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 2018 using data as of September 4, 2019. The entanglement scar coding (Task 2) reports on data for 2017 and compares 2017 findings to previous years. Anthropogenic case study reports (Task 3) describe cases first documented in 2017. The near-real-time matching (Task 4) reports on matching efforts from September 1, 2018 to August 31, 2019. Finally, the visual health coding (Task 5) reports on data through 2017, with some 2018 data and newly added data prior to 2017 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 is now approaching the previous average of around 3,800 per year. 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 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. 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.

Since the last catalog report, there have been 3,618 sightings added to the Catalog, 2,635 identifications confirmed, and 12 new whales added. In addition, 15 whales became presumed dead and two were resurrected. The last three years have had the highest number of presumed deaths on record. There are currently 746 cataloged whales, 462 of which are presumed to be alive- a decrease of three from last year’s report. In 2018, there were three dead whales documented, substantially fewer than the 17 recorded in 2017. With the change in right whale distribution patterns, there have been increasing numbers of sightings reported opportunistically; 27 of the 63 contributing individuals/organizations in 2018 do not normally collect and submit right whale images. 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. Finally, we upgraded the software that manages access to DIGITS via the web, a service that allows all users to view and download all the data they have contributed to the Catalog.

One noteworthy Catalog project during this performance period was a massive export of images. Over 400,000 images were exported to FlukeBook, an automated, on-line, matching website, so that they, along with NOAA, could develop a front end to an automated matching algorithm created by a 2016 Kaggle competition. This system shows promise for matching aerial images to aerial images. 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, which is 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 2017 indicate a continued high level of interactions between fishing gear and right whales with a crude entanglement rate (newly discovered entanglement scars as a proportion of whales seen) of 17.1% and an annual entanglement rate of 26.6%. These rates are above the average crude entanglement rate of 15.5% and the 25.0% 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 86.1%. In 2017, there were 62 entanglement interactions, including 14 serious entanglements, a continued high proportion of moderate and severe injuries (42%), and a continuing decline in the juvenile population (down to 20%). At 3.9% of all entanglement injuries, the 14 serious injuries represent the highest documented serious entanglement rate in 38 years.

Anthropogenic case studies were developed for one new vessel strike case and nine new entanglement cases documented in 2017. These case studies include photographs and life history data, and, for the entanglement cases, rope polymer information where available. The vessel strike case has 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 matching support for their 16 whales. We provided near-real time matching support for the biopsy effort in Cape Cod Bay (matching 32 of 41 sightings) and the Gulf of St. Lawrence (matching 510 of 544 sightings). Finally, since the last Catalog report, we were able to promptly match seven of the 10 dead whales (even with little to no callosity information), all five newly-entangled whales, and two of the three injured or sick whales.

Finally, visual health coding for 3,075 sightings of 368 right whales was completed since the last report, bringing the Visual Health Assessment Database up to date through 2017. 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 in 2016 and 2017 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, decreased in 2017 following spikes in 2015 and 2016. 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 2018

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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 2018 time period and all data reported on are as of September 4, 2019. The database, as of this date, including all data prior to 2019, 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 2018)

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.

Because NEAq is primarily responsible for photographic identifications, our catalog reports only describe the status of photographic sightings. As of September 4, 2019, there were a total of 78,399 records from 1935 through 2018: 77,616 associated with photographs where the identification was made primarily through the photographs (even if genetic data were also available), 0 fecal sightings, 732 satellite tagged sightings, and 51 sightings with either genetics and no photographs (n=5) or where there were some photographs, but the identification was made primarily through genetics (n=46).

