkins and the Department of Fisheries and Oceans with their matching while they were in the field in the Gulf. Finally, we rapidly identified four reportedly entangled whales, two dead whales (both challenging as always), and four newly injured whales.

Finally, visual health coding for 3,819 sightings of 422 right whales was completed since the last report, bringing the Visual Health Assessment Database up to date through 2018. Analyses of health scoring over time indicate that the distribution shift of right whales since 2010 is impacting our ability to effectively monitor the health of this population. The annual proportion of whales presumed to be alive that were sighted and scored for health declined over recent years, as has the annual proportion of whales scored for body condition. Though still low relative to the pre-2010, increases in sighted and assessed whales from 2016-2018 suggest that shifting survey priorities and strategies have begun to reverse this trend. Lastly, the proportion of whales with compromised body condition, while still high relative to that of skin, decreased again in 2018 following spikes in 2015 and 2016. In contrast, the prevalence of compromised skin condition rose in both 2017 and 2018. This new information on condition is available to researchers and managers for various efforts, including long term and real time assessments of right whale health.

Task 1: Maintenance of the North Atlantic Right Whale Catalog: 01 January - 31 December 2019

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I. Introduction

The New England Aquarium's (NEAq) right whale research team is responsible for curating the right whale identification database, herein referred to as the "Catalog". As curators, we receive photographs from numerous research groups, whale watch vessels, and individuals from all parts of the North Atlantic Ocean. These photographs are processed in the order in which they are received and then integrated into the Catalog database. The annual Catalog report describes changes to any of the matching and integrating processes and provides a summary of the status of the complete Catalog, as well as information on the data for the given year. This report covers the 2019 time period and all data reported on are as of September 1, 2020. The database, as of this date, including all data prior to 2020, was exported and queried for this report. A CD of that exported database is enclosed with this report.

This part of the report has nine sections: I) Introduction, II) Catalog Overview, III) Computerized Database Summary, IV) New Animals, V) Presumed Dead and Resurrected, VI) Mortality, Entanglement, and Significant Injuries, VII) Photo Contributors, VIII) Catalog Related Publications and Reports, and IX) References. The Catalog Overview section is intended to provide an overview of both the Catalog as a whole, and the given year's data in particular.

II. Catalog Overview

(Data collected through December 2019)

The database is an identification database, not just a photo-identification database. In the past, only photographed sightings of right whales were included. As of June 2005, "sightings" was redefined to include high quality positions from identified whales that were satellite tagged, genetically identified by genotypes from skin samples collected from any photographed or unphotographed whale, and potentially genetic identifications from fecal "sightings" (i.e. when no whale is photographed in direct association with the sample). These three additional data types were added as options for inclusion in the database because all can potentially be linked to a cataloged individual. Fecal sightings were initially added to the Catalog, but were subsequently removed because there is currently no reliable method to link most samples to an individual whale (i.e. there is not adequate right whale DNA in the feces to reliably genotype them). In the future, any sample that can be confidently assigned to an individual will be re-entered. In January 2014, 732 records of satellite tagged whales were entered into the Catalog. Each of these records represents a single, high-quality location for each day a cataloged, tagged whale transmitted a position.

Because NEAq is primarily responsible for photographic identifications, our Catalog reports only describe the status of photographic sightings. As of September 1, 2020, there were a total of 83,181 records from 1935 through 2019: 82,380 associated with photographs where the identification was made primarily through the photographs (even if genetic data were also available), 0 fecal sightings, 747 satellite tagged sightings, and 54 sightings with either genetics and no photographs (n=5) or where there were some photographs, but the identification was made primarily through genetics (n=49).

Even with recent fluctuations in the number of right whale sightings contributed to the Catalog, the number of images submitted to the Catalog annually remains high. Each of these digital

images has to be reviewed and either deleted or coded for body area and view direction. In addition, the increased use of video cameras in Canada and Unoccupied Aerial Systems (UAS, or drones) in various regions has resulted in hundreds of images or screen grabs per sighting. These sightings require more time to process as we delete excess images. While time consuming, this is an important step as it improves our matching efficiency.

There have been ongoing problems with timely data submission. The primary problem occurs with unusual sighting events where data are either not submitted, or the submissions are incomplete. Tracking down data and images after the fact is extremely time consuming, and we have to know a sighting exists to do so. One specific example recently is the data for entangled whale #4423 described in the Entanglement section below. According to the Center for Coastal Studies' (CCS) private disentanglement website, this whale was first seen entangled on April 25, 2019. More than a year and half later, the NEFSC Atlantic Marine Assessment Program for Protected Species team has still not submitted images or data to the Catalog. Given the number of people who utilize the Catalog for analyses, the absence of this important sighting in the Catalog is unfortunate. The data submission issue used to almost always involve sightings of entangled whales, disentanglement events, mortality events, and off-season sightings where the chain of command for data submission was unclear, but now we also have issues tracking down data and images from opportunistic sightings, including those posted on YouTube and Facebook. In some entanglement cases, some images have been emailed, submitted to the CCS, or uploaded to a FTP site, but there are no accompanying data (e.g. date, time, location, platform, observer, behaviors), and no indication of whether all the available images are accounted for. Even with supposedly complete uploads to FTP sites, there are sometimes large gaps in image sequencing that are unexplained. We have tried to rectify the problem in several ways: 1) we ask contributors to submit all images and associated data of entangled whales within a day or two of each sighting, including images and data taken from multiple platforms on that given day; 2) we keep a list of every event we hear of for which photographs of a right whale should exist and periodically check to see if we have received images and data from that event; and 3) we have asked contributors to compare sightings in their own local database to what we have in the Catalog (because there are often sightings that we never knew about and only the contributor can determine if data are missing). For example, through this latter effort, we learned that we were missing all data from one entire research cruise that had occurred three years prior. So far, only one contributor has done the comparison we asked for, but we will continue to request it. These submission issues hamper our ability to provide accurate and complete data on right whales, and are extremely time consuming for us to resolve.

We focus on "completing" years in sequential order. Because no year will ever have 100% of its sightings matched (due to poor quality images and sightings that may only be matchable in the future, either through genetics or photographs), we have decided to define a year as "complete" when 90% or more of the sightings are matched or deemed unmatchable. The breakdown of the matching status for sightings from 2000 to 2019 is provided in Appendix 1. The percentage complete dropped a bit from 99% in the 2000's to 95% to 98% in this decade. Many of the unmatched sightings in recent years are calves that have yet to be cataloged. Cataloging the 2011 to 2019 calves is proving to be more challenging than usual because of the scarcity of calf sightings with their mothers on the feeding grounds (thus no photographs of the calf after its callosity has developed). Also, a calf's callosity can change in its first few years of life;

therefore, it is helpful to photograph them as one and two year olds during that period of callosity development. The distribution shift has also resulted in fewer juveniles photographed during this period. Combined, these factors have led to a delay in calves being cataloged. As an example, the new whale #4170 that was added this past year and is described under the New Whale section below, was born in 2011, but not cataloged until 2020 because she was not seen for many years after her calf year. This example shows that it may take years, using a combination of photo-identification and genetics data, to link post-calf sightings back to a calf and then catalog that whale. Currently, an average of 78% of the calves born between 2011 and 2019 have been cataloged in contrast to the average of 89% cataloged in the previous eight years. This delay in cataloging calves impacts our annual matching success.

We have completed 98% of the matching for 2018 data and 30% for 2019 data (Appendix I). The percent matched for the 2019 data is higher than the percentage for 2018 in last year's report (20%) - a noteworthy fact given the increase in sightings contributed in 2019 (563 more sightings, or an increase of 15%) and the disruption caused by the COVID-19 pandemic. Some 2019 data were submitted late (over 600 sightings from DFO in May 2020) and other data have yet to be submitted. Given these delays and the increase in submissions, the previous year's data will never be fully processed by the time of this report. For this reason, we focused on confirming at least one sighting of each whale matched by teams in the field for the year we report on. So, although the percentage of sightings matched and confirmed in 2019 is low, the 347 unique individuals identified so far for the 2019 right whale year is high. The details of the 2019 data matching status categorized by observer are reported below and in Table 1 of Section VII.

Each year, we undertake a variety of other catalog related tasks, which are necessary to make the Catalog run smoothly and to better leverage the data within. This past year we: 1) added 15 days of satellite tag locations for entangled whale #3125 to capture the movements of this known individual from the Gulf of St Lawrence to Cape Cod and 2) continued working with right whale geneticists at Trent and St. Mary's University, primarily focusing on identifying dead whales this year. While genetics is not part of this contract, those cases that lead to identifications should be noted here. Since the last Catalog report, there were three identifications made solely or primarily through genetics that resulted in a whale being cataloged or a catalog whale linked back to an unidentified calf. These include: #4504 and #4612, calves from 2015 and 2016 respectively, added to the catalog and #4540 linked to the 2013 calf of #1612. It was also determined that two dead whales did not match any whale for which we have a sample. The dead whale from Clam Harbor, N.S. on July 23, 2012 (incident #86957) was a haplotype B female profiled at eight loci with no matches and the partial skull from Martha's Vineyard on September 4, 2018 (IFAW18-245Eg) was a haplotype D female profiled at nine loci with no matches. The latter is described in more detail in the Mortality section below. This Catalog-related work strengthens the data in the Catalog and improves our ability to monitor vital rates in this population.

This past year, we exported Catalog data to 16 different investigators who submitted data-use applications through the North Atlantic Right Whale Consortium. These exports were for a variety of investigations, but two required large numbers of images to be exported from the Catalog for automated intelligence (AI) training. One export involved over 240,000 images to train an algorithm to identify right whales from satellite imagery. The other involved an updated

image export for automated right whale matching. For the latter, we sent the FlukeBook right whale AI team another 62,000+ images of recently identified whales to compliment the 400,000 images exported to them the previous year. These images are used to improve the training of their automated matching algorithm. We also developed a two-way link between FlukeBook and the Catalog public website (see "The public catalog and the E catalog" section below). As the excitement over this new matching tool grows, it is important to clarify where it will fit into the Catalog process. It will speed up matching for many aerial sightings and eventually may help us match shipboard photographs to other shipboard photographs. It is unlikely that it will be able to compare aerials to shipboards and vice versa. In short, it will help with some identifications, but identifications are only one small component of the Catalog work. The Catalog has to be maintained in such a way to allow for assessments of health, anthropogenic scarring, behaviors, and associations. To accomplish this, the Catalog staff have to import and review all the images, code the sightings for what the whale looks like, code the images for view direction and body part, review images for behaviors and associations, select images for deleting when there are hundreds per sighting, and code sighting batches for heath and anthropogenic scarring. The staff will also continue to match all shipboard images, catalog new animals, track links to the genetics database, and confirm each automated match is correct *and* that all the images in that sighting are the same whale (particularly important with social groups). The coding of images and sightings is also what enables us to identify dead whales floating belly-up using obscure marks. In short, maintaining the high-level of detail in the Catalog data allows us to monitor many metrics for this population, including changes in anthropogenic impacts, which in turn inform management efforts.

Definition of terms

With the advent of the DIGITS database (described under Section IV), it is now possible to track the status of each sighting with more detail. Here we explain the terms used throughout the report.

Matched: Confirmed- a sighting that has been reviewed by at least two different researchers, both of whom agreed on a match to a cataloged whale.

Matched: Unconfirmed- a sighting that has been matched to a cataloged whale by one researcher, but is awaiting confirmation by a second person.

Not Matchable- a sighting that has been determined by at least two researchers to not be matchable to any other whale sighting or cataloged whale (due to poor quality photographic information).

Intermatched- a sighting that has been matched to at least one other sighting, but has not been matched to a cataloged whale. Intermatch codes allow us to track these "in between" sightings. An intermatched sighting has not necessarily been checked by a second matcher; that whale may in fact match a cataloged whale, another intermatch whale, or it may be a new whale to the Catalog that is awaiting a composite drawing and final confirmation that it is unique (see Section III below for more details).

Not Yet Matched- a sighting that may have been reviewed by several researchers, but for which no match or intermatch has yet been found.

Adult- any whale that is of known age and nine years or older, any whale of unknown age with a sighting history of eight years or more, or any female that has given birth.

Juvenile- any known age whale between its calf year and eight years old, if it has not given birth.

Gender- sex determined by either genetics, visual assessment of the genital region, or repeated association with a calf.

Presumed Dead- any whale that has not been sighted for six years or more (see Section V below for details).

Resurrected- any presumed dead whale that is later re-sighted.

Other Terms- Year is defined in two different ways throughout the report.

Right Whale Year- December 1 to November 30. This definition is used to minimize the confusion caused by the calving season spanning two calendar years. For example, counts of whales or mother/calf pairs in the southeast U.S. would be artificially high if using data based on the calendar year. Right whale year is used for the following sections of this report: Catalog Data- 2019only in Section III, Section VIII, and Appendix III.

Calendar Year- January 1 to December 31. Calendar year is more easily understood and is used for the following sections of this report: Catalog Data- All Years in Section III, for determining ages in Sections V and VI, and for Appendix I.

Catalog data- all years (Summary of all photographed sightings through December 31, 2019)

a. Summary of sightings

(n= 82,380)

Assessment Complete (92%)		Assessment Incomplete (8%)	
Matched: Confirmed	73,261	Matched: Unconfirmed	382
Not Matchable	2,935	Intermatched	429
		Not Yet Matched	5,373

Since the last catalog report, there have been 4,764 sightings added to the Catalog and 4,487 identifications confirmed.

b. Summary of cataloged whales

(n=761)

All Whales

	Male	Female	Unknown	**Total**
Gender	365 (48.0%)	321 (42.2%)	75 (9.8%)	761
	Adult	**Juvenile**	**Unknown**	**Total**
Age Class in 2019	625 (89.5%)	65 (9.3%)	8 (1.2%)	698*

* Totals for gender and age class differ because 63 cataloged whales died before 2019 and, therefore, did not have an age class recorded in 2019. An additional eight *cataloged* whales died in 2019, but had age class records in 2019.

Presumed Living in 2019

	Male	Female	Unknown	**Total**
Gender	260 (56.8%)	175 (38.2%)	23 (5.0%)	458

	Adult	Juvenile	Unknown	**Total**
Age Class in 2019	388 (84.7%)	62 (13.5%)	8 (1.8%)	458

Presumed Dead as of 2019

	Male	Female	Unknown	**Total**
Gender	77 (33.2%)	103 (44.4%)	52 (22.4%)	232

Known Dead (cataloged whales only)

	Male	Female	Unknown	**Total**
Gender	28 (39.4%)	43 (60.6%)	0 (0.0%)	71

	Adult	Juvenile	Unknown	**Total**
Age Class at Death	44 (62.0%)	24 (33.8%)	3 (4.2%)	71

Eight of the cataloged dead whales died in 2019 and are included in the age row in "All Whales" above. The remaining 63 dead whales are not included in that tally.

Catalog data- 2019 only (this is for the "right whale year", which includes data from December 1, 2018 through November 30, 2019)

Explanations of area abbreviations can be found in Appendix II. The numbers and percentages below do not match Appendix I because those results are for the calendar year, not the right whale year. Also, 15 satellite-tag-only "sightings" of entangled whale #3125 were entered in the last year.

a. Summary of sightings- 2019

(n= 4,649)

Assessment Complete (34.8%)		Assessment Incomplete (65.2%)	
Matched: Confirmed	1,600	Matched: Unconfirmed	395
Not Matchable	20	Intermatched	155
		Not Yet Matched	3,029

b. Distribution of sightings

Five Main Right Whale Areas					
BOF	**CCB**	**FL/GA**	**GSC**	**RB**	
70	1,343	153	61	2	
Other SEUS and Mid-Atlantic Areas					
NC	**NJ**	**NY**	**SC**		
2	5	10	4		
Other Northeast Areas					
GB	**GMB**	**GOM**	**JL**	**MB**	**SNE**
489	2	3	4	51	495
Other Areas North and East					
ESS	**GSL**	**NRTH**			
11	1,954	5			

c. Summary of identified whales

With 35.1% of all 2019 sightings for the right whale year matched and confirmed, 347 individual right whales have been identified (note: the 35.1% matched reported here differs from the % matched reported in Appendix I because the latter is for the 2019 *calendar* year). The numbers in section d below are noticeably low for GSL as we are have not fully processed those data. Also, section d includes some of the same individuals between areas; zeros in that section indicate that no whale from that area has been identified yet. (*Another 15 whales have been partially identified*: *no cataloged whale, 15 calves from various years, and no whales of unknown age*).

	Male	Female	Unknown	**Total**
Gender	200 (57.7%)	133 (38.3%)	14 (4.0%)	347
	Adult	Juvenile	Unknown	**Total**
Age Class in 2019	294 (84.7%)	48 (13.8%)	5 (1.5%)	347

d. Distribution of identified whales

Five Main Right Whale Areas					
BOF	**CCB**	**FL/GA**	**GSC**	**RB**	
13	262	16	11	1	
Other SEUS and Mid-Atlantic Areas					
NC	**NJ**	**NY**	**SC**		
1	2	5	3		
Other Northeast Areas					
GB	**GMB**	**GOM**	**JL**	**MB**	**SNE**
134	1	3	2	25	124
Other Areas North and East					
ESS	**GSL**	**NRTH**			
1	33	2			

Summary of deaths, resurrections, and new whales cataloged in 2019
(Details provided in Sections V, VI, and VII)

a.) Whales Presumed Dead	11
b.) Whales Resurrected	1
c.) Whales Added to Catalog*	
i. In 2019	0
ii. In 2020	15
d.) Confirmed Deaths	
i. Cataloged whales	8
ii. Carcasses not ID'd to Catalog	2

* These figures are since the last report, not just for the year 2019.

III. Computerized Database Status

Sighting effort data
All of the NEAq survey data from December 1, 2018 to November 30, 2019 have been compiled, proofed and corrected in the University of Rhode Island (URI) format. These computer data and summary sheets from each survey day have been sent to URI to be incorporated into the Sightings database housed there. The Sightings database includes all sightings of right whales, whether there are photographs or not, and all right whale focused survey effort. The Catalog database only includes sightings that can potentially be linked to an individual right whale (primarily through photographs); all of the Catalog sightings are included in the Sightings Database.

Database link with URI sightings database
The link between the Catalog database and the Sightings database is periodically refreshed. To do this, the Catalog data are exported and sent to URI. Dr. Bob Kenney (URI) compares sightings and effort data against the Catalog data to look for discrepancies, and then fills in several columns in the Catalog database that allow individual sightings to be linked to the effort database. Those columns, and any corrections to the corresponding data, are returned to NEAq. Philip Hamilton (NEAq) then reviews all unresolved issues that Dr. Kenney discovered. If the suggested corrections agree with the source data housed at NEAq, Mr. Hamilton makes the appropriate corrections in the Catalog database. If the data at NEAq do not match the suggested changes, then Mr. Hamilton and Dr. Kenney investigate which are the correct data, and the appropriate changes are made in either database. Mr. Hamilton then replaces all of the URI columns in the Catalog database with the updated ones. The process of comparing databases and sleuthing out and fixing discrepancies is important for creating a link between the two databases; it also serves as an excellent second check of the data.

The Catalog data were last sent to Dr. Kenney on January 21, 2020. Dr. Kenney returned the data with questions or issues on March 11, 2020. Mr. Hamilton reviewed the 42 potential errors that needed to be investigated on March 13, 2020: all were investigated, the solution noted for those that could be resolved, and the record corrected, where necessary, in the live Catalog database. Mr. Hamilton uploaded the final data on April 6, 2020.

We continue to proof the location data as soon as they are entered. We also periodically have GIS analyst Brooke Hodge (NEAq) map all sightings to highlight any clearly erroneous entries. There are two searches: one that flags sightings that map on land and another that flags sightings from the same platform on the same day that are too far away from each other to be accurate.

Catalog database

Since the creation of DIGITS (Digital Image Gathering and Information Tracking System), the database and software interface whose development was funded by the National Science Foundation (NSF) and launched in June 2005, the database and images are maintained in MS SQL on a server hosted by the NEAq. The data and images are accessed either via the Aquarium's Local Area Network (LAN) (for those on the NEAq campus) or via the Internet. There are two methods of accessing the system over the Internet: using a virtual private network (VPN) and the DIGITS software installed on one's local computer, or by an Internet browser using Citrix. In the latter case, the DIGITS software operates on the Citrix server and the system is accessed through a link to a secure website. Citrix can be used from a variety of computer platforms and is relatively fast over a range of Internet connection speeds. All images and data are backed up daily to another server at NEAq and then from that server to cloud storage (details provided below). All access to the system is controlled by several levels of password protection. Major contributors to the Catalog are provided access via Citrix to see and export all their own data at any time.

Although all data are maintained in MS SQL, a MS Access front end is used to allow NEAq researchers to perform standard queries and to export data into local data tables. This MS Access front end is a read-only feature. The size of the MS SQL database, which includes all the images within DIGITS, is currently about 1.5 terabytes in size.

NEAq maintains detailed drawings of each whale that provide a summary of all matching features for that individual at a glance. These composites are drawn directly in Adobe Photoshop Elements. The old hand-drawn composites were scanned in and both the old and new composites are updated in Photoshop as needed to provide matchers with the most up-to-date visual summary of each whale. A contractor used to do these drawings, but now one of our staff is fully trained. A total of 15 composites were created or updated since the last Catalog report. Creating new composites and updating existing composites improves the efficiency with which we, as well as contributors, are able to make identifications.

Maintaining DIGITS requires additional resources. All the servers and backups are managed by CTO Plus of Arlington, MA. Basic maintenance of the software itself is provided as a donation from Parallax Consulting, LLC. This year, we hired Parallax to make some improvements to the DIGITS software. Because not all of the requested changes have been completed, a new version of the DIGITS software incorporating these changes has not yet been deployed. These changes have taken longer than anticipated due to competing demands for the programmer's time. We anticipate completion of the requested changes and deployment of the updated software by early 2021.

Since the last Catalog report, the operating system for DIGITS' App Server, Web Server and secondary Domain Controller was scheduled to go "end of life" in January of 2020. This

software was upgraded from 2008 to 2016 in December 2019. In January 2020, the version of Citrix was upgraded to the latest version compatible with Windows Server 2016. As a reminder, Citrix allows DIGITS users to access the system from any device, and allows contributors to download their own data at any time. Finally, the virtual Netscaler was upgraded as part of this process as well. We anticipate no additional software or hardware upgrades for at least a year or two.

Database structure

The database is housed in 79 tables in MS SQL Server and to describe the entire structure of the database would be cumbersome. In general, the tables serve several basic functions. They allow for a variety of coded matching features and image descriptions (e.g. body part, view direction, photo quality) to be recorded and searched for (16 tables). They also allow researchers to track the status of data sets and log issues in the system (3 tables) and to track the matching/confirming status of sightings (6 tables). In addition, there is now a field to flag a sighting if there has been a discrepancy between the genetic and photo-identification analyses for that sighting (e.g. if a sample of DNA was collected and a genotype was determined). In these cases, the discrepancy will be rectified after a thorough investigation, but the sighting will still be flagged as having had a discrepancy. An additional field is filled in indicating whether the photo-identification or genetic information was the primary resource used to make the final identification.

The public catalog and the E catalog

In 2006, as part of a grant from NSF, we developed a public website that provides photo-identification background, training, and access to a web-based version of the old MS Access E Catalog. This website (www.neaq.org/rwcatalog) utilizes the live DIGITS data, and therefore requires minimal upkeep (since sightings data are automatically updated every time a match is confirmed). Images are updated when new "primary" images are selected for matching purposes. Any image that is flagged as a primary image in DIGITS is also visible on the website. In 2020, using funds from a private foundation, we completed the redesign of the website to improve its overall look and function, and to allow for a direct link between the FlukeBook website where some automated matching is now available. The updated website has an improved interface with the ability to zoom on images and to perform more detailed searches for whales. It was also restructured to allow a link to a specific whale- a feature that was not available before. This allows potential matches detected by FlukeBook's AI to link directly to a Catalog page; any potential match found on FlukeBook can be inspected on the Catalog website with the click of a button.

An additional web resource for the Catalog is background information on the Anderson Cabot Center for Ocean Life at the New England Aquarium's website (https://www.andersoncabotcenterforoceanlife.org). Information on how to photo-identify right whales, including photographic examples of all the different matching features, was revamped on this site in 2019 and the new pages launched in the fall of 2019.

In 2012, we developed a new external catalog called the E Catalog. This Catalog was created to help experienced researchers identify individual right whales while at sea. It is an electronic, off-line catalog that contains images of all cataloged whales and some intermatch whales. The E Catalog is updated twice a year (June/July and November/December) and is exported using the

DIGITS software. A Dropbox link is sent to approximately eight team leaders covering each of the main right whale habitats. In 2018, the E Catalog set-up routine was modified to function in the new SQL 2016 environment. The E Catalog is now only compatible with Windows 8 or higher.