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. The primary issues used to involve sightings of entangled whales, disentanglement events, mortality events, and off-season sightings where the chain of command for data submission was unclear. Now, the main issue is tracking down data and images from opportunistic sightings, including those posted on YouTube and Facebook, although obtaining images for dead whales and some Canadian researchers is still a problem. In some entanglement cases, some images have been emailed, submitted to the Center for Coastal Studies, 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 1990 to 2018 is provided in Appendix 1. In general, the percent complete in recent years has been lower because there are many sightings of calves that have yet to receive a Catalog number. Cataloging the 2012 to 2017 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 fewer calves being cataloged. 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 58% of the calves born between 2012 and 2017 have been cataloged in contrast to the average of 85% cataloged in the previous four years. This delay in cataloging calves has decreased our matching success. For example, 74% of the unmatched whales in 2013 and 2015 are calves from that or previous years; if those calves were cataloged, the matching status for both years would increase to 98% matched.

We have completed 96% of the matching for 2017 data and 20% for 2018 data. The percent matched for the 2018 data is low for a number of reasons. There were delays in 2017 data submission (some data were just received and other are still outstanding), a large number of Canadian video-only sightings that are time consuming to process, delays caused by the complexity of tracking down and processing 17 dead whale events, and a 25% increase in the number of sightings contributed. Because of these delays, we completed 2017 later than anticipated and that delayed the processing of 2018 data. For that reason, we focused on confirming at least one sighting of each whale matched by teams in the field in 2018. So, although the percentage of sightings matched and confirmed is lower, the number of unique individuals identified so far in the 2018 calendar year is high (in fact, the count of 343 unique individuals is the exact same as for 2017 in last year's report). We have hired additional help and plan to catch up on 2018 data by mid-year 2020. The details of the 2018 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. This past year we: 1) updated the primary images for most whales, providing more up-to-date images for the Catalog website; 2) did a re-training on how to correctly code images; and 3) continued working with right whale geneticists at Trent and St. Mary's University, primarily focusing on identifying dead whales this year. These tasks strengthen the data in the Catalog and improves our ability to monitor vital rates in this population.

One noteworthy Catalog project during this performance period was a massive export of images. Over 400,000 images were exported to FlukeBook, an automated, on-line, matching website, so that they, along with NOAA, could develop a front end to an automated matching algorithm created by a 2016 Kaggle competition. This system shows promise for matching aerial images to aerial images. 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, which is 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- 2015 only 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, 2018)

a. Summary of sightings

(n= 77,616)

Assessment Complete (92%)		Assessment Incomplete (8%)	
Matched: Confirmed	68,774	Matched: Unconfirmed	275
Not Matchable	2,797	Intermatched	454
		Not Yet Matched	5,316

Since the last catalog report, there have been 3,618 sightings added to the Catalog and 2,635 identifications confirmed.

b. Summary of cataloged whales

(n=746)

All Whales

	Male	Female	Unknown	**Total**
Gender	357 (47.8%)	313 (42.0%)	76 (10.2%)	746
	Adult	Juvenile	Unknown	**Total**
Age Class in 2018	608 (88.6%)	73 (10.6%)	5 (0.8%)	686*

* Totals for gender and age class differ because 60 cataloged whales died before 2018 and, therefore, did not have an age class recorded in 2018. An additional two *cataloged* whales died in 2018 (the third was never identified) but had age class records in 2018.

Presumed Living in 2018

	Male	Female	Unknown	**Total**
Gender	261 (56.5%)	176 (38.1%)	25 (5.4%)	462
	Adult	Juvenile	Unknown	**Total**
Age Class in 2018	389 (84.2%)	68 (14.7%)	5 (1.1%)	462

Presumed Dead as of 2018

	Male	Female	Unknown	**Total**
Gender	73 (32.9%)	98 (44.1%)	51 (23.0%)	222

Known Dead (cataloged whales only)

	Male	Female	Unknown	**Total**
Gender	23 (37.1%)	39 (62.9%)	0	62
	Adult	Juvenile	Unknown	**Total**
Age Class at Death	36 (58.1%)	23 (37.1%)	3 (4.8%)	62

Two of the cataloged dead whales died in 2018 and are included in the age row in "All Whales" above. The remaining 60 dead whales are not included in that tally.

Catalog data - 2018 only (this is for the "right whale year" which includes data from December 1, 2017 through November 30, 2018.)

Explanations of area abbreviations can be found in Appendix II. The percentages below do not match Appendix I because those results are for the calendar year, not the right whale year.

a. Summary of sightings - 2018

(n= 3,192)

Assessment Complete (21.1%)		Assessment Incomplete (78.9%)	
Matched: Confirmed	665	Matched: Unconfirmed	247
Not Matchable	10	Intermatched	34
		Not Yet Matched	2,236

b. Distribution of sightings

Five Main Right Whale Areas

BOF	CCB	FL/GA	GSC
19	1,015	33	150

Other SEUS and Mid-Atlantic Areas

GMEX	NC	NJ	NY	VA
5	5	1	3	15

Other Northeast Areas

GB	GOM	JL	MB	SNE
4	1	8	570	139

Other Areas North and East

ESS	GSL	ICE	NRTH
8	1,213	2	1

c. Summary of identified whales

With 21.1% of all 2018 sightings for the right whale year matched and confirmed, 327 individual right whales have been identified (note: the 21.1% matched reported here differs from the 19.9% matched reported in Appendix I because the latter is for the 2018 *calendar* year). The numbers in section d below include the same individuals between areas; zeros in that section indicate that no whale from that area has been identified yet. (*Another nine whales have been partially identified*: *one cataloged whale, five calves from various years, and three whales of unknown age. The number of unique individuals these nine animals represent may decrease once the three whales of unknown age have been fully identified and all matches confirmed*.)

	Male	Female	Unknown	**Total**
Gender	189 (57.8%)	124 (37.9%)	14 (4.3%)	327
	Adult	Juvenile	Unknown	**Total**
Age Class in 2018	274 (83.8%)	50 (15.3%)	3 (0.9%)	327

d. Distribution of identified whales

Five Main Right Whale Areas					
	BOF	**CCB**	**FL/GA**	**GSC**	
	4	130	8	33	
Other SEUS and Mid-Atlantic Areas					
	GMEX	**NC**	**NJ**	**NY**	**VA**
	0	1	0	2	7
Other Northeast Areas					
	GB	**GOM**	**JL**	**MB**	**SNE**
	1	1	2	87	26
Other Areas North and East					
	ESS	**GSL**	**ICE**	**NRTH**	
	0	100	1	0	

Summary of deaths, resurrections, and new whales cataloged in 2018
(Details provided in Sections V, VI, and VII)

a.) Whales Presumed Dead	15
b.) Whales Resurrected*	2
c.) Whales Added to Catalog*	
i. In 2018	2
ii. In 2019	10
d.) Confirmed Deaths	
i. Cataloged whales	2
ii. Carcasses not ID'd to Catalog**	1

* These figures are since the last report, not just for the year 2018.
** A segment of right whale skull found on August 16, 2018 is not included in this count as it is currently unclear if it is from a previously known mortality. Genetic analysis is pending.

III. Computerized Database Status

Sighting effort data
All of the NEAq survey data from December 1, 2017 to November 30, 2018 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 May 14, 2018. Dr. Kenney provided a preliminary report of his work on June 6, 2018. He considered it preliminary because he was still awaiting 2017 aerial survey data from NEFSC. Mr. Hamilton reviewed the 24 potential errors that needed to be investigated by August 30, 2018: all were investigated, the solution noted for those that could be resolved, and the record corrected, where necessary, in the live Catalog database. On September 4, 2019, Dr. Kenney decided to move ahead and considered the comparison complete without the NEFSC 2017 data. Mr. Hamilton uploaded the final data on September 10, 2019.

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 1.3 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 drawing, but now one of our staff is fully trained. A total of 13 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 2020.

Since the last Catalog report, the Citrix Netscaler software was upgraded to version 12.1.53-12. Citrix NetScaler is an all-in-one web application delivery controller that performs tasks such as traffic optimization, L4-L7 load balancing, and web application acceleration while maintaining data security. It monitors server health and allocates network and application traffic to additional servers for efficient use of resources. Citrix allows DIGITS users to access the system from any devices, and allows contributors to download their own data at any time. This software was last upgraded in 2012.