IV. New Animals

Calves are only made into new animals and assigned a Catalog number if their identifying features are photographed well enough to be subsequently matched. A "new" non-calf whale is "created" (i.e. given a number and classified within the Catalog) when no matches with existing cataloged animals can be found and when enough good quality photographs exist for it to be matched to subsequent sightings. Sometimes it takes several years to collect enough photographs of an individual before it can be classified as a new animal. In addition to these new animals, beginning in 2017, we created another class of new whales: calves known to have been born and known to have been lost without any carcass found that could definitively be linked to that individual. The logic for doing this is that we know for certain these animals existed and that they will not be double counted. Only the calves of mothers who were seen with their calf and then without that calf on the calving ground are candidates. This is a conservative approach because there have been calves that were never seen with their mothers on the feeding grounds, but through genetics, we know they survived.

Since the last Catalog report, there have been 15 new whales added to the Catalog: none in 2019 and 15 (so far) in 2020. Four of them were unknown age and 11 were calves from past years born in 2011 (n=1), 2013 (n=3), 2015 (n=2), 2016 (n=3), and 2017 (n=2). It is interesting to note that many of these new whales are solely, or primarily, seen around Cape Cod, MA or Long Island, NY.

A listing of these new whales along with their sex, birth year, and identifications of their mother and father (determined through genetics) are provided below. Any of these new additions that have noteworthy sighting histories (e.g. the whale was only seen offshore and had very few sightings, or it was first seen as a reproductive female) also have a narrative provided.

Added in 2020

Catalog No.	Sex	Birth Year	Mother	Father
4170*	Female	2011	3270	1249
4312*	Female	2013	2912	1981
4342*	Male	2013	2042	
4360*	Unknown			
4370*	Unknown			
4505*	Male	2015	2605	2018
4540*	Female	2013	1612	
4550	Female	2015	1950	

4610	Female	2016	1810	
4612*	Female	2016	1812	
4680	Male	2016	3680	
4710*	Unknown			
4711	Male	2017	1711	
4715*	Unknown	2017	1515	
4720	Unknown			

"*" indicates a narrative is provided below

#4170 (8 y.o female) - This whale was first seen January 15, 2011 off the coast of Florida with her mother, #3270. The pair remained in the waters of Florida through the end of February, were seen off South Carolina in March, and were seen only once in northern waters- in June in Great South Channel. Her next sighting was not until five years later when she was seen in Great South Channel in April of 2016. This is an unusually long gap in sightings for a young whale, delaying our ability to catalog her. She has only been seen four times since then: three times south of Nantucket in 2017 and 2019, and once in Cape Cod Bay in 2019. A genetic sample has been obtained from this whale.

#4312 (6 y.o female) - This whale was first seen December 28, 2012 off the coast of Georgia with her mother, #2912. The pair remained in the waters of Georgia and Florida through February 5th and were not seen again that year. Re-identifying calves not seen later in the year is challenging. She was only seen twice in the next five years: in December 2014 and April 2017, both times south of Nantucket. Like #4170, she has only been seen south of Nantucket or east of Long Island, NY. A genetic sample has been obtained from this whale.

#4342 (6 y.o male) - This whale was first seen December 19, 2012 off the coast of Georgia with his mother, #2042. The pair remained in the waters of Georgia and Florida through February 14th and were not seen again that year. He was next seen in June the following year in Great South Channel. He has been seen only one to three times a year since then and always south or east of Cape Cod or near Long Island, NY. A genetic sample has been obtained from this whale.

#4360 (6+ y.o unknown sex) - This whale was first seen September 29, 2013 in Roseway Basin. Its head shape suggests it may have been young at the time. Since then, it has only been seen around Cape Cod. It was next seen in April 2017 in Great South Channel and has only been seen two or three times a year since then. No genetic sample has been obtained from this whale.

#4370 (6+ y.o unknown sex) - This whale was first seen April 17, 2013 in Cape Cod Bay. It has only been seen four other times and always in or near the Bay: once more in 2013, twice in 2014, and once in 2015. At its last sighting in April 2015, it had a strange, deep wound on the tail- a circular wound with the peduncle at the center. If the wound persisted, it looked as if all of the fluke would fall off. The cause of the wound is unknown. No genetic sample has been obtained from this whale.

#4505 (3 y.o male at his death in 2018) - This whale was first seen January 19, 2015 of the coast of Georgia with his mother, #1612. The pair were last seen in the southeast on February 8th; and then in 2017 and April of 2018, he was seen south of Cape Cod or east of Long Island. He was genetically linked to the dead whale IFAW18-244Eg from August 25, 2018. A full description is provided in the Mortality section below.

#4540 (6 y.o female) - This whale was added to the Catalog in January 2020 based on sightings as an apparent juvenile starting in 2015. This whale had been assigned a temporary intermatch code of BK02SNE17. In February 2020, the results from a genetic sample collected in May 2019 were used to link it to the uncataloged 2013 calf of #1612. For this reason, her catalog number starts with 45 even though she is a calf from 2013 (and those calf numbers start with 43). She was one of the many calves from 2013 that were not seen after February of their calf year and thus were difficult or impossible to photo-identify. All of her sightings since 2013 have been around Cape Cod or NY. A genetic sample has been obtained from this whale.

#4612 (3 y.o female) - This whale was first seen February 1, 2016 off the coast of Florida with her mother, #1812. The pair remained in the waters of Florida and Georgia through March 1st before migrating north where they were seen northeast of Provincetown, MA in the Gulf of Maine, once in April and once in May. She was seen once south of Nantucket in April 2017 and has since been mostly seen in the Gulf of St. Lawrence. A genetic sample collected in September 2019 was used to link her to the 2016 calf of #1812- this link could not have been made solely based on photographs. A genetic sample has been obtained from this whale.

#4710 (2+ y.o unknown sex) - This whale was first seen March 21, 2017 south of Nantucket, MA. It has only had six sightings total- all south of Nantucket- two in the spring, one in July, and three in the winter. No genetic sample has been obtained from this whale.

#4715 (2 y.o unknown sex) - This whale was not seen in the southeast U.S. as a calf; its first sighting with its mother was on April 30, 2017 in Great South Channel. The pair were seen in the area over a two-week period and then disappeared. #4715 was next seen deep in the Gulf of Mexico in January and February of 2018. Its last sighting was in May 2018 in Cape Cod Bay. No genetic sample has been obtained from this whale.

There are a number of other whales that may be added to the Catalog in the future. Some are calves that were only seen on the calving ground and will only be added to the Catalog if future photographs provide enough information to match to their bellies or mandibles OR if: 1) genetic material was obtained from them when they were calves associated with their mothers and 2) that genetic profile matches a second sample collected in later years after their callosities have fully formed. These genetic matches allow us to link unknown juveniles back to known calves. The number of new whales above that are only seen around Cape Cod underscores the need to collect genetic samples in this area to make these important linkages to past calves. Due to the changes in right whale distribution in the summer months, many of the recent calves have not

been photographed after their callosity has developed, while still with their mothers, making subsequent re-identification challenging. This challenge is compounded by the fact that we have fewer sightings of them as one- or two-year-olds (see #4170 and #4312 above as examples), an important transition time in their physical appearance. Excluding the 39 calves that remain in limbo (some going back as far as 1991), there are three whales with intermatch codes that have been seen in more than one year. These will either be matched to existing cataloged animals or intermatched to other sightings (including potentially uncataloged calves from past years) and added to the Catalog in the future.

V. Presumed Dead and Resurrected Animals

Any animal in the Catalog that is not sighted during five consecutive years becomes classified as "presumed dead" at the end of the sixth year of no sightings (Knowlton *et al.* 1994). An analysis of all sighting gaps for 323 whales that had more than one sighting through 2003 supported the 6-year criterion. Of the 3,343 gaps analyzed, only 1% was six years or more, compared to over 75% that were sighted in the previous year (Hamilton *et al*. 2007). However, not every whale classified as presumed dead is actually dead. Thus far, between 1990 and 2018, there have been a total of 47 sightings gaps longer than five years for whales that were later re-sighted and, therefore, reclassified as alive (i.e. "resurrected") - three of those were whales that were resurrected twice. These 47 resurrections represent 18% of the 261 presumed deaths during that time period. Many of these mistakenly presumed dead classifications occurred primarily due to gaps in sighting effort in Great South Channel and Roseway Basin, and these gaps were filled in from 2004 to 2006. Great South Channel and Gulf of Maine effort have remained relatively high since 2004, although there has been some decrease in effort in recent years. For this reason, there were only five resurrections between 2005 and 2015. In the four years since, there have been six resurrections, which may be, in part, because whales are shifting their habitats. Presumed deaths have been consistently high since 2015 (68 presumed deaths between 2015 and 2019, compared to 29 for the previous five years). Given the large number of *known* mortalities in the last five years, we are concerned that this increase in presumed mortality may reflect true, undetected mortalities.

The presumed dead assessment has a number of flaws. Although a whale becomes presumed dead in a given year, it does not mean that the whale actually died in that year. A whale that is classified as presumed dead in 2019 may have died at any time during the previous five years. Findings by Pace *et al.* (2017) indicate that whales may be dying much sooner than six years after their last sighting and highlights how such a presumption artificially inflates the numbers in the living population. Mr. Hamilton (NEAq) did a recent analysis looking at the time between the first sighting of a dead whale and the last sighting alive for 42 dead whales identified to the Catalog. The average time was 5.7 months, which also supports the hypothesis that whales die more quickly than the six-year buffer indicates. Therefore, the presumed dead calculation should be seen as a crude, but easily calculated, assessment that provides a ballpark determination of the number of cataloged whales that remain alive.

In 2019, 11 animals were classified as presumed dead (five of them calving females) and one animal was resurrected. The last three years have had the highest number of presumed deaths on record. Details of the presumed dead and resurrected animals' sighting history are provided

below, as well as their sex and what their age was *at their last sighting*. For all sections below, a "+" after the age means the actual age is not known and the number is a minimum age *at the time of their last sighting*, based on both their calving history (whale assumed to be at least five years old if their first sighting was with a calf) and sighting history. It should be noted that the database was searched to determine whether there were sightings of any of these whales awaiting confirmation that would be resurrected once those matches were confirmed. Any such matches were confirmed before the writing of this report and those data would be included below.

Presumed dead

#1154 (32+ y.o. male) - This whale, named Gray, was first seen in the Bay of Fundy in August 1981. He was seen frequently in the Bay in the 1980's and then disappeared for over ten years from 1989 to 2001. He sired at least one calf in the 1980's: #1941 born in 1989. Beginning in 2001, he was only seen around Cape Cod. His last sighting was May 1, 2013 in Cape Cod Bay; there were some outward indications of ill health at the time in the form of skin lesions and reduced body condition. A genetic sample was obtained from this whale.

#1173 (32+ y.o. unknown sex) - This whale, named 2 Dot, was first seen in Great South Channel in May 1981. It has only been seen there, in Roseway Basin, and in the middle of the Gulf of Maine. Like Gray above, it disappeared for most of the 1990's- missing for nine years from 1989 to 1998. It is likely a male and it is unknown whether it sired any calves as no genetics were collected over its 32 year sighting history. It was last sighted January 15, 2013 in Great South Channel; there were no outward indications of ill health at the time. No genetic sample had been obtained from this whale.

#1174 (32+ y.o. male) - This whale was first seen in Great South Channel in May 1981. Over the years, he has been seen in most northern habitats, though only once in the Bay of Fundy. Like Gray and 2 Dot above, he disappeared for most of the 1990's- missing for nine years from 1989 to 1998. He sired at least one calf, #3980 (2009 calf of #2503). He was last sighted February 26, 2013 south of Martha's Vineyard, MA; there were no outward indications of ill health at the time. A genetic sample had been obtained from this whale.

#1241 (31 y.o. female) - This whale, named Bugs, was first seen with her mother #1240, Baldy, in the Bay of Fundy in July 1982. Over the ensuing 31 years, she was seen every year except 1987- often in the Bay of Fundy or Cape Cod Bay. She had five calves between 1989 and 2010. She was last sighted April 29, 2013 in Cape Cod Bay; there were no outward indications of ill health at the time. A genetic sample had been obtained from this whale.

#1315 (30 y.o. female) - This whale, named Foster, was first seen with her mother #1314, Symmetry, in Cape Cod Bay in April 1983. She was seen primarily around the Cape and of the southeastern US over the years. She had four calves between 1992 and 2013. She was last sighted May 1, 2013 in Massachusetts Bay with her fourth calf; there were no

outward indications of ill health at the time. A genetic sample had been obtained from this whale.

#1705 (26 y.o. female) - This whale, named Phoenix, was first seen with her mother #1151, Mavynne, off the Georgian coast in January 1987. She was involved in a calf swap that year as described in Frasier *et al.* (2010). The calves of Mavynne and whale #1004, Stumpy, were swapped and Phoenix was raised by Stumpy from Feb 17, 1987 onward. She was seen every year from 1987 to 2013 except 1998. She was seen in all five of the primary habitats in the U.S. and Canada. She had four calves between 1996 and 2012. She was last sighted September 19, 2013 in Roseway Basin in a surface active group; there were some outward indications of ill health at the time in the form of poor skin and body condition. A genetic sample had been obtained from this whale.

#2042 (23 y.o. female) - This whale was first seen with her mother #1142, Kleenex, off the Georgian coast in January 1990. She was not photographed in only three years over her 23 year sighting history. She was seen in all five of the primary habitats in the U.S. and Canada, but the majority of her sightings were in the Bay of Fundy or off the southeast U.S. She had just one calf in 2013 at the age of 23, though she was seen in the southeast in seven years as an adult and so may have had previous unsuccessful pregnancies. She was last sighted February 14, 2013 off the Georgia coast with her first calf; there were some outward indications of ill health at the time in the form of poor skin and body condition. A genetic sample had been obtained from this whale.

#3123 (12 y.o. female) - This whale was first seen with her mother #1123, Sonnet, off the Georgian coast in February 2001. She was photographed every year over her 12 year sighting history- often in the Bay of Fundy or off the southeast U.S. She had just one calf in 2010 at the age of nine. She was seen July 12, 2012 off the Virginia coast entangled with weighted lines going down to some depth. A snorkeler cut the line and the whale sped off, apparently free. Her next and final sighting was five days later on July 17, still off Virginia. There was extensive damage to the skin on her peduncle and flukes, both of which had extensive wounds. A genetic sample had been obtained from this whale.

#3630 (7 y.o. male) - This whale was first seen with his mother #2710 off the Florida coast in December 2005. He was seen every year after that until his disappearance in 2014. He was photographed mostly around Cape Cod and in the Bay of Fundy, though he stopped going to the latter habitat after 2009. He was last sighted May 2, 2013 in Great South Channel; there were no outward indications of ill health at the time. A genetic sample had been obtained from this whale.

#3691 (7 y.o. male) - This whale was first seen with his mother #2791, Fenway, off the Florida coast in January 2006. He was seen frequently over his first three years, often in Cape Cod Bay and the Bay of Fundy. He was not seen from 2010 to 2012, and then just seen twice in 2013. He was seen in April of that year in Cape Cod Bay and then his final sighting was in the Gulf of St Lawrence on August 25, 2013, which was his first and only sighting in the Gulf. There were no outward indications of ill health at the time. A genetic sample had been obtained from this whale.

#4212 (1 y.o. female) - This whale was first seen with her mother #1812, War, off the Georgia coast in January 2012. She was seen off the Carolinas as a calf and as a one-year-old, and the remainder of her sightings after that were in Cape Cod Bay. Her last sighting was there on May 1, 2013; there were no outward indications of ill health at the time. A genetic sample had been obtained from this whale.

Resurrected

#1145 (42+ y.o. female) - This whale, named Grand Teton, was first seen in August 1981 in the Bay of Fundy with a calf. She's had seven calves (1981, 1984, 1991, 1996, 2002, 2005, 2010), with calving intervals ranging from three to seven years. Since 1991, she has been rarely seen in non-calving years. Her last calf was in 2010 and her last sighting before 2019 was with that calf in April of 2010. Her next sighting was May 7, 2019 in a rarely surveyed area southeast of Montauk, NY. Her longest sighting gaps before this nine-year gap were two four-year gaps: one between 1996 and 2000 and the second between 2005 and 2009. A genetic sample has been obtained from this whale.

VI. Mortalities, Entanglements, and Significant Injuries

Overview

There were 10 mortalities discovered in 2019. No calves were known to have died, so the minimum death count for the year remains at 10. A summary of the deaths are presented below and details for nine of the ten are available in Bourque *et al*. (2020), which can be found here. Five right whales were first seen entangled in 2019, including one carcass, and one was seen still entangled from a previous year's entanglement. Three whales were first seen gear-free in 2019 (two of the five first seen entangled in 2019). There were no new cases of significant, non-lethal injuries caused by propellers or entanglements in 2019. We use the term "significant injuries" instead of "serious injuries" because these injuries do not necessarily match the criteria for a serious injury as determined by NMFS (Anderson *et al*. 2008) or by NEAq (Knowlton and Kraus 2001). They include any entanglement scars, propeller cuts, and any other dramatic or noteworthy wounds, as determined by a subjective assessment.

Mortalities

#4023 (9 y.o. male) - The carcass of this whale, named Wolverine, which is referenced as MARS2019-130 and Carcass #1, was found floating belly up with blood visible in the water on June 4, 2019 in the Gulf of St Lawrence. The carcass was identified by a distinctive white pattern on his belly. He was towed to Miscou Island, NB and necropsied on June 7. The mortality report lists this death as a suspected vessel strike. The last confirmed sighting of this whale alive was December 14, 2018 off New York.

#1281 (40+ y.o. female) - The carcass of this whale, named Punctuation, which is referenced as MARS2019-146 and Carcass #2, was found floating on her side with a large opening in her body cavity on June 20, 2019 near the Cabot Straight in the Gulf of St Lawrence. The carcass was towed to shore and a necropsy was conducted on June 25, 2019 in Petit Étang, NS. The mortality report states the death was due to sharp trauma,

vessel strike (probable). There was some concern that she was pregnant at the time given she last calved in 2016; however, no fetus was found and the fecal progesterone levels indicate she was not pregnant. The last confirmed sighting of this whale alive was just 13 days earlier on June 7 in the Gulf.

Unknown ID (unknown age unknown sex) - This whale, the carcass of which is referred to as MARS2019-202 and Carcass #8, was first seen floating dead north of Glacier Bay, Cape Breton, NS on June 24, 2019. Although photographed on the 24th, images were not sent and reviewed until July 18 and thus the carcass was referred to as #8 even though its death was the 3rd detected of the year. The reporting party was an anonymous fisherman and June 24 is the only sighting of this carcass. It was *relatively* close to Carcass #9 and bore some physical resemblance, but not enough to determine whether they were the same animal. The Marine Animal Rescue Society (MARS) team determined it best to consider the two carcasses as separate individuals. No genetics were collected from this carcass; therefore, there will be no future updates on its identity.

#1514 (34+ y.o. male) - The carcass of this whale, named Comet, which is referenced as MARS2019-161 and Carcass #3, was found floating on his left side on June 25, 2019 in the Gulf of St Lawrence. The carcass was identified by a distinctive white scar on his right side- the scar that earned him his name. He was towed to Norway, PEI and necropsied on June 28. The mortality report lists this death as caused by blunt trauma, vessel strike (probable). The last confirmed sighting of this whale alive was June 7, 2019 in the Gulf of St Lawrence.

#3815 (11 y.o. female) - The carcass of this whale, which is referenced as MARS2019-168, QC2019064, and Carcass #4, was found floating belly up on June 25, 2019 in the Gulf of St Lawrence. The carcass had little skin left on it, but just enough to see scars on the chin and leading edge of the flukes. Those scars, along with the information that she was female, were enough to identify her. The carcass was seen repeatedly in June and July, and finally washed ashore on the Magdalen Islands, QC on July 31. No necropsy was conducted and the cause of death remains unknown. The last confirmed sighting of this whale alive was June 7, 2019 in the Gulf of St Lawrence.

#3329 (16 y.o. female) - The carcass of this whale, which is referenced as MARS2019-169, QC2019070, and Carcass #5, was discovered dead on the beach on a remote section of the southeast coast of Anticosti Island, QC on June 25, 2019. A full necropsy was not performed on this carcass due to its location, but some measurements and samples were collected on June 26. The carcass was lying left side up and an identification was made based on the callosity that was showing, scars on the chin, and the distinctive white pigmentation pattern on the ventral chin. No cause of death was determined. The last confirmed sighting of this whale alive was April 25, 2019 in Cape Cod Bay.

#3450 (15+ y.o. female) - The carcass of this whale, named Clipper, which is referenced as MARS2019-170, QC2019071, and Carcass #6, was found floating belly up on June 27, 2019 in the Gulf of St Lawrence. It was identified based on small white scars on the black ventral surface of her body and the portion of its fluke that was missing. The

carcass was towed to shore and a necropsy performed on July 1, 2019 in Grand-Étang Bay, QC. The mortality report lists this death as caused by blunt trauma, vessel strike (probable). There was some concern that she was pregnant at the time given she last calved in 2016; however, no fetus was found and the fecal progesterone levels indicate she was not pregnant. The last confirmed sighting of this whale alive was June 10, 2019 in the Gulf of St Lawrence.

#3421 (15 y.o. male) - The carcass of this whale, which is referenced as MARS2019-223, QC2019121, and Carcass #7, was found floating belly up on July 18, 2019 in the Gulf of St Lawrence. The carcass was towed to shore and a necropsy performed on July 21, 2019 in Grand-Étang Bay, QC. The identification was not made until the carcass was photographed on the beach, at which point scars on the chin and flukes were used to match it to the Catalog. The cause of death could not be determined from the necropsy. The last confirmed sighting of this whale alive was June 10, 2019 in the Gulf of St Lawrence.

Unknown ID (unknown age, unknown sex) - This whale, the carcass of which is referred to as MARS2019-232 and Carcass #9, was first seen floating belly up east of Fourchu, Cape Breton, NS on July 21, 2019. The carcass was decomposed and it was unclear if it could have been the same as Carcass #8, which had been photographed approximately 55 nm north/northwest of this location on June 24. Many experts were consulted and a drift analysis done for both carcasses. The results were inconclusive and the MARS team determined it best to consider the two as separate carcasses. Some blubber was collected by DFO on July 22. That sample appears to have been lost, but would not have been useful for genetic analysis anyway. Therefore, no genetic data are available for this carcass and there will be no future updates on its identity.

#1226 (40+ y.o. male) - The carcass of this whale, named Snake Eyes, which was the only carcass found in the U.S. in 2019 and is referenced as AMCS184Eg2019, was found floating dead on his right side on September 16, 2019 south of Jones Beach Island, Long Island, NY. The carcass was towed to Jones Beach and a necropsy performed on September 18. Snake Eyes was a known entanglement case from August (see below), but no gear was found on the carcass. Because most of the skin was missing, the identification was made based on old scars and the pattern of indentations left by the recent entanglement. According to the necropsy, the cause of death was probable acute entanglement. This whale had last been seen alive and entangled in the Gulf of St Lawrence on August 6, 2019.

Updates on previously reported mortalities

IFAW18-245Eg - Last year's Catalog report briefly mentioned (in the "Summary of deaths, resurrections, and new whales cataloged in 2018" section) that a segment of right whale skull had been found, but the details were not provided in the Mortality section because it was unknown if it was a previously known mortality. This segment of right whale skull was found on August 16, 2018 on Long Point Beach, Martha's Vineyard, MA. The mortality was given a case number of IFAW18-245Eg and the bone was sampled on September 4, 2018 to determine whether or not it was a previously known

mortality. Drs. Tim and Brenna Frasier at Saint Mary's University in Halifax, NS were able to determine the sex (female), haplotype (D), and genotype at nine loci from two samples from this skull. The genetic profiles do not match any whale in the population (living or dead), and one of the alleles at microsatellite locus RW4-17 does not exist in the current population. To date, Drs. Frasier have identified this allele only in a historic bone specimen dating back to 1000-1100 CE from the Faroe Islands, so while it is a known right whale allele, it has never been identified in the contemporary population. In addition, based on their experience subsampling more than 750 large whale bones for genetic analysis, they suggest that the images in the necropsy report of this skull specimen are consistent with the specimen being quite old. They suggest that the bone may be worth radiocarbon dating, with consideration of potential marine reservoir effects.

IFAW18-244Eg - Last year's Catalog report included a dead whale that was first seen floating dead off the coast of Martha's Vineyard on August 25, 2018. Measurements from the necropsy indicated that it was likely a calf of the year or a small juvenile. The genetics from this carcass match the 2015 calf of #2605 (recently cataloged as #4505) based on sex, haplotype, and all five loci for which both samples were profiled. The identification is further supported by the fact that both the dead whale and #2605's calf had a white belly and the two loci for which the dead whale was scored and the calf was not were consistent with it being the calf of #2605 (i.e. #2605 had at least one allele in common with the dead whale at those two additional loci). The necropsy report suggested that, based on length, the dead whale was likely younger than 2.5 years, but the measurements could not be precise as the flukes were missing.