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 web site. In 2019, we started a 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 will be occurring. The plan is to have the traffic directed from that website to the Catalog website to show images and sighting histories for any potential matches found through automation. The redesigned Catalog website will be launched in 2020.

An additional web resource for the Catalog is background information on the Anderson Cabot Center for Ocean Life at the New England Aquarium 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. Those new pages will be launched in the fall of 2019 and the public Catalog site will be linked to them.

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 ~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 new E Catalog is 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 12 new whales added to the Catalog: two in 2018 and ten (so far) in 2019. All of them were calves from past years born in 2013 (n=1), 2014 (n=1), 2015 (n=4), 2016 (n=5) and 2017 (n=1).

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 2018

Catalog No.	Sex	Birth Year	Mother	Father
4457	Male	2014	3157	
4601*	Unknown	2016	3101	

Added in 2019

Catalog No.	Sex	Birth Year	Mother	Father
4304*	Male	2013	1204	
4501	Male	2015	1701	
4511*	Male	2015	1611	
4539	Male	2015	3139	
4590*	Female	2015	2790	
4605*	Male	2016	3405	
4633	Female	2016	1233	
4640*	Female	2016	3440	
4650*	Male	2016	3450	
4714	Unknown	2017	2614	

"*" indicates a narrative is provided below

#4304 (5 y.o male) - This whale was first seen December 16, 2012 off the coast of Florida with his mother, #1204. The pair remained off the southeastern coast through early February 2013. They were next seen in Cape Cod Bay, Great South Channel, and the Gulf of Maine in April and May of that year. His last sighting as a calf was May 18th. He was not seen again for three years until he was seen in the Gulf of Maine in May 2016. Since that time, all his sightings have been around Cape Cod. His last confirmed sighting was April 30, 2018 in Cape Cod Bay. He has never been seen in the Gulf of St. Lawrence. A genetic sample has been obtained from this whale.

#4511 (3 y.o. male) - This whale was first seen February 8, 2015 off the coast of Florida with his mother Clover, #1611. The pair remained there through February and were subsequently seen together south of Cape Cod and in Massachusetts Bay in April, and the

Bay of Fundy in June. His post-calf sightings have all been around Cape Cod in 2017 and 2018. He has never been seen in the Gulf of St. Lawrence. A genetic sample has been obtained from this whale.

#4590 (3 y.o female) - This whale's first and only day seen as a calf on the calving grounds was March 9, 2015 off the coast of Georgia with her mother, #2790. The pair were next seen in Great South Channel in April and May before making their way up to the Bay of Fundy in June. Their last sighting together was there on June 29. She was next seen two years later south of the Cape in April, May, and June. In 2018, she was only seen in Cape Cod Bay in April and May. She has never been seen in the Gulf of St. Lawrence. A genetic sample has been obtained from this whale.

#4601 (2 y.o unknown sex) - This whale was first seen February 17, 2016 off the coast of Florida with its mother Harmonia, #3101. They remained in the southeast until March 12^{th}, and were next seen July 27 and 28 in the Gulf of St. Lawrence. In 2017, its' only sighting was south of Cape Cod. In 2018, it was only seen in the Gulf of St. Lawrence. It had severe, fresh entanglement wounds and made a prolonged close approach to the boat. It's last sighting was September 11, 2018 off Cape Breton among a pod of pilot whales. A genetic sample has been obtained from this whale.

#4605 (2 y.o male) - This whale was first seen January 30, 2016 off the coast of Florida with his mother Fuse, #3405. The pair remained in the southeast until March 7^{th} before traveling to Cape Cod Bay in April. After that, they were seen in the Gulf of St. Lawrence on July 5^{th}, and then the Bay of Fundy August 15 through September 4. He was seen just once in both 2017 and 2018- both times in Cape Cod Bay. A genetic sample has been obtained from this whale.

#4640 (2 y.o. female) - This whale was seen December 22 and 27, 2015 off the coast of Florida with his mother Cypress, #3440. After that date, she was raised by Harmony #3115 (she was part of a three-way calf swap that resulted in #3115 raising #3440's calf, #3860 raising #3115's calf, and the fate of #3860's calf remains unknown). She was first seen with #3115 on January 12, 2016 off the coast of Georgia. The pair remained together in the southeast through the end of that month. They were seen in Cape Cod Bay throughout April and she was last seen as a calf on May 20^{th} alone in Great South Channel. In 2017 and 2018, she was only seen in Cape Cod and Massachusetts Bays. She has never been seen in the Gulf of St. Lawrence. A genetic sample has been obtained from this whale.

#4650 (2 y.o. male) - This whale was first seen January 19, 2016 off Cape Canaveral, Florida with his mother Clipper, #3450. They traveled south through the beginning of February and entered Sebastian Inlet for a couple of days on February 8^{th}. The pair were last sighted in the southeast off the Georgia coast on February 28. They were next seen August 16^{th} in the Bay of Fundy where they remained through September 3. He was next seen on July 10, 2017 south of Cape Cod- his only sighting that year. All of his 2018 sightings were in the Gulf of St. Lawrence from July 31 to August 20. A 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. There is an unusually high percentage of recent calves that fit this description. Due to the change 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 #4304 above as an example), an important transition time in their physical appearance. Excluding the 38 calves that remain in limbo, there are eight 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 46 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 46 resurrections represent 17.5% of the 263 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 three years since, there have been five resurrections, which may be, in part, because whales are shifting their habitats. Presumed deaths have been consistently high since 2015 (57 presumed deaths between 2015 and 2018 compared to 18 for the previous three years). Given the large number of *known* mortalities in the last three years, we are concerned that this increase in presumed mortality may reflect true, undetected mortalities.

The presumed dead assessment has its 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 2018 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 2018, 15 animals were classified as presumed dead (four of them calving females) and two animals were 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

#1123 (31 y.o. female) - This whale, named Sonnet, was first seen in the Bay of Fundy in August 1981 as a calf with her mother Kleenex, #1142. She was seen almost every year for the next 31 years- often in the Bay of Fundy. She gave birth to five calves- her first in 1991 at the age of 10 and the last in 2011- just one year before she disappeared. Her longest previous sighting gap was three years. Her last sighting was in April 2012 in Great South Channel; there were no outward indications of ill health at the time. A genetic sample has been obtained from this whale.

#1151 (32+ y.o. female) - This whale, named Mavynne, was first seen in July 1980 approximately 30 miles southeast of Mt. Desert Island in the Gulf of Maine. She was seen in all the major habitats except Cape Cod Bay, but most of her sightings were in the Bay of Fundy. She has had six calves: her first in 1987 and her last in 2009. Her 1987 calf was part of a calf swap described in Frasier et al. (2010). Mavynne raised Stumpy's (#1004) biological calf, #1707, and Stumpy raised Mavynne's biological calf, #1705. Mavynne was entangled and anchored on Jeffreys Ledge on September 3, 2009 and was subsequently freed by the Center for Coastal Studies the following day. She has only had two previous sighting gaps: a three-year gap between 1982 and 1985 and a two-year gap between 1991 and 1993. She appeared thin at her last sighting in June 2012 on Jeffreys Ledge. A genetic sample has been obtained from this whale.

#1279 (30+ y.o. male) - This whale was first seen in August 1982 in Roseway Basin. For the first eight years, he was only sighted in Roseway, but after that was seen in the Bay of Fundy, Great South Channel, and the Gulf of St. Lawrence. He was rarely seen in consecutive years and was resurrected in 1997 after a seven-year sighting gap. He was last seen in June 2012 in Roseway Basin; there were no outward indications of ill health at the time. A genetic sample has been obtained from this whale.