Entanglements

First Reported in 2019

April 25, 2019: #4423 (5 y.o. male) - This whale was first seen entangled by the Northeast Fisheries Science Center's (NEFSC) Atlantic Marine Assessment Program for Protected Species (AMAPPS) aerial survey team approximately 25 nm east of Chatham in Great South Channel. There was line coming out of both sides of the mouth that came together below and behind the tail where there was what appeared to be a deflated buoy and a mass of line. The line went sharply down after that, suggesting there was some weight on the end. No response was mounted as the Center for Coastal Studies (CCS) disentanglement team was responding to entangled whale #2310 (described below). CCS gave it a case number of WR-2019-03. The whale was next seen on July 4, 2019 in the Gulf of St Lawrence with the entanglement configuration unchanged. He was seen many times throughout the season by many different research groups. On July 11, the Campobello Whale Rescue Team (CWRT) responded. After multiple attempts, using different pieces of equipment, the team thought that a cutting grapple may have cut line beneath what appeared to be a white buoy trailing deep and behind the whale. The team tried again on July 16 and thought they may have cut one side of the bridle line, but aerial observations on August 13 and 16 indicated that the entanglement configuration had not changed. A NEFSC aerial survey on October 28, 2019 found #4423 still in the Gulf and now apparently gear-free, likely having shed the gear slowly after some of the CWRT

interventions. This whale was seen in the Gulf in 2020 and appears to be healing. Before the April 25th entanglement, he had been last seen gear-free on August 20, 2018 in the Gulf of St Lawrence.

June 29, 2019: #4440 (5 y.o. male) - This whale was first seen entangled June 29, 2019 about 25 miles east of Miscou Island, NB in the Gulf of St Lawrence. The event was assigned a CCS case number of WR-2019-09. The whale had one or two wraps of relatively heavy line around the peduncle and extensive damage to the skin on the peduncle and flukes. On July 5, a research team from NEAq/Dalhousie University found the whale and attempted to grapple the line to attach a telemetry buoy. At that time, it became apparent that the whale was hog-tied with line going through the mouth and then wrapping around the tail stock. They had no success, nor did a team from DFO who made attempts after the NEAq team. The CWRT made attempts on July 9 and 16 and were eventually able to cut the line coming out of the left side of the mouth. By July 19th, the line had come completely out of the mouth, but was still wrapped around the peduncle. By August 14th, the remaining line had been shed and the whale was gear-free. The whale remained in the Gulf the entire time. He was seen in the Gulf in 2020 and appears to be healing. Before the June 29th entanglement, he had been last seen gear-free on April 14, 2019 in Cape Cod Bay.

July 4, 2019: #3125 (18 y.o. male) - This whale was first seen entangled on July 4, 2019 about 45 nm east of Perce, QC in the Gulf of St Lawrence. It was given a CCS case number of WR-2019-10. The entanglement involved the mouth and both flippers with many loops of line and a lot of trailing line. DFO fisheries officers responded the same day, but were not able to relocate the whale. He was later relocated by a NEFSC aerial team on July 19 and the NEAq team was able to attach a telemetry buoy to the trailing gear. Over the next few days, #3125 headed steadily east towards the entrance to the Gulf of St Lawrence. Tangly Whales from Newfoundland and DFO Conservation and Protection were able to work on the entanglement on July 23 and 25 after #3125 had left the Gulf and was making his way south. They believe they were able to make several cuts to the gear, but it was unclear exactly how the entanglement had changed. On August 1, he was 60 miles east of Cape Cod and a multi-agency entanglement response involving the USCG, NEFSC, and CCS was launched. The team was able to cut about 300 feet of line off the whale and then the whale sped away- still entangled, but less encumbered by trailing gear. He has not been seen since. Before the July 4th entanglement, he had been last seen gear-free on April 11, 2019 in Cape Cod Bay.

August 6, 2019: #1226 (40+ y.o. male) - This whale, named Snake Eyes, was first seen entangled on August 6, 2019 about 40 nm northwest of the Magdalen Islands in the Gulf of St Lawrence. He had several lines wrapping over his head and his tail appeared to be weighted down and possibly anchored. The entanglement was given a CCS case number of WR-2019-21. There were several days of bad weather after the initial entanglement and by the time a survey plane could check the area again, the whale was gone. He was not seen again until September 16 when he was found dead floating off Long Island, NY (see the Mortality section above). Before the August 6th entanglement, he had been last seen gear-free on July 16, 2019 in the Gulf of St Lawrence.

December 21, 2019: #3466 (15 y.o. male) - This whale was first seen entangled on December 21, 2019 approximately 20 nm south of Nantucket, MA. He had multiple yellow lines going through the mouth and trailing 20-30 feet behind him. The entanglement was given a CCS case number of WR-2019-33. No response could be mounted. He was seen south of Nantucket again January 18, 22 and 31, 2020 and the entanglement configuration remained unchanged. There have been no disentanglement responses for this whale. Before the December 21st entanglement, he had been last seen gear-free on April 29, 2019 in Cape Cod Bay.

Reported Prior to 2019 and Still Entangled by the End of 2019

February 3, 2019: #2310 (26+ y.o. male) - This whale was seen on February 3, 2019 by the NEAq aerial survey team southeast of Nantucket, MA. This was his first sighting since his initial entanglement sighting in the same general area on December 20, 2018. He still had a single line coming out of the right side of his mouth and trailing behind him. His condition had not deteriorated. He was seen one more time in 2019 on April 25 when he was found in Cape Cod Bay by the CCS aerial survey team. The CCS disentanglement team responded, but were unable to use a cutting grapple on the gear. He has not been seen since.

First Seen Free of Gear in 2019

Three right whales were first confirmed free of gear in 2019: two were first seen with the gear in 2019 and are described above (#1226 and #4440), and one was first seen entangled in May 2018 and is described below.

January 13, 2019: #4091 (9 y.o. female) - This whale was seen likely gear-free on January 13, 2019 by the NEAq aerial survey team south of Nantucket, MA. She had been seen one other time after her initial entanglement on May 12, 2018: on December 31, 2018, also south of Nantucket. No entanglement was visible at that sighting, but it was not completely clear that the line was gone. Drone imagery from a later sighting on March 27, 2019 further confirmed the absence of gear. She may have shed the gear as early as December 31, 2018.

Entrapments

No right whales were seen entrapped in fishing weirs in 2019.

Significant injuries

None to report for 2019.

VII. Photographic Contributions

Photos submitted from 69 different organizations or individuals who collected photographs between December 1, 2018 and November 30, 2019 that have been partially or completely processed and integrated into the Catalog database. Since not all data from these contributors

have been processed, tallies of sightings and images contributed may change. Table 1 provides a summary for each contributor, including:

1) the total number of photographed sightings (one sighting represents one photographed animal);
2) the percentage of those sightings that have been a) matched and confirmed, b) matched and awaiting confirmation, c) deemed not to be matchable, d) intermatched (i.e. multiple sightings of a whale that has yet to be matched to the Catalog), or e) not yet matched;
3) the total number of different individuals a) confirmed to the Catalog and b) intermatched.

All contributors of right whale photographs have received a letter or email acknowledging their contribution. In addition, a listing of the whales each contributor photographed, along with the whale's age and sex, is provided upon request. A listing of abbreviations used for regions and observers can be found in Appendix II and III, respectively.

Table 1: List of 69 organizations/individuals whose photographs were collected between December 1, 2018 and November 30, 2019.

Data may not be completely processed, so the number of sightings and images may change once data are complete. One sighting equals one photographed right whale and the number of images shown may be less than the number actually submitted (many redundant images are deleted when excessive numbers are submitted per sighting). The intermatch column refers to whales that have more than one sighting, but have not yet been matched to the Catalog. The "Other Unique Id'd" column counts unique intermatched whales. Region and observer abbreviations are explained in Appendix II and III.

			% of Total Sightings					# of Individuals		
			Matched							
Organization /	# of Sightings	# of Images	Confirmed	Unconfirmed	Not Matchable	Intermatched	Not Yet Matched	Confirmed Id'd	Other Unique Id'd	Total
AMCS										
MIDA	2	55	100.%	0.%	0.%	0.%	0.%	1	0	1
ANKE*										
NE	1	1	0.%	0.%	100.%	0.%	0.%	0	0	0
AWSC										
GSC	2	5	100.%	0.%	0.%	0.%	0.%	2	0	2
BAGL*										
NRTH	1	9	100.%	0.%	0.%	0.%	0.%	1	0	1
BHC										
NE	4	33	50.%	25.%	0.%	0.%	25.%	2	0	2
BHWW/AW										
GOM	4	72	75.%	25.%	0.%	0.%	0.%	3	0	3
BIWSC										
BOF	3	52	100.%	0.%	0.%	0.%	0.%	3	0	3
BONI										
BOF	1	29	100.%	0.%	0.%	0.%	0.%	1	0	1
BOS										
JL	3	58	66.7%	0.%	0.%	0.%	33.3%	2	0	2
BWRI										
SEUS	8	0	0.%	0.%	0.%	50.%	50.%	0	2	2
CACL*										
NE	1	16	100.%	0.%	0.%	0.%	0.%	1	0	1
CBPWP										
NRTH	3	49	33.3%	33.3%	0.%	33.3%	0.%	1	1	2
CC										
BOF	5	113	100.%	0.%	0.%	0.%	0.%	4	0	4
SEUS	2	16	50.%	0.%	0.%	50.%	0.%	1	1	2
CCG										
NRTH	47	23	4.4%	0.%	0.%	2.2%	93.3%	2	1	3
CCS										
GSC	11	318	91.7%	8.3%	0.%	0.%	0.%	9	0	9
JL	1	0	0.%	0.%	0.%	0.%	100.%	0	0	0
NE	1,026	12,671	81.9%	10.2%	0.2%	2.3%	5.4%	256	7	263
CHBA*										
SEUS	2	20	50.%	0.%	0.%	50.%	0.%	1	1	2
CHFA*										
SEUS	2	7	50.%	0.%	0.%	50.%	0.%	1	1	2
CMARI										
SEUS	11	193	81.8%	0.%	0.%	18.2%	0.%	8	2	10
CWI										
BOF	1	22	100.%	0.%	0.%	0.%	0.%	1	0	1

Table 1 (cont.)

			% of Total Sightings					# of Individuals		
			Matched							
Organization /	# of Sightings	# of Images	Confirmed	Unconfirmed	Not Matchable	Intermatched	Not Yet Matched	Confirmed Id'd	Other Unique Id'd	Total
DEHA*										
NE	2	2	0.%	0.%	0.%	0.%	100.%	0	0	0
DELA*										
SEUS	1	16	0.%	100.%	0.%	0.%	0.%	0	0	0
DFO										
BOF	3	0	0.%	0.%	0.%	0.%	100.%	0	0	0
EAST	4	8	0.%	0.%	25.%	0.%	75.%	0	0	0
NRTH	402	114	3.7%	0.%	0.%	0.%	96.3%	8	0	8
EDGR*										
SEUS	12	255	41.7%	8.3%	0.%	50.%	0.%	4	5	9
ERAB*										
NRTH	1	43	100.%	0.%	0.%	0.%	0.%	1	0	1
FTR										
BOF	1	3	100.%	0.%	0.%	0.%	0.%	1	0	1
FWRI										
SEUS	77	1,301	50.6%	2.6%	2.6%	44.2%	0.%	12	7	19
GAMO*										
SEUS	2	9	50.%	0.%	0.%	50.%	0.%	1	1	2
GDNR										
SEUS	8	289	37.5%	25.%	0.%	37.5%	0.%	2	2	4
GMWSRS										
BOF	9	197	55.6%	44.4%	0.%	0.%	0.%	4	0	4
GREMM										
NRTH	1	10	0.%	0.%	0.%	0.%	100.%	0	0	0
JARHO*										
SEUS	4	45	25.%	0.%	50.%	0.%	25.%	1	0	1
JEGR*										
SEUS	1	1	0.%	0.%	100.%	0.%	0.%	0	0	0
JESH*										
MIDA	1	35	0.%	100.%	0.%	0.%	0.%	0	0	0
JOPA*										
SEUS	2	14	50.%	0.%	0.%	0.%	50.%	1	0	1
KERA*										
NE	4	8	0.%	0.%	100.%	0.%	0.%	0	0	0
KEST*										
NE	3	12	33.3%	66.7%	0.%	0.%	0.%	1	0	1
KYME*										
SEUS	2	8	0.%	50.%	50.%	0.%	0.%	0	0	0
LM*										
BOF	4	57	75.%	0.%	0.%	0.%	25.%	2	0	2
MADMF										
NE	8	75	0.%	50.%	0.%	12.5%	37.5%	0	1	1
MALO*										
SEUS	2	6	0.%	0.%	0.%	0.%	100.%	0	0	0
MAMC*										
SEUS	1	13	0.%	100.%	0.%	0.%	0.%	0	0	0
MARS										
NRTH	6	95	100.%	0.%	0.%	0.%	0.%	3	0	3
MISN*										
NE	6	30	50.%	0.%	0.%	0.%	50.%	3	0	3
MIVHO*										
SEUS	2	10	0.%	0.%	0.%	0.%	100.%	0	0	0
MRC										
SEUS	2	33	50.%	0.%	0.%	50.%	0.%	1	1	2
NACH*										
NE	2	3	100.%	0.%	0.%	0.%	0.%	2	0	2
NAME*										
NE	1	14	0.%	100.%	0.%	0.%	0.%	0	0	0

Table 1 (cont.)

Organization /	# of Sightings	# of Images	% of Total Sightings					# of Individuals		
			Matched							
			Confirmed	Unconfirmed	Not Matchable	Intermatched	Not Yet Matched	Confirmed Id'd	Other Unique Id'd	Total
NEA										
BOF	14	329	92.9%	7.1%	0.%	0.%	0.%	8	0	8
GOM	64	516	32.8%	14.1%	0.%	1.6%	51.6%	21	1	22
GSC	3	0	0.%	0.%	0.%	0.%	100.%	0	0	0
MIDA	240	723	15.8%	0.8%	0.%	4.6%	78.8%	34	4	38
NEA/CWI										
NRTH	544	60	0.2%	0.2%	0.%	2.8%	96.9%	1	4	5
NEFSC										
GOM	424	2,730	46.9%	13.2%	0.5%	2.4%	37.%	128	6	134
GSC	44	16	2.3%	0.%	0.%	11.4%	86.4%	1	2	3
MIDA	255	1,812	49.8%	9.%	0.%	2.%	39.2%	104	2	106
NE	87	1,104	60.9%	8.%	0.%	5.7%	25.3%	43	3	46
NRTH	876	3,020	4.%	11.8%	0.%	1.6%	82.6%	24	4	28
NIHA*										
NRTH	1	4	100.%	0.%	0.%	0.%	0.%	1	0	1
NYDEC										
MIDA	3	31	66.7%	0.%	0.%	0.%	33.3%	1	0	1
ORD/SS										
MIDA	6	13	33.3%	16.7%	0.%	0.%	50.%	2	0	2
OSF										
MIDA	3	34	100.%	0.%	0.%	0.%	0.%	3	0	3
PEFL*										
NE	21	54	33.3%	52.4%	0.%	0.%	14.3%	7	0	7
QLM										
BOF	29	300	93.1%	6.9%	0.%	0.%	0.%	7	0	7
RINE*										
MIDA	2	53	50.%	0.%	0.%	0.%	50.%	1	0	1
RIST*										
SEUS	2	19	50.%	0.%	0.%	50.%	0.%	1	1	2
RONE*										
SEUS	2	19	50.%	0.%	0.%	50.%	0.%	1	1	2
RORO*										
SEUS	2	39	0.%	50.%	0.%	50.%	0.%	0	1	1
STRO*										
SEUS	4	44	50.%	0.%	0.%	50.%	0.%	2	2	4
SWFSC										
NE	42	577	59.5%	38.1%	0.%	2.4%	0.%	24	1	25
TC										
EAST	2	17	0.%	0.%	100.%	0.%	0.%	0	0	0
NRTH	67	84	13.4%	6.%	0.%	0.%	80.6%	6	0	6
TT-NYDEC										
MIDA	4	73	100.%	0.%	0.%	0.%	0.%	4	0	4
UNK										
EAST	1	4	0.%	0.%	100.%	0.%	0.%	0	0	0
NRTH	3	8	66.7%	0.%	33.3%	0.%	0.%	2	0	2
UPEI										
NRTH	1	22	100.%	0.%	0.%	0.%	0.%	1	0	1
USCG										
NE	1	1	0.%	0.%	0.%	0.%	100.%	0	0	0
WESH										
SEUS	2	26	50.%	0.%	0.%	50.%	0.%	1	1	2
WHOI										
NE	185	982	25.4%	15.7%	0.%	0.5%	58.4%	35	1	36
	4,649	**29,182**								

VIII. Catalog Related Publications and Reports

Since the last Catalog report on October 31, 2019, the following reports and publications that utilize data from the Catalog have been either published or submitted:

Bourque, L., Wimmer, T., Lair, S., Jones, M., Daoust, P.-Y. 2020. Incident Report: North Atlantic Right Whale Mortality Event in Eastern Canada, 2019. Collaborative Report Produced by: Canadian Wildlife Health Cooperative and Marine Animal Response Society. 210 pp.

Christiansen, F., Dawson, S.M., Durban, J.W., Fearnbach, H., Miller, C.A., Bejder, L., Uhart, M., Sironi, M., Corkeron, P., Rayment, W. and Leunissen, E., 2020. Population comparison of right whale body condition reveals poor state of the North Atlantic right whale. Marine Ecology Progress Series, 640, pp.1-16.

Fauquier D, Long, K, Biederon I, Wilkin S, Rowles T, Henry A, Garon M, Fougeres E, Baker J, Ziccardi M. 2020. Report of the Workshop on North Atlantic Right Whale Health Assessment. June 24-26, 2019. Silver Spring, Maryland 56 p

Henry AG, Garron M, Morin D, Reid A, Ledwell W, TVN Cole TVN. 2020. Serious Injury and Mortality Determinations for Baleen Whale Stocks along the Gulf of Mexico, United States East Coast, and Atlantic Canadian Provinces, 2013-2017. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 20-06; 53 p. Available from: https://www.fisheries.noaa.gov/new-england-mid-atlantic/northeast-fisheries-science-center-publications

Knowlton AR, Zani MA, Howe KR, Hamilton PK, Burgess LA, Graham KM, Pettis HM, Kraus SD, Brown MB. 2019. Research, Monitoring and Conservation of the North Atlantic Right Whale (Eubalaena glacialis) in the southern Gulf of St. Lawrence and the Bay of Fundy – 2019. Report to Irving Oil. 61 pp.

Martins MCI, Miller C, Hamilton P, Robbins J, Zitterbart D, Moore M. 2020. Respiration cycle duration and seawater flux through open blowholes of Humpback (Megaptera novaeangliae) and North Atlantic Right (Eubalaena glacialis) whales. Mar Mamm Sci. http://dx.doi.org/10.1111/mms.12703

O'Brien O, McKenna K, Baumgartner M, Redfern J. 2020. Megafauna Aerial Surveys in the Wind Energy Areas of Massachusetts and Rhode Island with Emphasis on Large Whales. Summary Report Part 1: Sightings and Data – Campaign 5, 2018-2019. Report to Massachusetts Clean Energy Center. 63 pp.

Oleson EM, Baker J, Barlow J, Moore JE, Wade P. 2020. North Atlantic Right Whale Monitoring and Surveillance: Report and Recommendations of the National Marine Fisheries Service's Expert Working Group. NOAA Tech. Memo. NMFS-F/OPR-64, 47 pp.

Pettis HM. 2019. Monitoring injured North Atlantic right whales: December 2019 report. A report to the Volgenau Foundation. 10 pp.
Pettis HM, Pace RM, and Hamilton PK. 2019. North Atlantic Right Whale Consortium 2019 annual report card. Report to the North Atlantic Right Whale Consortium, November 2019. 19 pp.

Radvan S. 2019. Effects of inbreeding on fitness in the North Atlantic right whale (Eubalaena glacialis). Honours thesis Submitted to Saint Mary's University, Halifax, Nova Scotia. 63 pp.

Tetra Tech and LGL. 2020. Final Comprehensive Report for New York Bight Whale Monitoring Aerial Surveys, March 2017 – February 2020. Technical report prepared by Tetra Tech, Inc. and LGL Ecological Research Associates, Inc. 211 pp. + appendices. Prepared for New York State Department of Environmental Conservation, Division of Marine Resources, East Setauket, NY. May 18, 2020

IX. References

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Bourque, L., Wimmer, T., Lair, S., Jones, M., Daoust, P.-Y. 2020. Incident Report: North Atlantic Right Whale Mortality Event in Eastern Canada, 2019. Collaborative Report Produced by: Canadian Wildlife Health Cooperative and Marine Animal Response Society. 210 pp.

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Knowlton, A.R., Kraus, S.D., and Kenney, R.D. 1994. Reproduction in North Atlantic right whales (Eubalaena glacialis). Canadian Journal of Zoology 72:1297-1305.

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. Ecology and Evolution: 1-12.

Appendix I. Matching status for the past 20 years through December 31, 2019 as of September 1, 2020.

A detailed breakdown of the matching status of all sightings from 2000 to 2019. Data for "Matched- to be confirmed" sightings are available only for sightings with digital images, of which there are few prior to 2003. The numbers and percentages provided here do not match those provided in Section II for 2019 because those are for the right whale year (December 1 to November 30), not the calendar year.

Year	Not yet matched	Matched- to be confirmed	Confirmed match	Confirmed not matchable	All sightings	% matched	% confirmed
2000	169		2995	122	3286	94.86%	94.86%
2001	166		3603	214	3983	95.83%	95.83%
2002	119		2452	154	2725	95.63%	95.63%
2003	55		2120	231	2406	97.71%	97.71%
2004	19	1	1706	114	1840	98.97%	98.91%
2005	7		3261	140	3408	99.79%	99.79%
2006	22		2680	101	2803	99.22%	99.22%
2007	35		3608	125	3768	99.07%	99.07%
2008	13		4033	118	4164	99.69%	99.69%
2009	57		4524	117	4698	98.79%	98.79%
2010	25		3143	68	3236	99.23%	99.23%
2011	44		3327	108	3479	98.74%	98.74%
2012	50		2018	59	2127	97.65%	97.65%
2013	56		1784	65	1905	97.06%	97.06%
2014	100		2217	87	2404	95.84%	95.84%
2015	73	1	1631	69	1774	95.89%	95.83%
2016	20		2160	30	2210	99.10%	99.10%
2017	71		2897	158	3126	97.73%	97.73%
2018	60	6	3652	115	3833	98.43%	98.28%
2019	2697	375	1306	18	4396	38.65%	30.12%

Appendix II. List of abbreviations for all areas and regions.

Region	Short Code	Description	Corresponding Area	Description
BOF	F	Bay of Fundy	BOF	Bay of Fundy
EAST	E	East of Mainland US and south of 46 degrees (Azores, East Scotian Shelf, Spain, Bermuda, Canary Islands)	EAST ESS	Catch all area for unusual eastern sightings East Scotian Shelf
GOM	O	Gulf of Maine, North of Cape Anne other than Jeffreys Ledge (Mt. Desert Rock, etc.)	GB GMB GOM	George's Bank Grand Manan Banks Gulf of Maine
GSC	G	Great South Channel	GSC	Great South Channel
JL	J	Jeffreys Ledge	JL	Jeffrey's Ledge
MIDA	A	Mid-Atlantic (North of Georgia to New England)	DBAY DEL MD NC NJ NY SC SNE VA	Delaware Bay Delaware Maryland North Carolina New Jersey New York South Carolina Southern New England Virginia
NE	M	New England (Cape Cod and Massachusetts Bays)	CCB MB	Cape Cod Bay Massachusetts Bay
NRTH	N	North of 46 degrees	CFG GSL ICE NRTH	Cape Farwell Grounds Gulf of St. Lawrence Iceland Catch all for all other northern sightings
RB	R	Roseway Basin	RB	Roseway Basin
SEUS	S	Southeast (Georgia, Florida, Gulf of Mexico)	FL GA GMEX	Florida Georgia Gulf of Mexico
UNK	X	No region or area listed	UNK	Unknown

Appendix III. Abbreviations for 69 data contributors from December 1, 2018 through November 30, 2019.

"*" indicates the sighting was contributed by an individual, not an organization.

Abbreviation	Primary Contact	Organization Name (if applicable)
AMCS	Rob DiGiovanni	Atlantic Marine Conservation Society
ANKE*	Angela Keith	
AWSC		Atlantic White Shark Conservancy
BAGL*	Baradoz Glaz	
BHC	Laura Howes	Boston Harbor Cruises
BHWW/AW	Julianne Taylor	Bar Harbor Whale Watch/Allied Whale
BIWSC	Shelley Barnaby (Longergan)	Briar Island Whale & Seabird Cruises
BONI*	Bob Nicholl	
BOS	Dianna Schulte	Blue Ocean Society for Marine Conservation
BWRI	Jamison Smith	Blue World Research Institute
CACL*	Patrick Clarke	Cape Clasp
CBPWP	Elizabeth Zwamborn	The Cape Breton Pilot Whale Project
CC	Chris Slay	Coastwise Consulting
CCG	Stephanie Ratelle	Candian Coast Gurad viaDFO - Gulf Region
CCS	Brigid McKenna	Center for Coastal Studies
CHBA*	Charla Basran	
CHFA*	Chris Faunce	
CMARI	Melanie White	Clearwater Marine Aquarium Research Institute
CWI	Moe Brown	Canadian Whale Institute
DEHA*	Dena Hankins	
DELA*	Dennis Laguador	
DFO	Stephanie Ratelle & AndrewWright	Department of Fisheries and Oceans Canada
EDGR*	Ed Gerstein	Florida Atlantic University
ERAB*	Eric Abbot	
FTR		Fundy Tide Runners
FWRI	Tom Pitchford	Florida Fish and Wildlife Conservation Commission
GAMO*	Gary Moore	
GDNR	Clay George	Georgia Department of Natural Resources
GMWSRS	Heather Koopman	Grand Manan Whale and Seabird Research Station

Appendix III. (cont.)

Abbreviation	Primary Contact	Organization Name (if applicable)
GREMM	Michel Moisan	Groupe de recherche et d'éducation sur les mammifères marin
JEGR*	Jeffery Grubb	
JELO*	Jeremy Lormis	
JESH*	Jennifer Shockey	
JOPA*	Jonathan Parker	
KERA*	Kelly Ran	
KEST*	Ken Stuart	
KYME*	Kyle Meyer	
LM*	Laurie Murison	Grand Manan Research Station
MADMF	Erin Burke	Massachusetts Division of Marine Fisheries
MALO*	Millie Lopez	
MAMC*	Mark McGahn	
MARS	Andrew Read & Tonya Wimmer	Marine Animal Response Society
MISN*	Michael Snow	
MIVHO*	Michael Van Horn	
MRC	Julie Albert	Marine Resources Council
NACH*	Nathan Chamberlain	
NAME*	Nate Meyer	
NEA	Monica Zani & Orla O'Brien	New England Aquarium
NEA/CWI	Monica Zani	New England Aquarium/Canadian Whale Institute
NEFSC	Allison Henry & Lisa Conger	Northeast Fisheries Science Center
NIHA*	Nick Hawkins	
NYDEC		New York Department of Environmental Conservation
ORD/SS	Laura Morse	Orsted Energy/Smultea Consulting
OSF	Chip Michalove	Outcast Sport Fishing
PEFL*	Peter Flood	
QLM	Danielle Dion	Quoddy Link Marine
RINE*	Richard Neal	Frying Pan Tower
RIST*	Richard Staiert	

Appendix III. (cont.)

Abbreviation	Primary Contact	Organization Name (if applicable)
RONE*	Ron Netherson	
RORO*	Rob Royston	
STRO*	Stacey Roberts	
SWFSC	John Durban	Southwest Fisheries Science Center. After 2019, these data are coded as SEAI/DR (Southall Environmental Associates Inc)
TC	Stephanie Ratelle	Transport Canada- via DFO
TT-NYDEC	Ann Zoidis	Tetratech
UNK		Unknown- sightings of dead whales reported to DFO by fishermen- the observers' names were not provided to NEAq
UPEI	Laura Bourque & Pierre-Yves Daoust	University of Prince Edward Island/Atlantic Veterinary College, Canadian Wildlife Health Cooperative
USCG		U.S. Coast Guard
WESH		WESH Channel 2 (Orlando, FL)
WHOI	Michael Moore	Woods Hole Oceanographic Institution

Task 2: Final Report on 2018 Right Whale Entanglement Scar Coding Efforts

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Overview

This report summarizes right whale entanglement scarring analyses for 2018 using sightings and photographs from the North Atlantic Right Whale Consortium (NARWC) Identification Database. The goal was to compare the frequency and rate of scar detections in 2018 to those of 2010-2017 (data provided in previous reports) as well as to the prior 30 years of data (1980-2009), as reported by Knowlton et al. (2012). As part of this annual review effort, we have categorized each new entanglement event in terms of injury severity levels of minor, moderate, and severe as defined in Knowlton et al. (2016; see Appendix 1) and compared frequency at these levels to prior years. Additionally, two-page case studies for all whales with attached gear and a one-page case study for all whales with severe injuries and no attached gear were developed.

These annual reports are useful in monitoring all entanglement events that occur in both the United States and Canada to see if and how management efforts influence the frequency, rate and severity of entanglement events (beyond those cases of actively entangled or severely injured whales as reported in near real-time).

The methodology used for scar coding and analyses are detailed in the Knowlton et al. papers (2012; 2016) and thus are only summarized briefly below.

Explanation of analyses described in report

Scar coding was carried out for all animals sighted in 2018 and any new, pre-2018 sightings added to the catalog since the 2019 report. Scar coding was also carried out for any new whales added to the catalog with sightings up to and including 2018. In addition to calculations of annual population entanglement rates and detection of new entanglement events, explanations are provided below for several analyses that are described in the papers mentioned above and presented in this report for the 2018 data.

Crude entanglement rate

This analysis presents the number of new entanglement detections by year as a proportion of the number of animals identified in each year independent of how well the animal was photographed. The year a scar was detected may not represent the year the entanglement occurred (i.e. if the whale had not been seen for many years) so this analysis is only useful for documenting that entanglements have occurred, but does not provide precise annual entanglement rates.

Annual entanglement rate

To obtain an assessment of the minimum annual rate of entanglement, subsets of animals seen and adequately photographed in both years of sequential two-year combinations (e.g., 2017/2018) were analyzed. For an animal to be considered adequately photographed, clear images showing the entire area of the dorsal peduncle or one of the fluke insertion areas were required in both years to allow for inter-year comparisons. For calves and one year olds, the peduncle area had to be well-photographed in only the second year to be included. Lastly, any whale that had evidence of an entanglement event in Year 2 elsewhere on the body that would have been detectable from photographs in Year 1 or an entanglement that was known to have occurred within Year 2 of the two-year timeframe was also included.

Age at Entanglement Detection
To determine whether there were differential entanglement rates between age classes, the percentage of annual entanglement events by age group for these recent years was examined and compared to prior years reported in Knowlton et al. (2012). The age when the entanglement was first detected was used for this analysis.

Time Frames of Entanglements
To estimate the timeframe of an entanglement event (i.e. the period within which the whale must have encountered the fishing gear) the dates of the last sighting without the scarring or attached gear and the first sighting with the scarring or attached gear were identified. Entanglement time frames were classified as follows: 1) within six months, 2) within one year, 3) within two years, 4) within three years, 5) greater than three years and 6) unknown time frame.

Animals carrying gear and with severe entanglement wounds
Entanglement events at which whales were seen with attached fishing gear and/or with deep wounds from entanglement (as defined in Appendix 1) were categorized as a "serious entanglements" according to New England Aquarium (NEAq) criteria. The percentage of the annually sighted population with a serious entanglement was calculated.

Entanglement locations
Determining the location where entanglements may have occurred was evaluated in two ways. First was via an inquiry with NOAA Fisheries about the draft 2018 Atlantic Large Whale Entanglement Report for those whales with gear attached – although it was not available for review, NOAA Fisheries was able to provide information on gear type and country of origin where available (David Morin, pers comm.); second was a review of short timeframe scarring events (<6 months) to determine the location of the individual whale before and after entanglement injury detection and provide likely country of origin where possible.

<u>Scar coding results</u>

A summary of all entanglements from pre-1980-2018 (only 7 events pre-1980) and those that were documented in 2018 only are provided below:

- Total number of animals reviewed in all years: **761**
    - # of batches analyzed (one batch equals all sightings of an individual grouped within each area/season in a given year) – all years: **20,536**
    - 2018 batches analyzed: **848**
- Number of separate entanglement events detected - all years pre-1980-2018: **1,624**
    - 2018 events: **59**
        - Female – 23
        - Male – 33
        - Unknown sex - 4
- Percentage of population entangled at least once: 658/761 **86.5%**
    - # of females in the population through 2018: **321**
    - % of females entangled at least once: 281/321 **87.5%**
    - # of males in the population through 2018: **365**
    - % of males entangled at least once: 344/365 **94.2%**

- # of unknown sex in the population through 2017: **75**
- % of unknown sex entangled at least once: 33/75 **44.0%**

An additional 16 events were added from previous years – one in 2008, one in 2012, one in 2013, two in 2014, one in 2015, six in 2016, and six in 2017. Reasons for the addition of new events in previous years include: 1) the addition of new animals to the catalog with sighting histories that began prior to 2018; 2) recent identifications of older sightings; 3) recently added better quality images of animals which provided evidence that a certain scar visible prior to 2018 was from entanglement – these events were back-coded to the appropriate year.

Crude entanglement rate

The annual detection of new entanglement scars between 1980 and 2009 ranged from 8.6% (in 1987) to 33.6% (in 1999) with an average of 15.5%, SD +/- 5.5% (Knowlton et al. 2012). The 2010-2018 period ranged from 10.9% to 22.4% with an annual rate average of 16.9%, slightly above the 30-year average. For 2018, this rate was 17.0% indicating no detectable drop in crude entanglement rate (Table 1).

Table 1. *Crude entanglement rate. Note: all years updated.*

Year	# of individuals sighted	# of newly detected entanglements	Percentage
2010	422	66	15.4%
2011	438	98	22.4%
2012	376	58	15.4%
2013	302	33	10.9%
2014	373	65	17.4%
2015	276	39	14.1%
2016	329	72	21.9%
2017	378	68	18.0%
2018	**347**	**59**	**17.0%**

Annual rate of entanglement

As reported in Knowlton et al. (2012), for each two-year period from 1980/1981 through 2008/2009, the percentage of adequately photographed individuals with evidence of a new entanglement occurrence by year two of the given time period ranged from 13.4% to 50.0% with an annual average of 25.0%, SD =+/- 10.0% (Appendix 2).

Although Table 2 has not been updated for the years prior to 2017/2018 for this report, the previous scarring report indicated that all but one year (2014/2015) were above the average of 25%. 2017/2018 is also above the historical average with 30.3% of adequately photographed individuals showing signs of entanglement occurrence by 2018.

Table 2. *Annual entanglement rate (years prior to 2017/2018 not updated with recent data)*

Year	Adequately photographed	Entangled by year 2	Entanglement rate
2009/2010	197	52	26.4%
2010/2011	194	77	39.7%
2011/2012	137	44	32.1%
2012/2013	50	15	30.0%
2013/2014	83	28	33.7%
2014/2015	87	17	19.5%
2015/2016	100	34	34.0%
2016/2017	158	42	26.6%
2017/2018	**178**	**54**	**30.3%**

Timeframes of entanglement

The timeframe of entanglement detection (i.e. the maximum timeframe within which the event must have occurred based on time between sightings without and then with entanglement scars) has decreased over the decades with nearly half of all events detected within a one-year timeframe since 1990, and 66% of the events detected within a two-year timeframe.

For 2010 and 2011, 70% and 76% of the entanglement detections were determined within a one-year timeframe, respectively. In 2012, this percentage increased to 79% (Table 3) showing further improvement in the ability to detect events quickly. However, in 2013-2016, this percentage dropped with just over 50% events detected within a one-year timeframe. This pattern improved somewhat in 2017 with 59% of the cases detected within one-year. In 2018, this improved dramatically with 80% sighted within a one-year timeframe. This is likely the result of increased survey efforts and sightings in both the Gulf of St Lawrence and southern New England, both of which have been identified as new high use areas. It is valuable to keep this percentage detected within 6 months or 1 year as high as possible in order to help us assess the effects of management changes implemented to mitigate entanglement impacts.

Table 3. *Total number and percentage of detections within given timeframes. Note: all years updated.*

	# of events	<6 mo	< 1 year	< 2 years	< 3 years	>3 years	Unknown timeframe
2010	65	24 (37%)	22 (33%)	14 (22%)	3 (5%)	2 (3%)	
2011	98	35 (36%)	40 (40%)	13 (13%)	5 (5%)	2 (2%)	4 (4%)
2012	58	27 (47%)	19 (32%)	4 (7%)	4 (7%)	3 (5%)	1 (2%)
2013	33	8 (24%)	10 (31%)	7 (21%)	4 (12%)	4 (12%)	
2014	65	15 (23%)	17 (27%)	15 (23%)	8 (12%)	8 (12%)	2 (3%)
2015	39	9 (23%)	13 (33%)	7 (18%)	3 (8%)	6 (15%)	1 (3%)
2016	72	19 (26%)	17 (24%)	22 (30%)	2 (3%)	12 (17%)	
2017	68	25 (37%)	15 (22%)	8 (12%)	12 (18%)	7 (10%)	1 (1%)
2018	**59**	**21 (36%)**	**26 (44%)**	**6 (10%)**	**2 (3%)**	**2 (3%)**	**2 (3%)**

Age at entanglement detection
Data from historical analyses have shown that calves and juveniles are entangled at a higher rate than adults. In 2010-2012, this pattern continued with 52% to 65% of all the entanglement detections involving calves and juveniles. In the 2013-2016 data, this pattern shifted with only 33% to 37% of entanglement events involving calves or juveniles (Table 4). In 2017, this pattern increased slightly with 40% of entanglements involving calves or juveniles. But of concern is the declining proportion of calves and juveniles in the population from 2010 through 2017. This continuing decline in juveniles is likely the result of reduced reproductive activity in recent years but could also be related to undetected mortalities that may be occurring in young whales when they get entangled in strong ropes (Table 4; Knowlton et al. 2016).

Table 4. *Entanglement events by age group. Note: all years updated*

	Calf	Juvenile (1-8 years old)	Adult (>8 years old)	Unknown age	% of 0-8 yo in population presumed alive
2010 n = 65	3 (5%)	31 (47%)	29 (45%)	2 (3%)	35% 181/512
2011 n = 98	7 (7%)	51 (52%)	34 (35%)	6 (6%)	35% 181/514
2012 n = 58	1 (2%)	37 (64%)	17 (29%)	3 (5%)	32% 166/516
2013 n = 33	3 (9%)	10 (30%)	20 (61%)	0 (0%)	30% 158/520
2014 n = 65	2 (3%)	20 (31%)	43 (66%)	0 (0%)	28% 147/520
2015 n = 39	1 (3%)	13 (33%)	23 (59%)	2 (5%)	27% 143/524
2016 n = 72	7 (10%)	21 (29%)	43 (60%)	1 (2%)	25% 131/522
2017 n = 68	0 (0%)	28 (41%)	35 (52%)	5 (7%)	21% 108/505
2018 n = 59	**0 (0%)**	**13 (22%)**	**41 (69%)**	**5 (9%)**	**16% 79/479**

Serious entanglements: Whales carrying gear or with severe entanglement wounds only
Knowlton et al. (2012) combined the number of animals carrying gear (independent of injury severity) with the number of animals with severe entanglement wounds (without attached gear) and divided that total by the number of animals seen in a given year to determine the percentage of 'serious entanglements' for all years. The result for 1980-2009 showed an annual average serious entanglement rate of 1.2% (range 0.0 – 3.0%; SD = +/- 0.8%) (Appendix 2). For 2010-2017, all years have been above this average rate with a range from 1.4% to 3.8%. In 2018, the rate increased to 4.3% making it the highest year over this 39-year study (Table 5).

Case studies for the gear-carrying whales can be found under Task 3. Figure 1 provides case studies for the whales with severe injuries and no gear attached. Below is a summary of these events for 2018.

In 2018, there were 15 whales with serious entanglements: six carrying gear and nine with severe injuries. Of the six with attached gear, one (#3893, a 10- year old female) was found dead. Two of the remaining five were unable to be disentangled - #3312, a 15-year old male who has not been seen since detected with gear and is likely dead and #2310, a 25+ year old male who was in decline at subsequent sightings; and the other three with attached gear were either partially disentangled (#3843) or shed their gear (#3960, #4091) and have been resighted in reasonable condition.

Of the nine whales with severe injuries only, one (#3296) is in very poor condition and not likely to survive. The remaining eight have been resighted in 2019 in fair or improving condition but their health will continue to be monitored using the visual health assessment developed by Pettis et al. (2004) to assess whether their entanglement results in a decline in health.

Table 5. *Serious entanglements (whales with gear or severe injuries only). All updated except for the potentially dead tally.*

	2010	2011	2012	2013	2014	2015	2016	2017	**2018**
With attached gear	5	11*	5*	3	7*	4*	7	9	**6**
Severe injuries only	1	3	6	1	7	3	5	5	**8**
% of all sighted individuals with serious entanglements (gear + severe injuries)	1.4% (6/422)	3.2% (14/438)	2.9% (11/376)	1.3% (4/302)	3.8% (14/373)	2.5% (7/276)	3.6% (12/329)	3.7% (14/378)	**4.3% (15/347)**
Total of (dead/ potentially dead)	3 (2/1)	5 (1/4)	6 (2/4)	3 (1/2)	9 (2/7)	2 (0/2)	10 (2/8)	14 (2/12)	**6 (3/3)**

* The tallies in 2011 and 2012 include one unidentified entangled carcass in each year, in 2014, two unidentified entangled carcasses, and in 2015, two live unidentified entangled whales.

Entanglement injury severity

Above we described whales with 'serious entanglements' as any whale carrying gear or with severe wounds only. Here, we tabulate the severity of the wounds resulting from *all* the entanglement events in a given year. Entanglement injury severity was divided into three categories (minor, moderate, severe; see Appendix 1 for criteria) based on extensiveness and

depth of the wounds. Knowlton et al. (2016) showed that moderate and severe entanglement injury rates have increased significantly over the three decades analyzed (1980-2009) with increasing rates noted in each year from 1997 onward and with statistically significant increases noted from 2000 onward. Although the recent data from 2010-2018 have not been analyzed statistically in comparison to the prior three decades, the proportion of entanglements resulting in moderate to severe injuries remains high with an average of 35% (range 24-44%). 2018 was above the average with 37% (Table 6). The proportion of 2018 cases resulting in severe injuries was at the highest level documented for the past 9 years at 24% (2010-2017 range: 7 – 22%; Table 6).

Table 6. *Entanglement events according to injury severity by year. The number in parentheses is the subset that was seen carrying gear. Note: all years updated.*

Year (# of events)	Minor	Moderate	Severe
2010 (n = 65)	42 (0); 65%	17 (0); 26%	6 (5); 9%
2011 (n = 99)*	69 (2); 70%	23 (5); 23%	7 (4); 7%
2012 (n = 59)*	45 (1); 76%	5(1); 9%	9 (3); 15%
2013 (n = 33)	22 (0); 67%	8 (1); 24%	3 (2); 9%
2014 (n = 67)*	44 (0); 66%	9 (0); 13%	14 (7); 21%
2015 (n = 41)+	26 (0); 63%	8 (0); 20%	7 (4); 17%
2016 (n = 72)	42 (0); 58%	18 (1); 25%	12 (6); 17%
2017 (n = 68)	40 (1); 59%	16 (3); 24%	12 (5); 17%
2018 (n = 59)	**37 (1); 63%**	**8 (0); 13%**	**14 (5); 24%**

* *The tallies in 2011 and 2012 include one unidentified entangled carcass in each year, and in 2014, two unidentified entangled carcasses. All carcasses are included in the severe tallies.*

+ *In 2015 there were two cases of whales carrying gear that were not able to be identified. We have included them in the severe tally even though injury severity could not be determined.*

Entanglement country of origin

As discussion within the Atlantic Large Whale Take Reduction Team (TRT) continues to focus on understanding where entanglements occur, we have attempted to describe what the scarring events and attached gear cases can and cannot tell us.

For the six cases with attached gear, two (#3312 and #3960) were attributed to Canadian unknown gear type, one (#3893) was attributed to Canadian snow crab, one (#4091) was attributed to US unknown gear type and two (#2310 and #3843) were unknown gear type/ country of origin. (David Morin, pers. Comm.).

For scarring cases involving no gear, 16 cases occurred within a six-month period as shown in Table 7. Two of these likely occurred in US waters, six in Canadian waters, and for the remaining eight, country of origin could not be determined.

With all gear and scarring-only cases combined, 27% or 16 of 59 cases could be attributed to likely country of origin - 12 occurred in Canadian waters, 4 occurred in U.S. waters, and the remaining 43 cases could not be attributed to country of origin.

Table 7. *Entanglement scarring only cases determined to have occurred within a 6-month time period with sex, age, injury severity, and their likely country of origin. Note: CCB = Cape Cod Bay, MB = Massachusetts Bay, SNE = southern New England, GB = Georges Bank, MB = Massachusetts Bay, GSL = Gulf of St Lawrence, SNE = southern New England, BOF = Bay of Fundy.*

RW #	Date seen prior to scar detection	Date with new scars detected	# of days	Age, sex, injury severity	Area seen prior	Area seen with new scars	Likely country of origin
4180	17-Jun-18	16-Jul-18	29	Adult female; MODERATE	GSL	GSL	Canada
2791	17-Jun-18	19-Jul-18	32	Adult female; MINOR	GSL	GSL	Canada
3546	04-Jun-18	11-Jul-18	37	13 y.o. female; MINOR	GSL	GSL	Canada
3840	12-Mar-18	21-Apr-18	40	Adult male; MINOR	MB	CCB	US
2760	17-Jun-18	31-Jul-18	44	Adult male; MINOR	GSL	GSL	Canada
3860	27-Apr-18	11-Jun-18	45	10 y.o. female; MINOR	CCB	GSL	Unknown
3812	07-Jun-18	01-Aug-18	55	10 y.o. male; MINOR	GSL	GSL	Canada
3515	12-Aug-18	14-Oct-18	63	13 y.o. female; SEVERE, DEAD	GSL	GB	Unknown
4601	06-Jun-18	21-Jul-18	45	2 y.o. female; SEVERE	GSL	GSL	Canada
3981	04-May-18	20-Jul-18	77	9 y.o. male; MINOR	CCB	GSL	Unknown
3992	23-Mar-18	09-Jun-18	78	9 y.o. male; MINOR	SNE	GSL	Unknown
3904	21-Aug-18	24-Nov-18	95	9 y.o. female; SEVERE	GSL	SNE	Unknown
4615	28-Mar-18	05-Jul-18	99	2 y.o. male; SEVERE	CCB	GSL	Unknown
4505	23-Apr-18	25-Aug-18	124	3 y.o. male; SEVERE, DEAD	SNE	SNE	US
2910	31-Jul-18	11-Dec-18	133	Adult male; MINOR	GSL	CCB	Unknown
4539	29-Oct-17	21-Apr-18	174	3 y.o. male; MINOR	GSL	MB	Unknown

Discussion

Results from our 2018 scarring assessment indicate a total of 59 entanglement events, 15 of which were serious entanglements. The proportion of whales with serious entanglements, 4.3% of all sighted individuals, was the highest proportion documented over the 39-year period, with 2017 the second highest year at 3.9%. Clearly this trajectory points in the wrong direction. Of great concern is the fate of juveniles. Of the 15 serious entanglements, 11 involved adults ranging from 9 to 31 years old including one dead female at 10 years old. Of the four juveniles involved, ages ranging from 2 to 8 years old, one was dead (3-year-old male). The continued high level of involvement of adults in serious entanglements suggests that juveniles may be drowning in gear, as appears to have occurred with #4505 (see Figure 1), and these cases are probably not always observed or documented if they drown at depth. This hypothesis is being

born out with the continuously declining proportion of juveniles in the presumed living population which decreased from 35% in 2010 to 16% in 2018. This is an alarming statistic. Although this decline in juveniles is partially attributable to a notable reduction in calving over these past 10 years, the loss of juveniles to entanglement is likely much higher than documented from detected events.

In 2018, of the 15 whales with a serious entanglement, i.e. attached gear and/or severe injury, eight are male and seven are female. Two of the seven are reproductive females but one (#3515) was found dead in 2018. Of the remaining five females, four are 8 to 10 years old and likely just entering into their reproductive years and one is two years old.

Looking at the injury severity of the 59 entanglement events, the proportion that resulted in moderate or severe injuries remained high at 37% in 2018 with the highest proportion of severe injuries documented in a given year at 24%. We have clear evidence that even if a whale survives a severe entanglement injury, their survival is greatly reduced and this is even more pronounced for reproductive females (analysis in progress). Furthermore, these severe injuries may also lead to reduced fecundity for those few reproductive females that survive the trauma.