#3111 (11 y.o. male) - This whale was first seen off the coast of Florida in January 2001 with his mother Clover, #1611. For the next four years, he was seen almost exclusively off the southeastern U.S. or in the Bay of Fundy. From 2008 to 2011, he changed that pattern to the southeast and Cape Cod Bay. He was seen entangled in the Bay of Fundy in September 2011 and partially disentangled at that time. His only sighting after that was in March 2012 in Massachusetts Bay. At the time, he had extensive scarring and it could not be determined whether he was still entangled . A genetic sample has been obtained from this whale.

#3195 (11+ y.o. unknown sex) - This whale was first seen in April 2001 in the Great South Channel. Compared to other whales, he has had relatively few sightings (15) over his 11 year sighting history. He has been seen almost exclusively in Great South Channel, with a few sightings in the Gulf of Maine and Massachusetts Bay. He had a four-year sighting gap between 2008 and 2012. His last sighting was in May 2012 in Great South Channel; there were no outward indications of ill health at the time. A genetic sample has *not* been obtained from this whale.

#3220 (15+ y.o. female) - This whale had a calf with her at her first sighting off the coast of Georgia in January 2002. She was assigned a minimum age of 15+ for this report assuming she was at least five years old at that sighting. She and her calf were only seen one more time that year, off South Carolina in February. Her next sighting was almost ten years later again with a calf in the southeast in December 2011. She and her calf were seen off Florida in December and early January, Georgia in late January, and her last sighting was of the pair off South Carolina in early February 2012. A genetic sample has been obtained from this whale.

#3470 (8+ y.o. male) - This whale was first seen in April 2004 east and south of Montauk, NY. Since then, he has been seen almost exclusively in the Great South Channel- with just three sightings in the middle of the Gulf of Maine. He has relatively few sighting records and his longest sighting gap was two years. He was last seen May 2012 in Great South Channel. There were no outward indications of ill health at the time. A genetic sample has been obtained from this whale.

#3596 (7+ y.o. unknown sex) - This whale was first seen in January of 2005 in the middle of the Gulf of Maine. It has only three sightings- all in the Gulf of Maine in the winter. It was seen there in December 2007 and last in January 2012. A genetic sample has *not* been obtained from this whale.

#3610 (6+ y.o. male) - This whale was first seen in January 2006 off the coast of Florida. He remained off the southeast through mid-February and was seen later that year in September entangled in the Bay of Fundy. A disentanglement attempt was unable to be mounted until the following January when he was back in the southeast off the Georgia coast. He was partially disentangled and tagged with a telemetry buoy that showed him traveling up the coast to South Carolina and North Carolina later in January. He was seen gear free in April 2007 in Great South Channel. He was seen repeatedly after that in the southeast U.S., then Cape Cod Bay, then the Bay of Fundy. His last sighting was in

September 2012 in the Bay of Fundy, where he was photographed with extensive, fresh entanglement scarring that must have occurred between March and September of that year. A genetic sample has been obtained from this whale.

#3822 (5 y.o. male) - This whale was first seen in December 2007 off the Georgia coast with his mother, #1622. The pair were seen 32 times off the southeast coast that calving season through the end of February. Their only northern sighting was in Great South Channel in May. Since then, he was seen repeatedly in the southeast, Cape Cod Bay, and the Bay of Fundy. His last sighting was in March 2012 in Massachusetts Bay; there were no outward indications of ill health at the time. A genetic sample has been obtained from this whale.

#3995 (5+ y.o. female) - This whale was first seen in July 2009 approximately 80 miles east of Portsmouth, NH in the Gulf of Maine. In 2011, she was seen once in Cape Cod Bay in April and once in Great South Channel in May. In 2012, she was seen with a calf over 100 miles east of Provincetown, MA. She has only six sightings in the Catalog and all but one of those is far offshore. Because she had a calf at her last sighting, she was assigned a minimum age of 5+ for this report, assuming she had to be at least five years old at that sighting. There were no outward indications of ill health at the time of her last sighting. A genetic sample has *not* been obtained from this whale.