Our ability to monitor entanglement timeframes has improved with 80% of the 2018 entanglements documented within a one-year timeframe. Despite this improvement in monitoring entanglement occurrence on shorter timeframes, when we looked at cases that occurred within a 6-month timeframe or had attached gear that could be linked to a country of origin, we were only able to determine likely country of origin in 27% of the 59 cases – 12 occurred in Canada and four in the U.S. The four included two carcasses linked to Canada and one carcass linked to the U.S. Clearly, both countries have more work to do to address this existential threat to the survival of this species. As we have noted for many years, no fixed fishing gear type or country or region is immune to this entanglement threat to right whales and all large whales. If we are going to save this species from extinction, and save other large whale populations from this preventable trauma, there needs to be a dramatic and expedited change to how fixed gear fisheries are conducted in both countries. The continued improvements to ropeless fishing techniques are encouraging and will be a valuable tool for the more dangerous offshore gear types and for areas that are closed when right whale aggregations are present. We also advocate the use of ropes with 1700 lb breaking strength, ideally with weak sleeves or break points integrated every 40 feet to reduce the amount of trailing line that would be left on an entangled whale, thereby increasing the likelihood that the gear would be shed. The use of 1700 lb ropes should be mandated throughout the range at all times of year especially now that right whale distributions have become less predictable with climate change.

Regulatory changes in the U.S. and Canada have evolved in different ways to try and address this threat. In Canada, since the dramatic mortality event in 2017 where 12 right whales were found dead, including two entangled carcasses as well as five live whale entanglements in snow crab gear, the Department of Fisheries and Oceans Canada has taken dramatic measures aimed at mitigating this entanglement risk. These changes have included seasonal and dynamic closures in the Gulf of St Lawrence based on historical and real-time presence of right whales. Based on this 2018 assessment, it does not appear that the changes in that year resulted in a notable reduction in entanglement events as 12 cases out of 59 (20%) likely occurred in Canadian waters, primarily in the Gulf. In 2019 and 2020, until the scarring assessment is completed, it remains unclear

whether the more updated protection measure have resulted in fewer entanglements that can be traced back to Canada and more specifically, the Gulf. Entanglements with attached gear have been documented in both 2019 and 2020 as of October 31 (5 and 4 cases respectively) but only one case in 2019 (#1226) was known to have occurred in the Gulf of St Lawrence. The region and country where the other entanglements occurred is presently unknown.

In the U.S., needed regulatory changes are being proposed after near consensus was reached by the Atlantic Large Whale Take Reduction team in April 2019, but a proposed rule is presently stalled. However, a legal decision mandates that a rule be finalized by May 2021 which may include a combination of weak ropes, endline reduction, and closed areas to achieve a 60 to 80% reduction in risk.

The most recent population size assessment released by NOAA Fisheries in October 2020 indicates a further decline in the population with the 2019 tally at 366 individuals. Based on this 2018 scarring assessment and previous scarring reports, this rapid decline is not surprising considering the continuing documentation of serious injuries and deaths from entanglements, but it is particularly disheartening given that it is preventable. The right whale community knows that disentanglement is not the solution to this threat and, unless broad scale measures are quickly implemented throughout the right whale's range, we may lose this critically endangered species to extinction in a matter of decades.

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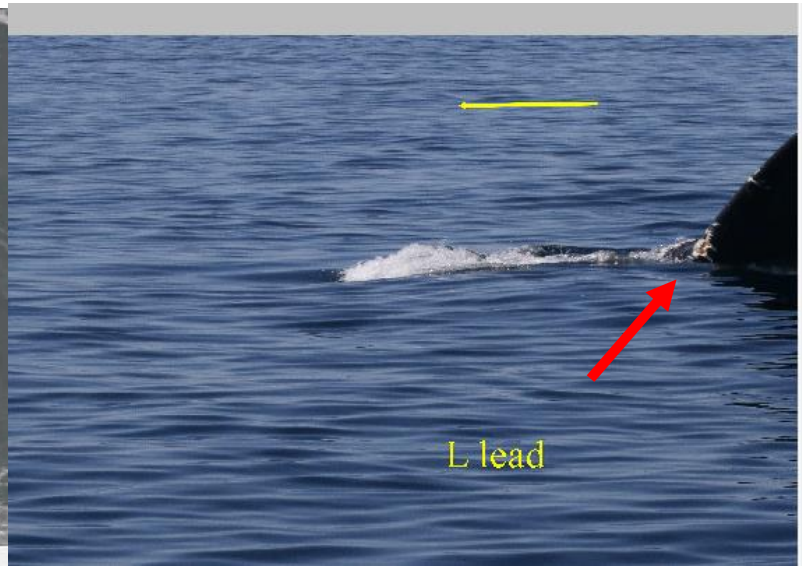
Figure 1. *Severe injuries caused by entanglement (no attached gear) documented in 2018 (listed in order of catalog #). Note: CCS = Center for Coastal Studies, GDNR = Georgia Department of Natural Resources, NEAq = New England Aquarium, NEFSC = Northeast Fisheries Science Center, NOAA = National Oceanic and Atmospheric Administration. Photos not taken by the initial observer are noted with observer and date.*

Catalog #	**Sex**	**Birth year**	**Date of entanglement detection (date seen prior)**	**Age at entanglement detection**	**Location when detected/Observer**
1708	Male	1987	6 Feb 2018 (25 Jun 2017)	31 years old	Cape Cod Bay/CCS

Description:
This 31-year-old male was seen with moderate to severe, raw entanglement injuries around the peduncle and insertions. An assessment of the injuries at a subsequent, vessel-based sighting on May 1, 2018 indicated some of them had not healed, although there has been no evidence of a decline in body or skin condition at subsequent sightings. He was last seen on April 6, 2019 in Cape Cod Bay but it was not possible to confirm if the injuries had fully healed from the aerial imagery.

Dorsal fluke – February 6, 2018



Left insertion – May 1, 2018 (NEFSC)

Catalog # Name	Sex	Birth year	Date of entanglement detection (date seen prior)	Age at entanglement detection	Location when detected/Observer
1817 Silt	Female	Unknown	13 Feb 2018 (17 Apr 2017)	30+ years old	Cape Cod Bay/CCS

Description:
This 30+ year-old reproductive female was seen with severe, raw entanglement injuries around the peduncle and insertions which were still not fully healed at a subsequent sighting in April 2018. She has shown no obvious evidence of decline as of last sighting in April 2019 although the wounds are not fully healed. Interestingly, she has not had a calf since 2009 and in that year suffered a moderate entanglement event.

Right peduncle and insertion - Feb 13, 2018

Dorsal fluke – Apr 6, 2019 (opportunistic)

Catalog #	Sex	Birth year	Date of entanglement detection (date seen prior)	Age at entanglement detection	Location when detected/Observer
3296	Male	2002	15 Feb 2018 (30 Apr 2017)	16 years old	Southeast US/GDNR

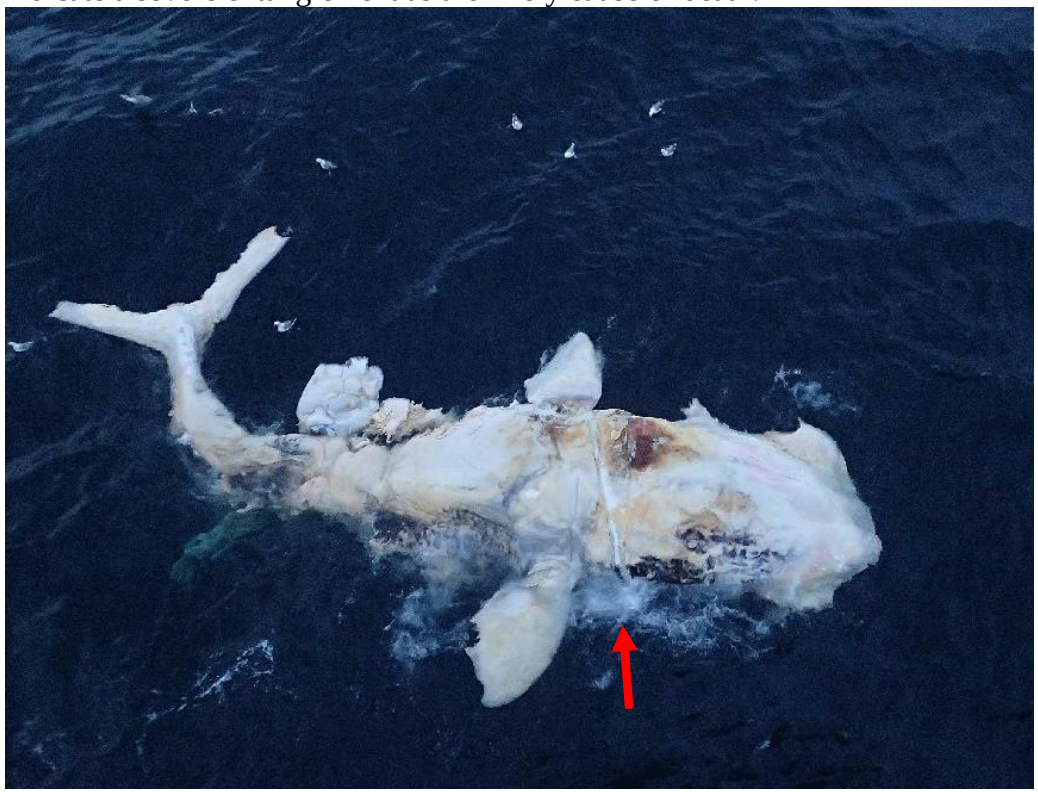
Description:
This 16-year-old male was seen in very poor condition with a portion of his right lip torn off and severe entanglement injuries around the peduncle. The head and body regions had extensive orange cyamid coverage and the whale was emaciated. He has not been sighted since Feb 2018 and is likely dead.

Aerial view showing missing right lip and orange cyamids on head

Aerial view of orange cyamids on body and tail injuries

Catalog #	Sex	Birth year	Date of entanglement detection (date seen prior)	Age at entanglement detection	Location when detected/Observer
3515	Female	2005	14 Oct 2018 (12 Aug 2018)	15 years old	Georges Bank/NOAA

Description:
This adult female carcass was observed ~100 nm east of Nantucket by a NOAA vessel. A sample was collected and it was identified genetically. #3515 was a reproductive female who last calved in 2013. A deep indentation across the ventrum between the flippers indicate a severe entanglement as the likely cause of death.



Decomposed carcass with arrow showing deep indentation across ventrum

Catalog #	Sex	Birth year	Date of entanglement detection (date seen prior)	Age at entanglement detection	Location when detected/Observer
3823 Sundog	Female	2008	24 Feb 2018 (2 Aug 2017)	10 years old	Cape Cod Bay/CCS and NEFSC

Description: This 10-year-old female was observed with severe injuries on the peduncle and leading edges of the flukes with moderate injuries on the head. In August and December 2018, she was coded as thin and with poor skin condition. She was sighted by NEFSC in June 2019 and her skin condition continues to be poor but her body condition could not be assessed.

Injuries on head - April 23, 2018 (NEFSC)

Dorsal peduncle and right tail stock - March 1, 2018 (NEFSC)

Catalog #	Sex	Birth year	Date of entanglement detection (date seen prior)	Age at entanglement detection	Location when detected/Observer
3904 Champagne	Female	2009	24 Nov 2018 (21 Aug 2018)	9 years old	Southern New England/NEAq

Description: This 9-year-old female was observed with moderate to severe injuries on the peduncle and minor injuries on the head. Although there is evidence of healing, the deep injury closest to the tail has not fully healed as of April 2019. In December 2018, she was coded with good body and skin condition and in April 2019, there was no visible evidence of decline in health.

Dorsal peduncle and left insertion

Dorsal peduncle and head injuries

Catalog #	Sex	Birth year	Date of entanglement detection (date seen prior)	Age at entanglement detection	Location when detected/Observer
4505	Male	2015	25 Aug 2018 (23 Apr 2018)	3 years old	Southern New England/Unk

Description: This 3-year-old male carcass was initially seen floating about 10 nm south of the Nantucket/Martha's Vineyard before it came ashore on Monomoy Island on Aug 30. A partial necropsy was conducted and severe entanglement injuries were noted at the right flipper suggesting a peracute underwater entrapment, i.e. drowning. Based on decomposition, the necropsy team estimated it had been dead 1-4 weeks and may have become entangled in that southern New England area based on his historical presence there.

Carcass observation on August 27, 2018 (Opportunistic)

Catalog #	Sex	Birth year	Date of entanglement detection (date seen prior)	Age at entanglement detection	Location when detected/Observer
4601 Gully	Female	2016	21 Jul 2018 (6 Jun 2018)	2 years old	Gulf of St Lawrence/NEAq

Description: This 2-year-old female was observed with severe injuries on head, blowholes, peduncle and insertions. Her skin condition was noted as poor but she was not considered thin. At her sighting on August 11, 2018, her right blowhole was not functioning. She approached the research vessel and circled for over an hour. She was sighted from June -August 2019 and her skin condition remains compromised and she may be slightly thin but no clear evidence of a dramatic decline and the right blowhole is now functioning.

Left head and blowholes

Dorsal peduncle and right tail stock

Catalog #	Sex	Birth year	Date of entanglement detection (date seen prior)	Age at entanglement detection	Location when detected/Observer
4615	Male	2016	5 Jul 2018 (28 Mar 2018)	2 years old	Gulf of St Lawrence/NEAq

Description: This 2-year-old male was observed with severe injuries on the peduncle and insertions and a minor scar across the rostrum. When sighted in August 2018, the wounds had not fully healed. In 2019 the wounds were still not fully healed and there was a decline in skin condition between February and July 2019.

Dorsal peduncle and right fluke insertion (13 Aug 2018 NEA/CWI)

Ventral peduncle and right fluke insertion (13 Aug 2018 NEA/CWI)

Appendix 1. TERMINOLOGY USED BY NEW ENGLAND AQUARIUM TO DESCRIBE WHALE ENTANGLEMENTS AND ASSOCIATED INJURIES (provided as Supplementary Material for Knowlton et al. 2016 paper)

Entanglement cases were identified either by the presence of gear wrapping any body part of a whale (a gear-based event) or by wrapping wounds and/or scars indicating a prior, unobserved entanglement (a scar-based event). Gear-based events may carry on for years or the gear may be shed by the whale (becoming a scar-based event) or removed through human intervention. In some cases the injuries can be observed to get worse if gear remains attached for a period of time and rope becomes embedded into the tissue due to drag or if the animal is growing.

We assessed two aspects of the severity of each entanglement event. First was the **entanglement injury severity** (this can be assessed in both scar- and gear-based cases) which categorizes the maximum injury severity observed throughout the duration of the entanglement event. Second was the **entanglement configuration risk** which categorizes the nature of the entangling gear (this can only be assessed for gear-based cases). The criteria for these two entanglement severity levels are described along with pictures and drawings below.

Entanglement injury severity

This category was used to describe the maximum injury severity in a given case. To obtain a maximum injury severity for each case, injury severity was categorized for five body areas – head/rostrum, mouth, body, flippers, and tail. For an injury to be attributed to entanglement, it had to show evidence of the rope having "wrapped" on a given body part. For each body area where entanglement injuries were found, they were described as low, medium, or high using the criteria below. The entanglement injury severity level was then defined for the entire animal as **minor, moderate, or severe** and is based on the maximum injury level determined for one or more body areas. For example, if five body areas all had low severity injuries, the entanglement severity level would be deemed minor. If any of the five body areas had a medium or high severity injury, the entanglement severity level for the whale would be moderate or severe accordingly.

LOW SEVERITY

- Injuries or scars in the skin that were less than ~2cm in width and did not appear to penetrate into the blubber.

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MEDIUM SEVERITY

- Injuries or scars that were greater than ~ 2 cm in width, and/or between 2 and ~8 cm in depth. This would include injuries that extend into the blubber (hypodermis layer).

New England Aquarium

HIGH SEVERITY

- Injuries that were greater than ~8 cm in depth and/or are known to extend into bone or muscle.

- This also includes cases of significant deformity or discoloration of fluke or flipper, for example a twisted fluke caused by torquing by rope/gear. A discolored appendage can indicate circulation impairment even in cases in which the entanglement itself is not visible.

Photo courtesy of Florida Fish and Wildlife Conservation Commission

Entanglement configuration risk

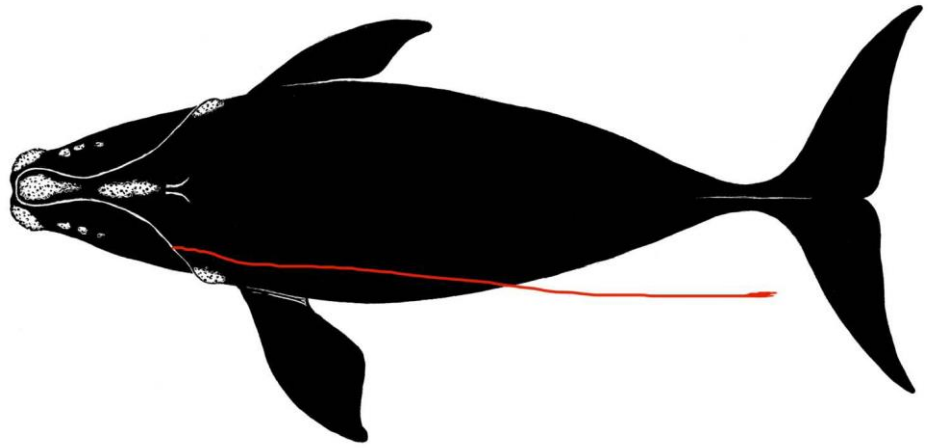
This assessment describes the layout of gear on a whale and does not take into account associated wounds. The configuration of gear on whale is generally used to assess the need for intervention, indicates how the whale may have become entangled, and may be used to make predictions about the fate of the whale if no subsequent sightings are available. For any whale that had fishing gear attached when first observed after an entanglement event, entanglement configuration risk was described as low or high, as described below. It should be noted that entanglements may shift and change over time and whales may be entangled for days to years. Considering this, whales assessed as having low risk entanglement configurations may have had high risk ones prior to discovery, and vice versa.

LOW

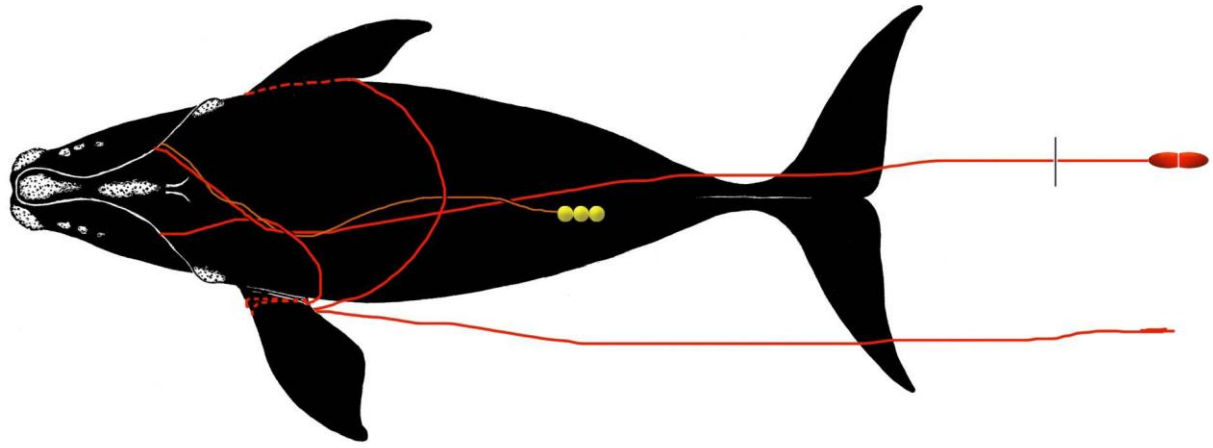
Low risk cases were those involving no tight wraps, only one attachment point, gear trailing less than one body length, and no heavy gear attached. In these cases, gear was often shed.

HIGH

High risk cases were those in which the whale had one or more of the following: at least one tight wrap, multiple contact points with the gear (attachment points: rostrum/mouth, flipper, body, or tail), trailing gear more than one body length, or which appeared to significantly impair or prevent movement. Although successful disentanglement efforts can reduce the configuration risk, the highest configuration risk observed at any point during the duration of the entanglement was assigned to each case.



Low risk entanglement configuration



High risk entanglement configuration

Appendix 2. Table from Knowlton et al. 2012 paper for comparative purposes

Table 1. *Eubalaena glacialis*. Annual tally of animals seen, new entanglement events recorded, and entanglement rates. For the calculation of annual entanglement, an animal was 'adequately seen' if the left, right, or dorsal peduncle was fully seen and well photographed in the given and prior calendar year. The annual entanglement rate was calculated from the number of new entanglements recorded by the second year of the 2 yr period. The serious entanglement rate is the number of events divided by individuals seen. See 'Methods' for details of additional criteria used in the calculation of annual and severe entanglement rates

Year	Crude entanglement			Annual entanglement			Serious entanglement	
	Individuals seen	New entanglements	Rate (%)	Ind. adequately seen over 2 yr	New entanglements	Rate (%)	No. of events	Rate (%)
1980	65	9	13.8				0	0.0
1981	102	20	19.6	6	2	33.3	1	1.0
1982	100	18	18.0	13	2	15.4	0	0.0
1983	76	11	14.5	14	7	50.0	1	1.3
1984	115	14	12.2	19	5	26.3	1	0.9
1985	104	15	14.4	21	5	23.8	1	1.0
1986	152	19	12.5	29	6	20.7	2	1.3
1987	152	13	8.6	25	4	16.0	1	0.7
1988	198	24	12.1	31	6	19.4	0	0.0
1989	205	18	8.8	39	6	15.4	0	0.0
1990	145	29	20.0	46	21	45.7	2	1.4
1991	161	15	9.3	23	7	30.4	0	0.0
1992	131	19	14.5	27	9	33.3	0	0.0
1993	175	20	11.4	29	9	31.0	2	1.1
1994	207	38	18.4	60	16	26.7	5	2.4
1995	220	22	10.0	82	11	13.4	2	0.9
1996	219	42	19.2	86	27	31.4	2	0.9
1997	247	83	33.6	124	46	37.1	6	2.4
1998	219	23	10.5	115	20	17.4	2	0.9
1999	228	57	25.0	106	21	19.8	4	1.8
2000	234	34	14.5	148	20	13.5	7	3.0
2001	278	41	14.7	137	24	17.5	5	1.8
2002[a]	300	45	15.0	133	25	18.2	8	2.7
2003	309	30	9.7	93	15	16.1	4	1.3
2004	281	43	15.3	78	29	37.2	4	1.4
2005	347	62	17.9	133	34	25.6	3	0.9
2006	339	54	15.9	173	44	25.4	2	0.6
2007	376	94	25.0	183	79	43.2	4	1.1
2008	386	71	18.4	211	59	28.0	9	2.3
2009	413	49	11.9	219	42	19.2	8	1.9
Mean (SD)			**15.5 (5.5)**			**25.9 (10.0)**		**1.2 (0.8)**

[a]Fishing gear changes requiring weak links introduced and some seasonal closures enacted

Task 3: Anthropogenic Injury Case Studies

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Introduction

With the advent of web-based technologies, the New England Aquarium (NEAq) and others have made tremendous strides in keeping the right whale community, especially Federal and state managers, apprised of entanglements and vessel strikes in near real-time. These avenues of communication, as described below, have been invaluable for alerting disentanglement teams, necropsy teams, and survey teams as necessary in order to collect appropriate information and to monitor each whales' response to the interaction.
The main avenues of communication that presently exist are:

1) The Center for Coastal Studies (CCS) Atlantic Large Whale Disentanglement Network – this site is used to send near real-time updates of actively entangled whales to a members-only network of potential responders along the eastern seaboard. CCS keeps each whale's page active until such time the whale has been disentangled, the gear has been shed, or the whale has died.
2) PlanEg and DeadEg emails – emails are sent by NOAA Fisheries or others to the PlanEg list (a list of managers and scientists potentially able to be on site or responsible for coordinating or managing a response) as soon as a carcass or an unusual event that could result in a carcass is documented. Near real-time identifications of the individual whales involved in these cases (Task 4 of this report) are disseminated via these lists as soon as they are made. Emails are sent to the DeadEg list, a broader distribution list for those who request to be kept apprised of such cases once the initial retrieval and necropsy planning effort is complete.
3) APB emails – this is a Google group set up by invitation only and initiated and managed by NEAq to alert survey teams and managers about any right whale that has severe injuries from any cause and/or looks in poor condition. Survey teams are asked to send any recent images to NEAq for monitoring purposes.
4) Serious Injury/Human Impact Report – every six months, a report on the addition of new entangled, vessel struck, or severely injured right whales as well as the status of existing cases of compromised individuals is compiled by NEAq and provided to NOAA Fisheries and the right whale community. The goal of these reports is to ensure that all right whales that show declining health, or could exhibit a decline, from their injuries are closely monitored and that annual estimates of human induced mortality and serious injury are as accurate as possible

All of the above efforts provide a valuable mechanism for NOAA Fisheries to maintain their annual serious injury determination reports and to keep the right whale community apprised of emerging issues.

Objectives and methods

The case study approach was initially developed in tandem with a study looking at rope strengths during which it was noted that there was no easy way to show fishermen and others the nature and impacts of entanglements (Knowlton et al. 2016). The goal of the case studies is to provide a

consolidated two-page summary report for each individual whale providing a clear visual depiction of the entangling gear configuration or vessel strike injuries using a drawing, details about the life history of each individual including sex, age when detected with the human impact, reproductive status, and, for entanglements, the minimum and maximum durations when gear was known or estimated to be attached. These durations use data through 2019 and reflect the minimum number of days observed with gear attached and the maximum number of days that the gear could have been attached (calculated as time from date seen prior to either date with line gone if it exists or last date seen with gear attached). In addition, the status of the individual at the present time and any other pertinent information about the human impact, such as rope parameters or vessel size estimates, is provided on the first page of each case study. Under the status category, we have noted whether the whale is considered Alive, Presumed Dead, Likely Dead or Dead. We have used the term "Likely Dead" to refer to cases with no subsequent sightings (but not yet deemed "Presumed Dead") with either a life threatening gear configuration risk or severe injuries that seemed more likely to lead to compromised health and likely death. The second page includes a suite of photographs showing the entanglement or vessel strike injuries.

Initially, 30 case studies were developed for the Knowlton et al. (2016) paper for entangled right whales with retrieved and analyzed fishing gear collected from 1994-2009 (and one case in 2010). With the funding provided by NMFS/NEFSC under this Task, we have continued the development of entanglement case studies for all right whales seen with attached gear independent of whether gear was collected or not. These case studies, from 1981 to the present are now posted at www.bycatch.org under the Research Programs tab and are updated each year. With the addition of the 2018 events, there are now 130 case studies posted.

For 2018, we have created six entanglement case studies. Drawings of three of these six cases are in progress; drawings were not able to be done for the other three cases as photographs of the entanglement were inadequate to fully understand the configuration. We also reviewed nine whales that had severe entanglement injuries and no attached gear. We did not do case studies for these animals; instead, we included pertinent information about their life history and condition along with images of their injuries under Task 2.

In addition, we have continued to create vessel strike case studies and present three case studies for the 2018 timeframe. No forensic assessments were done for these whales although an evaluation by A. Knowlton based on previous work done by Dr. Alex Costidis suggest that these strikes were likely caused by smaller vessels under 40 feet in length. It should be noted that any future forensic vessel strike assessments should be directly requested from Dr. Costidis by NOAA Fisheries as he would need funding to create a detailed case report that managers can then use for their management needs.

A summary of these cases is presented in Appendix 1b with case studies provided in Appendix IIb.

<u>Future steps</u>

We have determined that these case studies are particularly informative several years after the entanglement/injury event as they provide not only details about the event itself, but also some indication of the health, survival, and reproductive consequences of that event. For this reason, we will continue to create new case studies which coincide with the year for which the scar coding will be conducted. We will also update the status of individual whales in all previously created case studies in order to assist NMFS with their pro-rating efforts that are used in their serious injury determinations (see http://www.nmfs.noaa.gov/pr/pdfs/serious_injury_procedure.pdf). These updated case studies will continue to be posted at www.bycatch.org.

References

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

Appendix Ia. List of s newly completed cases studies for right whale entanglements in whale number order

EGNO	Age	Sex	Retrieved Gear?	Country of origin/gear type	Date first observed entangled	Date observed prior without injuries
2310	25+	Male	No	Unknown	20 Dec 2018	(12 Apr 2018)
3312	15	Male	No	Canada/Unknown	13 Jul 2018	(13 Jul 2018)
3843	10	Male	No	Unknown	30 Jul 2018	(7 Jun 2018)
3893	10	Female	Yes	Canada/Snow crab	22 Jan 2018	(29 Jul 2017)
3960	9	Male	No	Canada/unknown	20 Aug 2018	(6 Aug 2018)
4091	8	Female	No	US/unknown	12 May 2018	(6 May 2018)

Appendix Ib. List of three newly completed case studies for right whale vessel strikes

EGNO	Age	Sex	Country of origin	Estimated general vessel size	Date first observed with injuries	Date observed prior without injuries
3912	9	Female	Unknown	Small (<40 ft)	21 Apr 2018	(17 Apr 2017)
4145	7	Male	Unknown	Small (<40 ft)	1 Mar 2018	(28 Apr 2017)
4612	2	Female	Unknown	Small (<40 ft)	10 Jul 2018	(24 Apr 2017)

Appendix IIa. Right whale anthropogenic entanglement case studies provided on the following pages.

Species	Right Whale	Whale ID	2310

Date first observed entangled (date seen prior without gear)			20 Dec 2018 (12 Apr 2018)		
Sex	Male	Birth year		Age at entanglement	25+

Case study ID	CCS	NMFS	GEAR ID
	WR-2018-51	E48-18	
Gear sample collected?	No	Gear type	Unknown

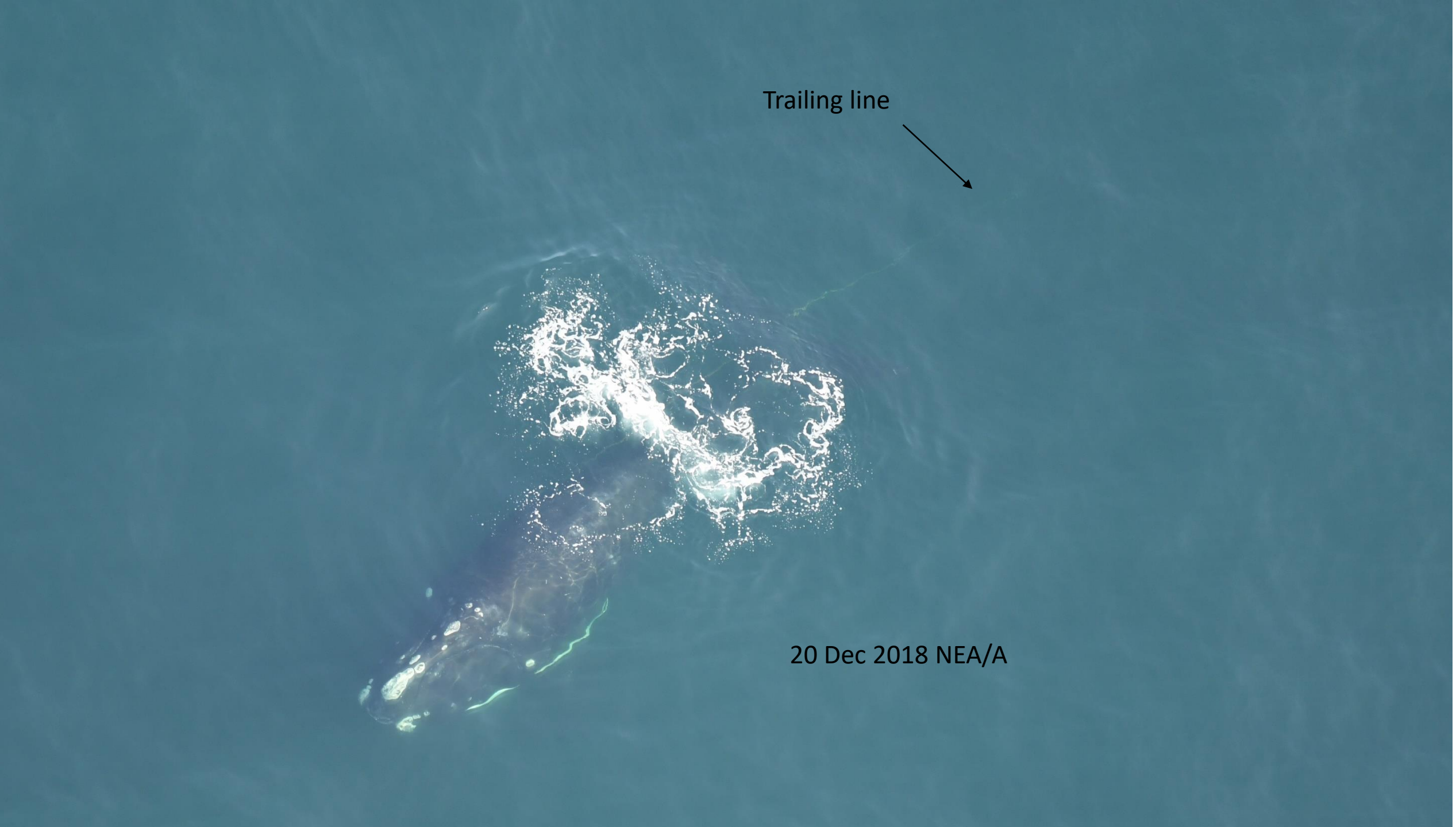
Photographs inadequate to determine complete entanglement configuration - no drawing available

Reproductive prior to/after entanglement detection					
Entanglement injury severity				Severe (due to duration)	
Entanglement configuration risk				High	
Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	Unknown	None	Unknown	None	Low
Duration of time carrying gear		Minimum 126 days, maximum unknown			
Disentangled?		No			
Status		Alive, last seen in 2019 still entangled			
Number of prior entanglements		0			

Entanglement configuration	Single line through mouth and trailing 1-2 body lengths on right side before sinking out of sight
Anchoring points	Mouth
Gear configuration confidence	High
Remaining questions	Length of trailing gear uncertain; rope shifted to bridle
Comments	Whale showing signs of decline at last sighting; long duration with gear

Polymer type		
Gear component		Unknown
Rope diameter (inches)		
Breaking strength (lbs)	Tested	
	New	

This case study was developed at the New England Aquarium with financial support from NOAA Fisheries. Whale data were provided by the North Atlantic Right Whale Consortium (www.narwc.org). All images are listed with appropriate credit information and taken under permit. Retrieved gear is assessed and archived by NOAA Fisheries. Entanglement diagrams courtesy of S. Landry, Center for Coastal Studies. Please contact Amy Knowlton (aknowlton@neaq.org) for potential use.


Trailing line
20 Dec 2018 NEA/A

Species	Right Whale	Whale ID	3312

Date first observed entangled (date seen prior without gear)			13 Jul 2018 (13 Jul 2018)		
Sex	Male	Birth year	2003	Age at entanglement	15

Case study ID	CCS	NMFS	GEAR ID
	WR-2018-09	E10-18	
Gear sample collected?	No	Gear type	Canadian unknown

Drawing in progress

Reproductive prior to/after entanglement detection					
Entanglement injury severity	Moderate				
Entanglement configuration risk	High				
Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	Low	None	Low	Low	Medium
Duration of time carrying gear	Minimum 1 day, maximum unknown				
Disentangled?	No				
Status	Alive? Not seen since 13 Jul 2018				
Number of prior entanglements	3				

Entanglement configuration	Single line through mouth and trailing several body lengths on both sides
Anchoring points	Mouth
Gear configuration confidence	High
Remaining questions	Unclear if bottom gear attached to line
Comments	Agitated, fresh blood, seen earlier in the day gear free

Polymer type		
Gear component		Buoy line
Rope diameter (inches)		
Breaking strength (lbs)	Tested	
	New	

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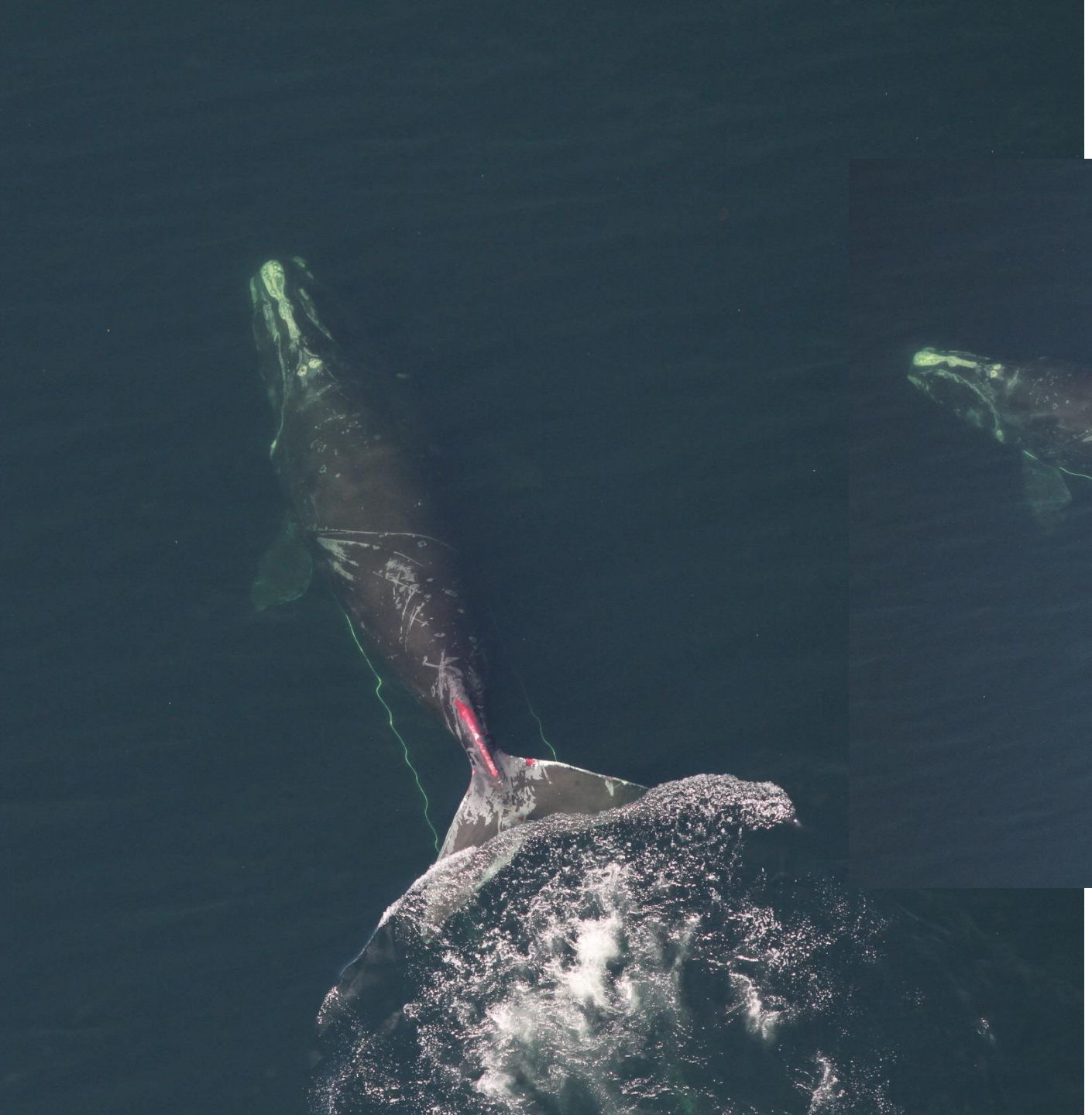

13 Jul 2018 NEFSC

Species	Right Whale	Whale ID	3843

Date first observed entangled (date seen prior without gear)			30 Jul 2018 (7 Jun 2018)		
Sex	Male	Birth year	2008	Age at entanglement	10

Case study ID	CCS	NMFS	GEAR ID
	WR-2018-18	E20-18	
Gear sample collected?	No	Gear type	Unknown

Photographs inadequate to determine complete entanglement configuration - no drawing available

Reproductive prior to/after entanglement detection					
Entanglement injury severity	Severe				
Entanglement configuration risk	High				
Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	Low	High	Unknown	Unknown	High
Duration of time carrying gear	Minimum 153 days, maximum 205 days				
Disentangled?	Yes, partial				
Status	Alive, last seen in 2019				
Number of prior entanglements	1				

Entanglement configuration	Rope thru mouth,across front rostrum; line with low drag buoy trailing ~ 1 body length; line likely weighted below whale
Anchoring points	Mouth
Gear configuration confidence	Low
Remaining questions	Unsure if rostrum wrap remains
Comments	Small amount of gear remains at left mouth; condition improving

Polymer type		
Gear component		Buoy line
Rope diameter (inches)		
Breaking strength (lbs)	Tested	
	New	

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30 Jul 2018 NEA

30 Jul 2018 GMWSRS

30 Jul 2018 GMWSRS

Species	Right Whale	Whale ID	3893

Date first observed entangled (date seen prior without gear)			22 Jan 2018 (29 Jul 2017)		
Sex	Female	Birth year	2008	Age at entanglement	10

Case study ID	CCS	NMFS	GEAR ID
	WR-2018-01	E20-18	
Gear sample collected?	Yes	Gear type	Canadian snow crab

Drawing in progress

Reproductive prior to/after entanglement detection	No/ --
Entanglement injury severity	Severe
Entanglement configuration risk	High

Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	High	High	High	High	Unknown

Duration of time carrying gear	Minimum unknown, maximum 176 days
Disentangled?	No
Status	Dead
Number of prior entanglements	3

Entanglement configuration	Multiple wraps thru baleen, over rostrum, around body and flippers; carcass decomposed
Anchoring points	Mouth, flippers
Gear configuration confidence	High
Remaining questions	
Comments	Carcass retrieved; ~271 ft of line removed at necropsy

Polymer type		Copolymer with lead strand in sections
Gear component		Buoy line
Rope diameter (inches)		5/8
Breaking strength (lbs)	Tested	
	New	9,000

This case study was developed at the New England Aquarium with financial support from NOAA Fisheries. Whale data were provided by the North Atlantic Right Whale Consortium (www.narwc.org). All images are listed with appropriate credit information and taken under permit. Retrieved gear is assessed and archived by NOAA Fisheries. Entanglement diagrams courtesy of S. Landry, Center for Coastal Studies. Please contact Amy Knowlton (aknowlton@neaq.org) for potential use.

26 Jan 2018 VAQF

28 Jan 2018 VAQF

Species	Right Whale	Whale ID	3960

Date first observed entangled (date seen prior without gear)			20 Aug 2018 (6 Aug 2018)		
Sex	Male	Birth year	2009	Age at entanglement	9

Case study ID	CCS	NMFS	GEAR ID
	WR-2018-29	E30-18	
Gear sample collected?	No	Gear type	Canadian unknown

Photographs inadequate to determine complete entanglement configuration - no drawing available

Reproductive prior to/after entanglement detection					
Entanglement injury severity	Severe				
Entanglement configuration risk	High				
Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	High	Low	None	None	High
Duration of time carrying gear	Minimum 1 day, maximum 13 days				
Disentangled?	No				
Status	Alive, last seen in 2019				
Number of prior entanglements	0				

Entanglement configuration	Multiple lines thru mouth,. over rostrum,, around body and tail stock; fresh blood at tail
Anchoring points	Mouth,, flukes
Gear configuration confidence	Low
Remaining questions	Weight attached? Gear shed during observation
Comments	Damaged baleen; whale thrashed for 2+ hours

Polymer type		
Gear component		Buoy line and unknown (multiple ropes involved)
Rope diameter (inches)		Larger diameter
Breaking strength (lbs)	Tested	
	New	

This case study was developed at the New England Aquarium with financial support from NOAA Fisheries. Whale data were provided by the North Atlantic Right Whale Consortium (www.narwc.org). All images are listed with appropriate credit information and taken under permit. Retrieved gear is assessed and archived by NOAA Fisheries. Entanglement diagrams courtesy of S. Landry, Center for Coastal Studies. Please contact Amy Knowlton (aknowlton@neaq.org) for potential use.

20 Aug 2020 NEA

Species	Right Whale	Whale ID	4091

Date first observed entangled (date seen prior without gear)			12 May 2018 (6 May 2018)		
Sex	Female	Birth year	2010	Age at entanglement	8

Case study ID	CCS	NMFS	GEAR ID
	WR-2018-03	E04-18	
Gear sample collected?	No	Gear type	US unknown

Drawing in progress

Reproductive prior to/after entanglement detection	No/ No
Entanglement injury severity	Minor
Entanglement configuration risk	Low

Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	None	None	Low	None	Low

Duration of time carrying gear	Minimum 1 day, maximum 250 days
Disentangled?	No
Status	Alive, last seen in 2019
Number of prior entanglements	3

Entanglement configuration	Single line wrapped on right flipper, trailing 50 ft, bullet buoy on right side of body
Anchoring points	Flipper
Gear configuration confidence	High
Remaining questions	Gear shed
Comments	Occurred between Cape Cod Bay and Great S. Channel

Polymer type		
Gear component		Buoy line
Rope diameter (inches)		
Breaking strength (lbs)	Tested	
	New	

This case study was developed at the New England Aquarium with financial support from NOAA Fisheries. Whale data were provided by the North Atlantic Right Whale Consortium (www.narwc.org). All images are listed with appropriate credit information and taken under permit. Retrieved gear is assessed and archived by NOAA Fisheries. Entanglement diagrams courtesy of S. Landry, Center for Coastal Studies. Please contact Amy Knowlton (aknowlton@neaq.org) for potential use.


12 May 2018 NEFSC

Appendix IIb. Right whale anthropogenic vessel strike case studies provided on the following pages.

Species	**Right Whale**
Whale ID #	**3912**
Necropsy/Other ID #	

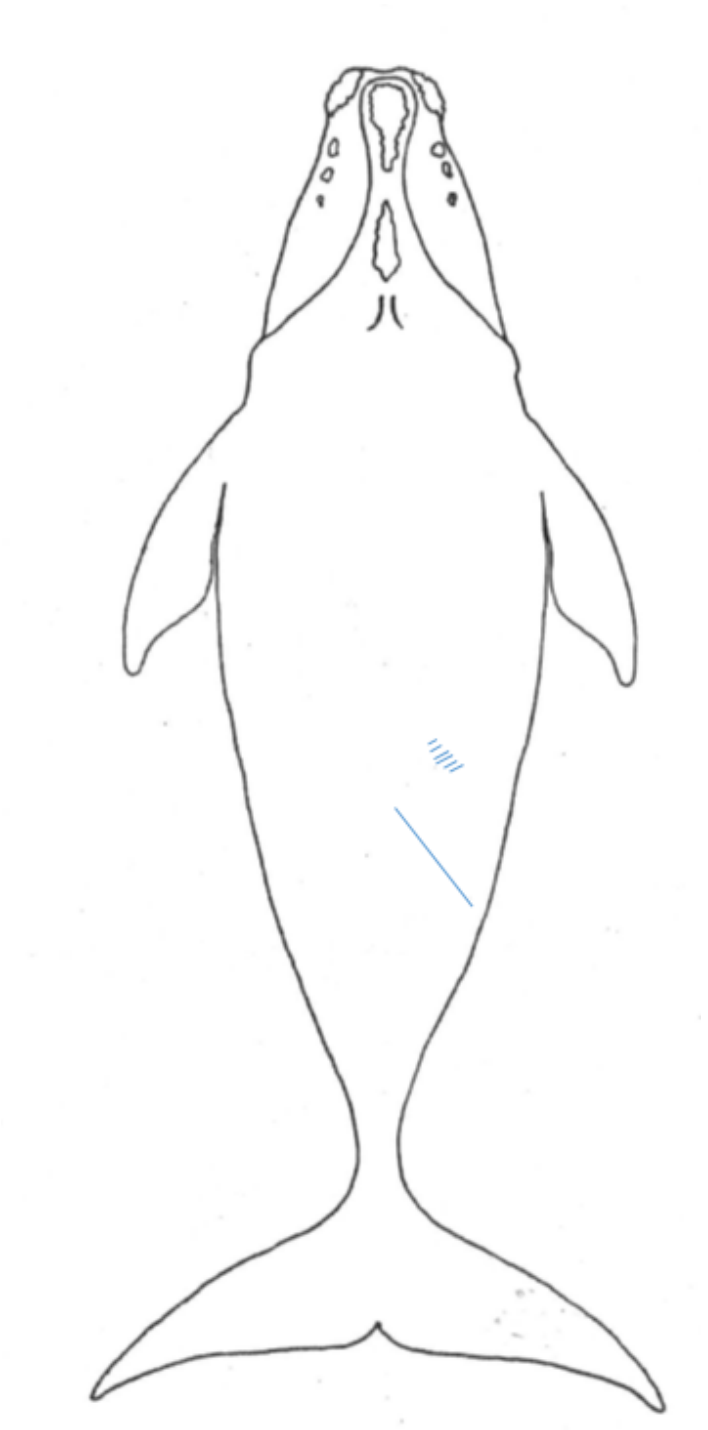
Sex	Female
Birth Year	2009

Age at Detection w/ Injury	9
Date First Detected w/ Injury	21 Apr 2018
Date Seen Prior w/o Injury	(17 Apr 2017)

Reproductive Prior Injury Detection	No
Reproductive After Injury Detection	No

Relative Wound Depth	Superficial
Body Region(s) With Injury	Body
Description of Injury	Propeller cuts
Status/Year Last Seen	Alive
MMPL Vessel Size Category	
Vessel Size Range	Analysis has not been done but likely <40 feet
Max Wound Length (cm)	

Vessel Related Comments	Six superficial healed propeller cuts on right flank.
Whale Related Comments	



This case study was developed at the New England Aquarium with financial support from NOAA Fisheries. Whale data were provided by the North Atlantic Right Whale Consortium (www.narwc.org).


27 Apr 2018 CCS

Species	**Right Whale**
Whale ID #	**4145**
Necropsy/Other ID #	

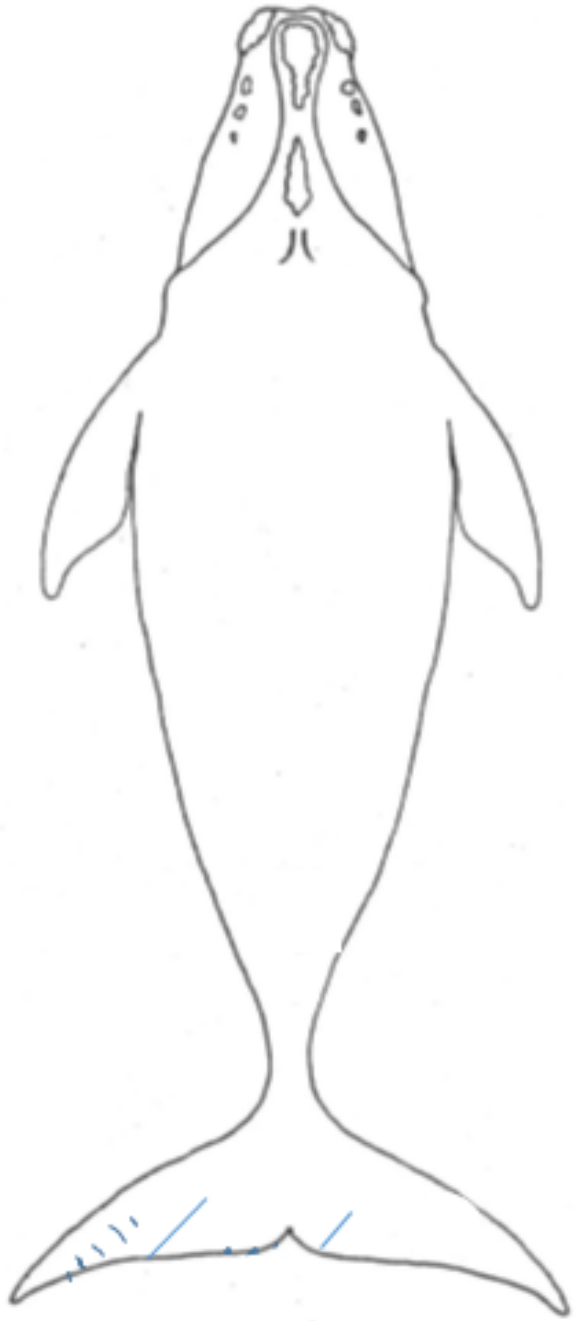
Sex	Male
Birth Year	2011

Age at Detection w/ Injury	7
Date First Detected w/ Injury	1 Mar 2018
Date Seen Prior w/o Injury	(28 Apr 2017)

Reproductive Prior Injury Detection	
Reproductive After Injury Detection	

Relative Wound Depth	Shallow
Body Region(s) With Injury	Tail
Description of Injury	Propeller cuts
Status/Year Last Seen	Alive
MMPL Vessel Size Category	
Vessel Size Range	Analysis has not been done but likely <40 feet
Max Wound Length (cm)	

Vessel Related Comments	Two series of superfial to shallow healed propeller cuts on left dorsal fluke lobe. One of the cuts punctures through the fluke near the trailing edge. Superficial line scar adjacent and to the right of each cut series.
Whale Related Comments	



This case study was developed at the New England Aquarium with financial support from NOAA Fisheries. Whale data were provided by the North Atlantic Right Whale Consortium (www.narwc.org).

1 Mar 2018 NEFSC

Species	**Right Whale**
Whale ID #	**4612**
Necropsy/Other ID #	

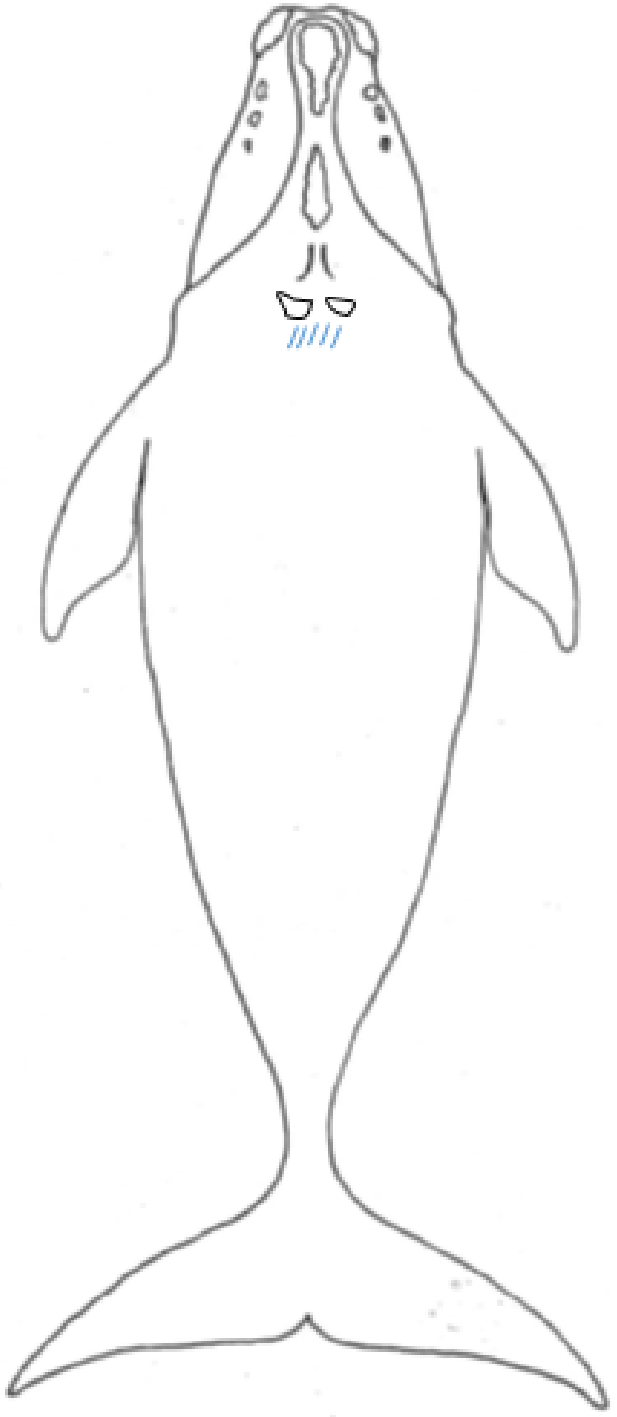
Sex	Female
Birth Year	2016

Age at Detection w/ Injury	2
Date First Detected w/ Injury	10 Jul 2018
Date Seen Prior w/o Injury	(24 Apr 2017)

Reproductive Prior Injury Detection	
Reproductive After Injury Detection	

Relative Wound Depth	Superficial
Body Region(s) With Injury	Head (just aft of blowholes)
Description of Injury	Propeller cuts
Status/Year Last Seen	Alive
MMPL Vessel Size Category	
Vessel Size Range	Analysis has not been done but likely <40 feet
Max Wound Length (cm)	

Vessel Related Comments	Five superficial healed propeller cuts aft of blowholes
Whale Related Comments	Whale had poor skin condition and orange cyamids on the body but unsure if this is related to vessel strike or an entanglement interaction also detected in this sighting batch.



This case study was developed at the New England Aquarium with financial support from NOAA Fisheries. Whale data were provided by the North Atlantic Right Whale Consortium (www.narwc.org).


11 Jul 2018 NEFSC

Task 4: Near Real-Time Matching for Biopsy Efforts, Entangled, Injured, Sick, or Dead Right Whales

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Objectives

The goals of this work were to provide near real-time matching for biopsy efforts, entangled, injured, sick, or dead right whales sighted from September 1, 2019 to August 30, 2020. The biopsy portion of this task initially focused primarily on the southeast U.S., but has since expanded. This year, the COVID 19 pandemic interrupted much of the biopsy effort; there was dedicated biopsy efforts on the calving ground off the southeastern U.S. and one team collected samples in the Gulf of St. Lawrence. Work in Cape Cod Bay and in the Gulf of St. Lawrence by our team was suspended and, while there was some effort in the Bay of Fundy in the summer, no right whales were seen by our team. Providing near real-time identifications for biopsy efforts allows researchers to determine high value targets for genetic sampling, minimize duplicate darting, and focus their photographic efforts on specific features to aid in particularly challenging identifications. The near real-time matching provides information on the last time a sick, injured or dead whale was seen alive/healthy/gear-free, potentially indicating where the harmful event took place. It also allows necropsy teams to be alerted to any individual-specific data that should be collected from dead whales. Finally, near real-time matching of entangled whales also provides individual sighting histories and age, which informs the decision of whether to intervene with entanglements, and whether genetic sampling should be undertaken if an intervention occurs.

Results

Matching for reproduction and biopsy efforts: Southeast U.S. and the feeding grounds
A list of females available to calve during the 2019/2020 season was sent to all survey teams on November 22, 2019, along with a list of all right whales that needed to be biopsied (i.e. need to have a skin sample collected for genetic analysis). Further, the newly exported E Catalog file was posted to both a Google Drive and Dropbox folder on November 12, 2019 and an email sent to team leaders to download it. For those who preferred to bypass a large download, the E Catalog was hand delivered to them on an external hard drive at the North Atlantic Right Whale Consortium meeting in Portland, ME on November 14 and 15, 2019.

For the southeast, images of 25 unique whales were reviewed. We were able to match/confirm 21 to currently cataloged whales and four to calves from 2019 which will be cataloged in the near future. A record of each identified whale is included in Appendix I, including age, sex, the specific sighting that was reviewed for identification purposes, the date that identification was confirmed, and whether the whale still needed to be darted at the end of the season. Eight of the ten calves of the year were biopsied on the calving ground (one was fatally injured and the other was seen only briefly). Aside from the mother/calf pairs, none of the other 15 whales needed to be biopsied, but two were biopsied before we determined who they were. A list of biopsied animals is included as Appendix II.

Our usual rapid matching work to support for darting efforts in Cape Cod Bay and the Gulf of St Lawrence was mostly suspended this year due to the COVID 19 pandemic. In Cape Cod Bay, the joint Northeast Fisheries Science Center/New England Aquarium (NEAq) biopsy effort was canceled, as was NEAq's photo-identification support of the Woods Hole Oceanographic Institution photogrammetry work since that work was canceled as well. In the Gulf of St.

Lawrence, the work of the Mingan Island Cetacean Studies (MICS) and NEAq/Canadian Whale Institute teams, which are usually the only two teams permitted and able to biopsy right whales in the Gulf, were both canceled due to COVID concerns or restrictions. We did supply near real time matching assistance to Nick Hawkins, a photo journalist who was one of only two vessel-based efforts in the Gulf in 2020. We matched 94 sightings of 51 different individuals including a 38-year-old male from which he collected a fecal sample for hormone analyses. It is also thanks to this matching effort that we were able to make a very challenging match to an entangled whale in October 2020. The match to four-year-old #4680, seen entangled off the New Jersey coast on October 11, could only be made using very small marks visible only in photographs from Nick Hawkins that we had identified during this near real-time matching work.

We also provided rapid matching assistance to the Canadian Department of Fisheries and Oceans (DFO) aerial survey effort- primarily in the beginning of the season. Finally, we provided a fecal sample collection kit, the E Catalog, and matching training for the DFO team aboard the *R/V Coriolis*, the other vessel-based right whale research team in the Gulf. Their work focused on attaching telemetry tags (DTAGS) and collecting UAV/drone imagery and breath and biopsy samples from right whales. Due to poor offshore Internet connection, the team was not able to supply us with any images, so we were unable to assist their efforts further.

We hope and anticipate that field efforts, including darting and the need for real time matching for that work, will resume in 2021.

Entangled or Entrapped Whales

During this contract period, there were four reports of newly entangled live right whales, and no previously entangled or entrapped right whales (Table 1). One of the reported entangled whales was in fact not entangled and we could not determine whether another was in fact entangled. These cases are described in the discussion.

Table 1. List of four newly entangled or entrapped whales that were first reported between September 1, 2019 and August 31, 2020 for which matching attempts or confirmations were made quickly. One of the reports was incorrect (the whale was gear-free) and one could not be confirmed.

Date	Incident	ID	Location and comments	ID Date	Darted previously?
12/21/19	First entangled	3466	Southeast of Nantucket	12/21/19	Yes
02/09/20	Reported as entangled	Unk	Off North Carolina		Unk
02/24/20	First entangled	3180	Southeast of Nantucket	02/24/20	Yes
07/18/20	Reported as entangled, was not	3333, 1307	Gulf of St Lawrence	08/18/20	Yes

All identifications were made as soon as possible and those identifications were relayed to all relevant parties as soon as they were confirmed.

Dead Whales

During this contract period, matching efforts were made on two dead right whales (Table 2).

Table 2. List of matching efforts on two sightings of dead whales that were first reported between September 1, 2019 and August 31, 2020.

Date	Incident	ID	Location and comments	ID Date	Darted previously?
09/16/19	Dead	1226	Off Long Island	9/18/2019	Yes
06/25/20	Dead	2020 calf of 3560	Off New Jersey	06/27/20	Yes

Injured or Sick Whales

In addition to the entangled whales above, there were two sightings of injured or sick whales for which rapid identification attempts were made during the reporting period (Table 3). Both were calves of the year: one was a fatal vessel strike (though no carcass was found) and the second was an injury of unknown cause that appeared to be superficial.

Table 3. List of sick or injured whales, other than those seen entangled in fishing gear, that were reported between September 1, 2019 and August 31, 2020 and were rapidly identified, or for which a significant effort was made to identify them rapidly.

Date	Incident	ID	Location and comments	ID Date	Darted previously?
01/08/20	Injured	2020 calf of 2360	Off Florida, many deep prop cuts to head	01/09/20	No
02/29/20	Injured	1017	Cape Cod Bay, 25+ minor propeller cuts down right flank	03/03/30	Yes
04/05/20	Injured	4539	Cape Cod Bay, propeller cut to blowhole	04/06/20	Yes
07/16/20	Injured	2020 calf of 3101	Gulf of St Lawrence, two wounds on right side, cause unknown	07/17/20	Yes

Opportunistic Sightings

Although not specifically part of our contract, we attempt to match any opportunistic sighting as soon as possible, especially mother/calf pairs or sightings from unusual locations or times of year. We received over 100 opportunistic sightings during this contract period. Some of the interesting rapid match results for these sightings include:

1) A one year old right whale, the 2019 calf of 2791, less than 100 meters from Eastport, ME on July 21, 2020;
2) A one year old right whale, the 2019 calf of 2503, breaching close to Long Island, ME, south of Mt Desert Island on August 9, 2020;
3) Lacrosse (#1249) seen off Brier Island, N.S. on August 20, 2020. He was the only photographed right whale in the Bay of Fundy in 2020! He had been in the Gulf of St Lawrence from June 16 through August 1;

4) A sighting from land of Calvin (#2223) and her calf on April 12, 2020- the first sighting of the pair up north and the only sighting around the Cape;
5) Mother #3560 and her calf during their month-long excursion into the Gulf of Mexico In February and March of 2020.

Discussion

Our matching support for the calving ground included the match or confirmation of 25 animals (Appendix I) and 10 darting events (Appendix II). One surprise this year was the presence of four of the seven calves from last year. While young juveniles were frequently seen in the region in the 2000's, they have been seen infrequently in this decade. One-year-old animals are always challenging to identify, but it has become even more difficult in recent years. Due to distribution shifts related to climate change, calves are seen less frequently in the spring and summer when their callosity patterns have developed more, and juveniles are also seen less frequently throughout the whale's range- not just off the southeast U.S. The high quality images from the southeast of these four yearlings this year allowed for the identification and ensure that these whales will be easy to catalog and re-identify going forward. Two of the 10 darted whales had been darted before. Because of the aforementioned challenge of cataloging calves recently, we encourage teams to biopsy any young looking whale if they can't identify it immediately. This does lead to occasional duplicate samples as was the case for the two whales this year, but those samples can still be useful. Duplicate samples have been very effective in looking for any photo-identifications errors in the Catalog in the past (Frasier et al. 2009).

Sadly, three of the rapid identifications were calves of the year that were either injured or dead. The calf of 2366 was intentionally not darted because it was so severely injured. To have 30% of the known calves injured within the first eight months of life is unprecedented, and unfortunate.

Both of the dead whale identifications were challenging. All the skin and much of the callosity tissue, as well as the fishing ropes that had entangled him, were gone by the time the carcass of Snake Eyes (#1226) was discovered. We had to use hard-to-detect marks and patterns to identify the carcass including the indentations where the line had gone through his mouth and over his head, the remains of the mandibular callosities, and the indent from an old wound on the left ventral body aft of the penis. The calf of #3560 was challenging because it was just six months old and the callosity was still developing. Also, all the images of this whale had not been processed. Katie Jackson of Florida Fish and Wildlife Research Institute made the initial match using images from the southeast and we were able to confirm them based on two small white scars on either side of the head near the blowholes.

Two of the reported entanglement cases are worth discussing. The report of an entanglement on February 9, 2020 was made by a fisherman who described the whale as entangled in either red buoys and/or in life jacket(s). There are only a few, poor-quality images and no entanglement is visible. The whale does have a large, bright white scar going over the blowholes and may be entangled, but neither our team, nor the Center for Coastal Studies team, could determine that. The case of the whale reported as entangled on July 18, 2020 is an interesting one. There was good aerial video taken of the incident which allowed us to piece together why the observer mistakenly reported one of the two whales as entangled. We reviewed the video promptly and

determined that it was two adult males, #1307 and #3333, exhibiting the head push behavior- a somewhat common behavior that is often associated with the underwater gunshot sound that some right whales produce. It is easy to interpret such behavior as a whale in distress as it can look like the whale is struggling at the surface, and their breathing pattern is different than a normal pre-deep-dive pattern. With the lens of a whale in distress, the observers then misinterpreted the extensive white scarring on the peduncle of one whale when it was underwater and behind the whale on the surface as a white buoy being towed behind the surface whale. It was an understandable mistake and we commend the observers for being so attentive.

In past years, the discussion would include details about the biopsy efforts on the feeding grounds. In 2020, the DFO team on the *R/V Coriolis* were the only ones able to collect biopsy samples outside of the calving ground and those images have yet to be submitted or uploaded to a Google drive.

Some research teams make their own matches in the field and many of those matches are accurate. However, near real-time matching is still important. A good example of this occurred in 2012 when a research team found a mother/calf pair offshore. The mom appeared to match a known cow, but not one that was known to have calved that year. The team biopsied the calf, knowing it could not have been previously sampled, but did not biopsy the mother since she was known to have been darted. Once we reviewed the images, we discovered that the mother was new to the Catalog (she looked very much like the cataloged whale the team believed her to be) and should have been biopsied as well. In this particular case, near real-time matching actually would not have helped, as the pair was never seen again. But if that had happened in any of the well-studied habitats with focused biopsy efforts, the error could likely have been rectified. This particular whale has not been seen since and still needs to be genetically sampled.

Support for real-time matching has proven to be an important means for identifying whales that need to be biopsied and also to identify dead and injured whales. It ensures that the efforts of all teams are more efficient as the right whale community continues to work collaboratively and diligently to learn all we can about this small and critically endangered population.

Acknowledgements

In the Southeast U.S., the following people contributed images and responded to questions and requests for additional images or information: Katie Jackson and Jen Jakush (Florida Wildlife Research Institute), Clay George and Trip Kolkmeyer (Georgia Department of Natural Resources), and Melanie White (Clearwater Marine Aquarium Research Institute). As in the past, the high level of cooperative responsiveness made the near real-time matching effort possible. In other regions, many researchers responded quickly to requests for images and data. The list is too long to mention everyone, but we particularly want to mention Tim Cole, Leah Crowe, and Allison Henry (Northeast Fisheries Science Center); Brigid McKenna (Center for Coastal Studies); Orla O'Brien (New England Aquarium); Christian Ramp (Mingan Island Cetacean Studies); Liz Thompson, Mylene Dufour, and Stephanie Ratelle (Department of Fisheries and Oceans, Canada); Nick Hawkins; Shelley Lonergan (Brier Island Whale and Seabird Cruises); Laura Howes (Boston Harbor Cruises); Danielle Dion (Quoddy Link Marine); and Andrew Westgate and Laurie Murison (Grand Manan Whale and Seabird Research Station).

References

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

Appendix I. List of 25 unique whales photographed in and around the southeast U.S. and reviewed by NEAq.
If a whale still needed to be biopsied for a genetic sample ("darted") at the end of the season, it is highlighted in grey.

Moms

Count	Whale ID	Age	Last calf	Mom darted?	Calf darted?	Comments	Confirmed sighting	Date confirmed
1	1612	34+	2013	Y	Y	Calf born between 12/23 and 12/30	2019-12-23-FWRI-A	23-Dec-19
2	1970	31+	2009	Y	Y		2020-01-08-CMAR Eg B	09-Jan-20
3	2223	18	2015	Y	Y	Off Wrightsville Beach, NC with another. Calf first seen 2/3/20	2019-12-15-DRHE*	16-Dec-19
4	2360	27+	2010	Y	N	Calf with prop wound on head at first sighting	2020-01-08-FWRI-A Eg A	09-Jan-20
5	2642	24	2010	Y	Y	Calf first seen 2/3/20	2020-01-02-FWRI-A Eg E	03-Jan-20
6	3101	19	2016	Y	Y	Calf born between 12/10 and 1/2	2019-11-23 News	25-Nov-19
7	3115	19	2016	Y	Y	Images sent to us 12/02/19, calf first seen 1/24/20	2019-11-30-JESH*	03-Dec-19
8	3290	18	2009	Y	N	Calf first seen 2/3/20	2020-01-01-FWRI-A E gE	02-Jan-20
9	3546	15	2014	Y	Y	Calf seen at first sighting	2020-01-25-FWRI-A Eg A	26-Jan-20
10	3560	15	NA	Y	Y	30 m off Sapelo Island; first time mom; calf born between 11/26 and 12/16, pair went to Pensacola, FL in the Gulf of Mexico	2019-12-16-CWMA	16-Dec-19

Appendix I (cont.)

Other whales

Count	Whale ID	Age	Sex	Darted?	Comments	Confirmed sighting	Date confirmed
1	1245	38	F	Y	Hilton Head, SC then GA 2/5	2019-11-27-Michalov	28-Nov-19
2	2040	30	F	Y	First off Savannah, GA, off Brunswick, GA on 1/6/20, off Nantucket, MA 2/20/20	2019-11-26-Michalov	27-Nov-19
3	2753	23	F	Y	Hilton Head, SC then GA 2/5	2019-11-27-Michalov	28-Nov-19
4	3343	17	M	Y		2019-12-28-CMAR Eg B	29-Dec-19
5	3617	14	M	Y	South Nags Head, NC, then GA	2020-01-15-Opportunistic	16-Jan-20
6	3623	14	M	Y		2020-01-27-CMAR Eg A	28-Jan-20
7	3680	14	M	Y		2020-03-09-CMAR Eg A	10-Mar-20
8	3714	13	M	Y		2020-01-16-FWRI-A Eg A	19-Jan-20
9	3960	11	M	Y		2020-01-02-FWRI-A Eg C	03-Jan-20
10	4501	5	M	Y		2020-01-02-FWRI-A Eg D	03-Jan-20
11	4617	4	F	Y	Darted 1/2/20	2020-01-02-GDNR Eg A	02-Jan-20
12	2019 Calf Of 1204	1	U	Y	Darted 1/16/20	2020-01-16-FWRI-V Eg A	17-Jan-20
13	2019 Calf Of 2503	1	U	Y		2020-01-29-CMAR Eg-B	30-Jan-20
14	2019 Calf Of 2791	1	F	Y		2020-02-18-Opportunistic	20-Feb-20
15	2019 Calf Of 3270	1	U	Y		2020-02-04-MRC	05-Feb-20

Appendix II. List of 10 right whales biopsied off the southeastern U.S. from December 1, 2019 to March 31, 2020.

Count	Whale	Biopsied as:	Date Confirmed
1	4617	2020-01-02-GDNR Eg A	02-Jan-20
2	2020 calf of 3101	2020-01-06-GDNR-Eg B	06-Jan-20
3	2019 calf of 1204	2020-01-16-FWRI-V Eg A	17-Jan-20
4	2020 calf of 3546	2020-01-25-FWRI-V Eg B	26-Jan-20
5	2020 calf of 3560	2020-01-25-FWRI-V Eg D	26-Jan-20
6	2020 calf of 2642	2020-02-03-FWRI-V Eg B	04-Feb-20
7	2020 calf of 3115	2020-02-04-FWRI-V Eg B	05-Feb-20
8	2020 calf of 2223	2020-02-04-GDNR Eg B	05-Feb-20
9	2020 calf of 1612	2020-02-05-GDNR Eg D	06-Feb-20
10	2020 calf of 1970	2020-02-24-GDNR Eg B	25-Feb-20

Task 5: Final Report on 2018 Right Whale Visual Health Assessment

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Introduction

The Visual Health Assessment (VHA) method was developed as a means to non-invasively assess right whale visual health using photographs routinely taken for photo-identification purposes (Pettis et al. 2004). Analyses of visual health assessment data have allowed us to clarify links between health, reproduction, anthropogenic impacts (fishing gear entanglements and vessel strikes), and survival (Pettis et al. 2004; Rolland et al. 2007; Schick et al. 2013; Rolland et al. 2016; Pettis et al. 2017). Additionally, the method can be applied to evaluate not only the present health condition of injured whales, but also describe changes in condition post injury, making it a useful tool to better inform annual injury determinations and estimates of human impact on this species. For example, annual reports of injured right whale health using the visual health assessment data are utilized by the National Marine Fisheries Service to facilitate the human induced serious injury and mortality determination procedure.

The VHA method is based on the evaluation of four parameters that can be assessed using shipboard and/or aerial images: body condition, skin condition, rake marks forward of the blowholes, and cyamids around the blowholes. These parameters were chosen based upon visible changes that are seen in whales that are known to be in poor health (e.g. chronic entanglement cases). Parameters are scored on a numerical scale, with lower scores indicating less severe or better condition (Table 1; see Pettis et al. 2004 and Rolland et al. 2007 for detailed reviews of the health assessment methodology and scoring criteria).

Table 1. Summary of health assessment parameters and scoring criteria.

Parameter	Code 1	Code 2	Code 3
Body Condition	Flat/convex back profile	Thin, moderately concave back profile	Severely concave back profile, emaciated
Skin Condition	Dark skin, clean skin	Significant skin lesions, severe sloughing	N/A
Rake Marks	Zero to Few marks	Moderate marks	Many marks, deep bright marks
Cyamids around Blowholes	Zero to few cyamids	Blowholes heavily covered with cyamids (Poor)	N/A

Objective and Methods

Health Assessments

The objective of this task was to update the VHA Database with all available photographed sightings of right whales added to the Identification Database (described previously under Task 1 of this report) since the previous update in 2019. Photographs from all sightings of an individual whale were grouped sequentially by right whale habitat (e.g. Gulf of Maine, Cape Cod Bay, Bay of Fundy) (Waring et al. 2015) and those groups of images were referred to as "sighting batches." These are the same batches used for the scarring analysis described above in Task II. All images in each batch were evaluated together and a single score was assigned for each visual parameter. If any change in a visual parameter occurred within a batch, this was noted and the score at the end of the given batch was the one assigned to the entire batch. Because the quality of the images varied from sighting to sighting, and only one side of a whale was photographed in some sightings, each visual health parameter score represents a composite of information gleaned from all the sightings in the batch. Health assessment scores and associated batch information, including date range of batch, habitat, and comments related to condition, were incorporated into the VHA Database. The database is linked to the Identification Database so that spatial, behavioral, and life history data can be coupled with health data.

Each year, there are previously assessed sighting batches for which new sightings become available or new sighting batches are added. For these cases, the health assessment scores for the existing batch were examined

and new information available in the new sightings was assessed and incorporated into the existing batch. Any new batches were assessed and coded as well. Under the current year of funding for this project, all health data through 2018 (including pre-2018 data that were added since the last funding period) were analyzed and the VHA Database is considered complete through 2018.

Database Summary Statistics

Once all batches were analyzed and the data entered, the VHA Database was queried to provide summaries by year of the number of photographed sightings, batches, platform type and individual right whales assessed.

Previous studies have shown that of the four parameters assessed using the VHA technique, skin and body condition are important indicators of North Atlantic right health and are associated with survival and reproductive success (Pettis et al. 2004; Schick et al. 2013; Rolland et al. 2016). We performed several assessments to investigate the annual rate of scoring of these two parameters for the population: 1) the annual frequencies of right whale sightings and batches over time were calculated; 2) the proportion of sightings collected from vessel vs. aerial platforms over time was calculated; 3) the proportions of right whales presumed to be alive (seen in a given year or any time in the five years prior, see Knowlton et al. 1994 for review) that were scored for skin and body condition were calculated by year; 4) the proportion of health assessment batches capable of being scored for skin and body condition were calculated to determine the suitability of available photographs for visual health assessment each year; and 5) the annual proportion of visually assessed whales with at least one compromised body or skin condition score was calculated to determine trends in compromised skin (score of 2) and body condition (score of 2 or 3) over time. This latter analysis excluded calving females of the year to remove the known impacts of reproduction on body condition.

Results

Update of Database

A total of 927 batches consisting of 46,506 images from 3,819 sightings of 366 individual right whales were evaluated and scored for visual health parameters for this update, including 56 whales assessed and scored in multiple years (Table 2). These visual health data were entered into the VHA Database and integrated with the Identification Database. The updated visual health data are now accessible via the North Atlantic Right Whale Consortium for scientists, managers, students, or other individuals with a bona fide purpose (NARWC 2019).

Database Overview

The updated VHA Database contains 19,906 batches consisting of 72,021 sightings from 1935-2018. The number of batches and associated sightings available to be assessed has varied annually (Figure 1, sample period 1980-2018 shown).

The percentage of sightings photographed by aerial and shipboard platforms has changed over time (Figure 2), with a continued increasing trend in aerial sightings. Between 1980–1999, 83% of right whale sightings were observed via shipboard platforms. Since then, only 42% of sightings have come from shipboard platforms. This is important because higher quality and more complete health assessment data are obtained from shipboard photographs. The relative percentage of aerial sightings remained high in 2018, and in fact, 2018 represents the highest proportion of aerial sightings (76.4%) in this study period. Though relatively insignificant in number, sightings of right whales from land and drone are represented in the database (total of 690 and 247 of 72,021 sightings, respectively, from 1980-2018).

Table 2. Number of batches with associated number of sightings and individual North Atlantic right whales, by sighting year, evaluated during the Visual Health Assessment Database update

Year	Batches	Sightings	Individual Right Whales
2006	1	1	1
2007	6	6	4
2008	2	24	2
2009	1	2	1
2010	2	2	2
2011	3	16	1
2012	3	3	3
2013	5	48	5
2014	5	6	5
2015	11	27	9
2016	10	29	6
2017	30	62	26
2018	848	3593	357
Total	**927**	**3,819**	**422***

*The total number of right whales assessed during this update was 422, including repeat samples of 56 individual whales in multiple years.

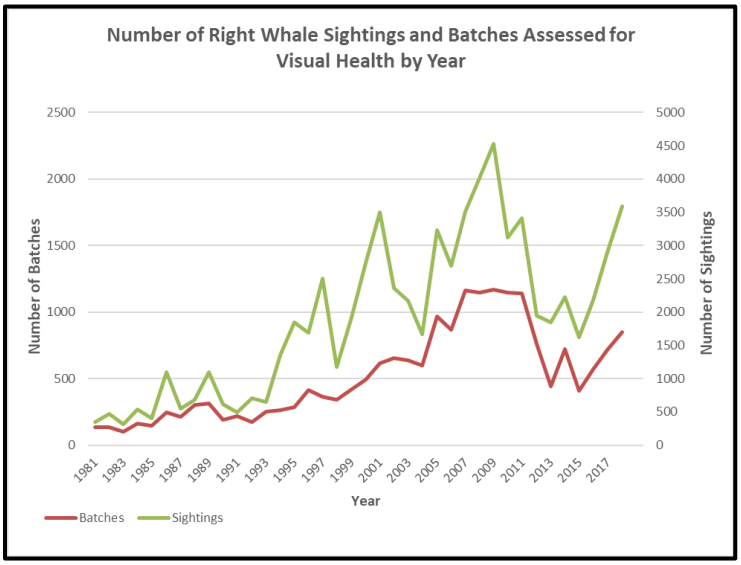

Figure 1. Count of North Atlantic right whale sightings and batches by year in the Visual Health Assessment Database 1980-2018.

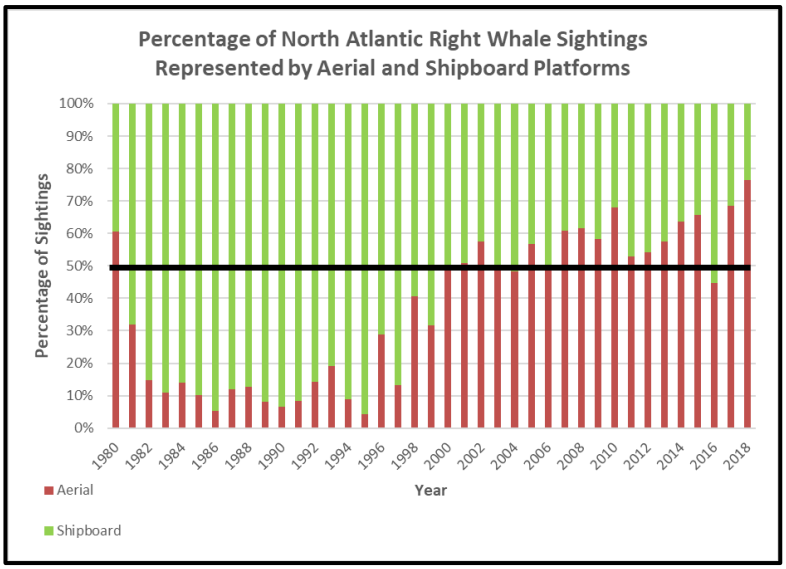

Figure 2. Percentage of North Atlantic right whale sightings scored for VHA represented by aerial and shipboard platforms between 1980- 2018. 50% line included in black. Land and drone based sightings are excluded from this analysis as they represent a relatively insignificant number of annual sightings.

Body and Skin Condition

The annual proportion of right whale sighting batches that were assessable for skin and/or body condition also varied by year and was consistently higher for skin condition (min/max% 62.7/95.5) than body condition (min/max% 30.1/82.4, Figure 3). The proportion of individual right whales presumed to be alive each year that were sighted and scored for either skin or body condition at least once varied by year (Figure 4). Between 1980 and 2018, the annual proportion of presumed alive right whales with scored skin condition was consistently higher (min/max% 37.9/82.4) than the proportion of presumed alive whales with scored body condition (min/max% 21.9/70.3).

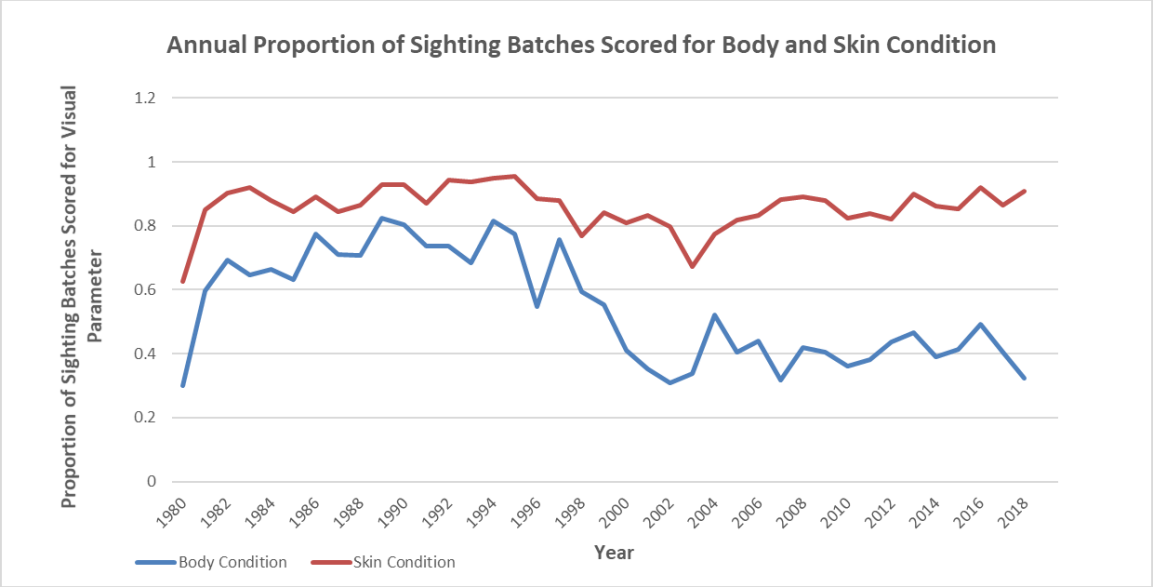

Figure 3. Annual proportion of right whale sighting batches that were scored for skin and body condition, 1980-2018.

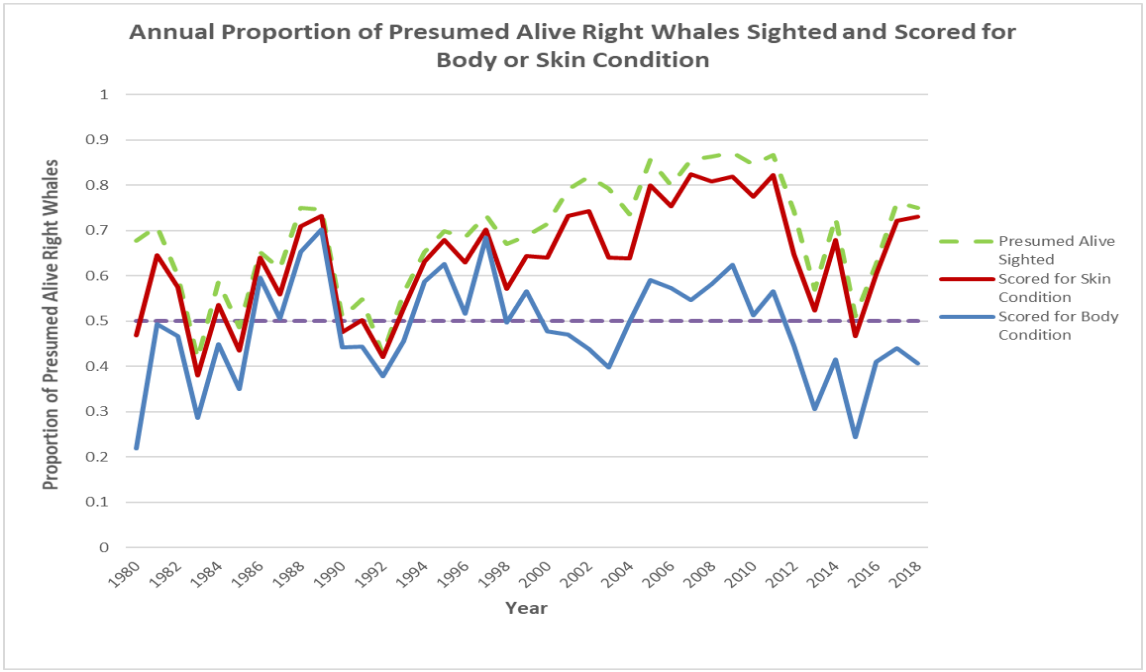

Figure 4. Annual proportion of presumed alive right whales that were seen and scored for skin and body condition by year, 1980-2018. Dashed purple line represents 50% presumed alive population.

The prevalence of compromised skin and body condition detected visually in North Atlantic right whales varied by year with peak prevalence of compromise for both parameters in the late 1990s and again in 2012 and 2016 for body condition (Figure 5). Both parameters showed similar trajectories until 2009 when a divergence occurred, with a higher proportional incidence of compromised body condition than skin condition detected every year since 2009. Over the last two years (2017-2018) prevalence of compromised body condition declined while that of skin condition increased.

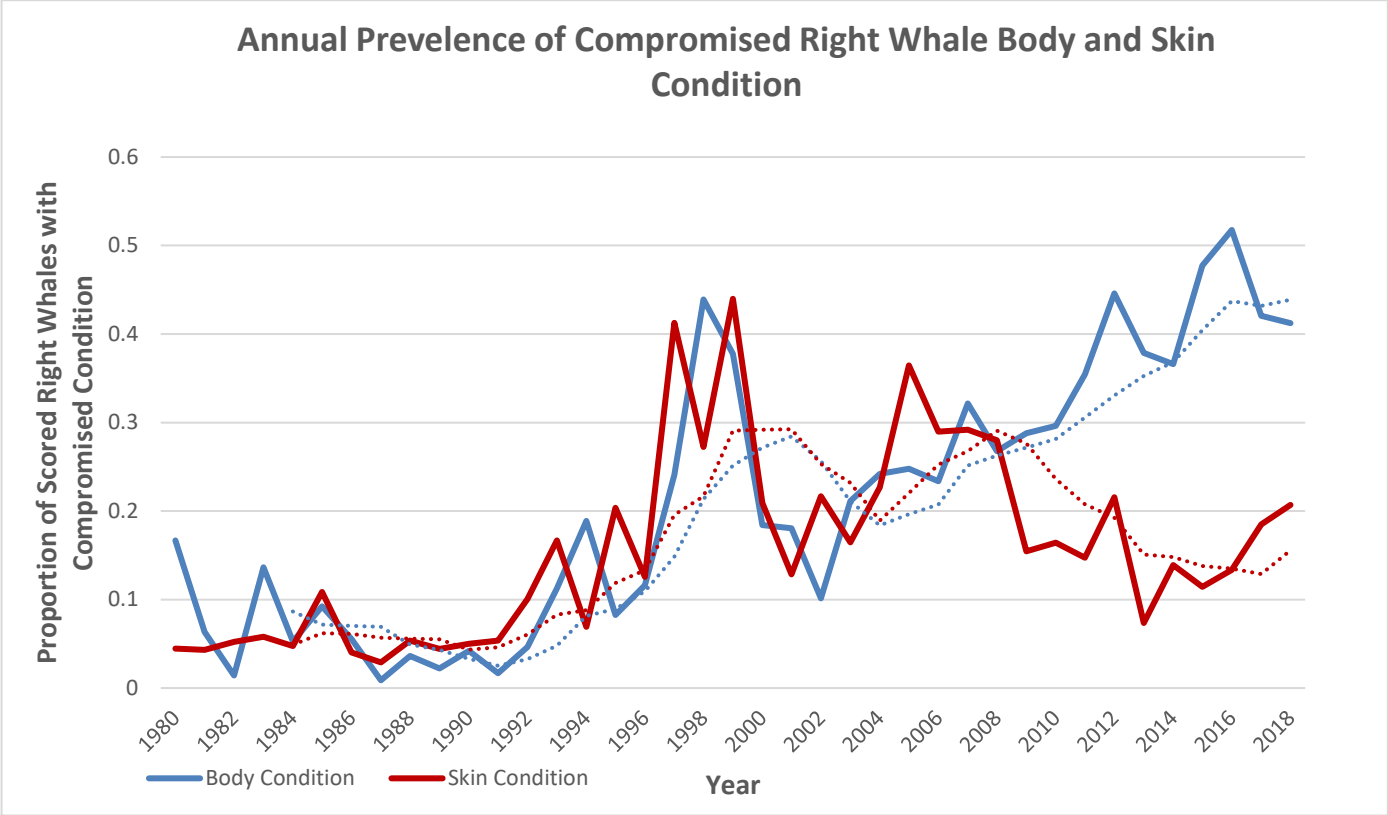

Figure 5. Annual proportion of right whales with compromised skin and body condition. Incidence was defined as at least one sighting batch for an individual right whale scored as compromised for skin or body condition by year, 1980-2018. Reproductive females were excluded from the body condition analysis in each of their calving years. Stippled lines represent 5-year rolling average.

Discussion

Visual health data for 422 right whales across 13 years (up from 368 across eight years in last year's assessments) were added to the VHA Database, making updated health data available to researchers and managers for various efforts, including long term and real time assessments of right whale health. These assessments are critical, particularly in emerging entanglement cases for which intervention is being considered, and must be developed rapidly. Additionally, the VHA technique has emerged as an important tool in monitoring the right whale population on multiple fronts, including investigating the impact of entanglement events on health and assessing the impacts of health on reproduction and survival. Over the past year, the VHA database has received several requests to use data for management and publication purposes, including proposals to:

1. Interpreting growth and body condition of North Atlantic right whales in the context of life history events and traumatic injuries
2. Develop an animal welfare assessment for North Atlantic right whales
3. Determine if right whale life history traits explain the different population trajectories for the thriving southern right whale compared to the imperilled North Atlantic right whale

Additionally, ongoing uses of the VHA Database include informing Bayesian model estimates of entanglement impact on right whale survival and reproduction and efforts to annually assess and monitor the impacts of anthropogenic injury on right whale health.

The ability to effectively monitor health is dependent on the availability of adequate photographs to score each parameter. Some visual parameters, including body condition, rake marks, and cyamids in the blowholes, are often difficult to assess using aerial images and therefore rely primarily on the availability of shipboard photographs. Since 2000, the proportion of right whale sightings photographed from aerial platforms has increased, with the lowest percentage of shipboard sightings recorded in 2018. This is likely related to several factors, including an increase in aerial survey effort on the calving ground in the southeast United States and Great South Channel in the 2000s. More recently, a shift in right whale distribution away from habitats traditionally surveyed by shipboard platforms (i.e. the Bay of Fundy) and into habitats primarily surveyed aerially (i.e. Cape Cod Bay and the Gulf of St. Lawrence) began in 2010. Additionally, the shift in distribution after 2010 resulted not only in a change of the predominant sighting platform, but also in a decrease in total photographed sightings and in the proportion of presumed living right whales seen annually compared to the 2000s. Though still lower than in the 2000s, the proportions of presumed alive whales sighted and those scored for skin and body condition have increased since a low point in 2015, likely due to increased survey efforts (both aerial and shipboard) in the Gulf of St. Lawrence. Sighting and visually assessing health of individuals each year are critical to not only understand changes in individual and population wide health over time, but also to adequately monitor both the impacts of anthropogenic injury (i.e. entanglements and vessel strikes) as well as emerging consequences of climate and oceanographic changes. For these reasons, it is important to continue to include vessel surveys in all high aggregation habitats. Additionally, the use of drone technologies to photograph right whales has increased over the last several years and this platform shows promise in aiding visual health assessments from overhead images, particularly with regards to body condition. Currently, we have a separately funded project that will use drone images to calibrate the visual health assessment indices with quantitative measurements of body condition (i.e. photogrammetry). The ultimate goal is to refine and narrow the uncertainty around visually assessed body condition scores, especially for the broad middle-condition category.

For much of the study period, the fluctuations in the prevalence of compromised skin and body condition for right whales were relatively synchronous (Figure 5). However, there was a marked divergence beginning in 2009 that remained through 2018, with a decrease in compromised skin condition coinciding with an increase in compromised body condition. The timing of this divergence is suspect, as it corresponds to the dramatic shift in right whale distribution observed following 2009. Whether this shift has contributed to the recent deterioration in body condition will be difficult to determine, however examining the potential consequences of the shift on health is worth pursuing as the consequences of poor body condition are many, including reduced

reproductive capacity and reduced resiliency in response to other stressors (intrinsic or extrinsic). It is encouraging to see that the prevalence of compromised body condition declined again in 2018. If right whales are finding habitats that remain stable in quality prey resources inter-annually, we would expect this decreasing trend to continue. The prevalence of compromised skin condition increased in 2018 (as it had in 2017 as well). Anecdotally, researchers have noted the development of skin lesions on right whales using the Gulf of St. Lawrence as the summer/fall seasons progress and this is an observation worth pursuing further.

The database remains an important tool in monitoring this endangered species, particularly given its utility in longitudinal comparisons of individual and population wide health. Maintaining and updating the database allows for: it to be integrated with other databases, population health to be examined by researchers and managers, the impact(s) of injuries on health to be examined, and comparisons of individual and population health trends over time. Recent analyses have utilized health assessment data to improve estimates of undetected mortalities in the population. The recent shift in right whale distribution coupled with the increasing proportion of aerial based sightings has significant implications for how effective monitoring efforts can be. Decisions about modified survey strategies must include consideration for not only locating and identifying individual right whales, but also best practices to ensure that information critical to important monitoring and management efforts (i.e. health assessment, scarring assessments) is effectively and efficiently collected.

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