#3996 (3 y.o. male) - This whale, named Calanus, was first seen as a calf in January 2009 off the coast of Georgia with his mother, #1711. The pair remained in the area through mid-February before making their way to Cape Cod Bay in April, which was the only northern habitat where they were documented that year. In 2010, he was seen in Great South Channel in May and on Jeffreys Ledge in October. In February 2012, he was seen entangled in Cape Cod Bay with line and webbing coming out of his mouth. He was still entangled seven months later at his last sighting in September 2012 on Jeffreys Ledge. A genetic sample has been obtained from this whale.

#4045 (2 y.o. female) - This whale was first seen as a calf off the coast of Florida in March 2010 with her mother Insignia, #2645. In April, they were seen off the North Carolina coast before heading to the Bay of Fundy in August. She was next seen back off the Florida coast in January 201, then south of Martha's Vineyard, MA in April. Her last sighting was July 2012 in Massachusetts Bay; there were no outward indications of ill health at that time. A genetic sample has been obtained from this whale.

#4110 (2 y.o. female) - This whale was first seen off the coast of Florida in December of 2010 with her mother Binary, #3010. The pair remained in the area through mid-February before migrating to an area southwest of Martha's Vineyard, MA in April. By September, the pair had swum to the Bay of Fundy, where they remained for at least eight days. She was seen off Georgia the following January and her last sighting was two months later in Massachusetts Bay in March 2012; there were no outward indications of ill health at that time. A genetic sample has been obtained from this whale.

#4201 (calf unknown sex) - This whale was first seen off the coast of Georgia in December 2011 with its mother Half Note, #1301. Unfortunately, Half Note has apparently been having difficulty nursing her calves in recent year: over time #4201grew increasingly thin and was last seen January 10th. Half Note was seen alone from January 24th to the 31st. As mentioned under the new whales section above, we now catalog calves known to have died on calving ground, and *all* of these calves become presumed dead six years later even though we know they died in their birth year. A genetic sample has *not* been obtained from this whale.

Resurrected

#1628 (32+ y.o. unknown sex) - This whale, named Peregrine, was first seen in June 1986 in Great South Channel. For the next three years, he was seen only in Roseway Basin. In the 1990's, he was seen solely in the Bay of Fundy. Since then, he has not been seen in either of those habitats, but rather has moved around the Great South Channel, Gulf of Maine, and southeastern U.S. (seen there in March 2007 and 2010). He was seen in the Gulf of St. Lawrence in 2006 and again in 2018, after a seven-year sighting gap. A genetic sample has *not* been obtained from this whale.

#1805 (30+ y.o. male) - This whale was first seen in August 1988 in Roseway Basin. He was seen there for the next five years and then disappeared for nine years. He was previously resurrected in 2001 with a sighting in Great South Channel. He was seen almost solely in Great South Channel throughout that decade. He was seen in Cape Cod Bay in 2009 and 2011 before disappearing again for another seven years. He was resurrected again due to a sighting in Great South Channel in May 2018. A genetic sample has been obtained from this whale.

VI. Mortalities, Entanglements, and Significant Injuries

Overview

There were three mortalities discovered in 2018 (this count does not include a segment of right whale skull found on Long Point Beach, Martha's Vineyard on August 16, 2018, as it is currently unclear if it is from a previously known mortality- genetic analysis is pending.) No calves were known to have died, so the minimum death count for the year remains at three. Six right whales were first seen entangled in 2018, including one carcass, and one was seen still entangled from a previous year's entanglement. One whale was first seen gear-free in 2018 (one of the six first seen entangled in 2018). There were four new cases of significant injuries: two were caused by propellers, one from an entanglement, and one was due to unknown causes. Details of each incident are described below. 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

#3893 (10 y.o. female) - This whale, the carcass of which is referenced as VAQS20181005Eg, was found floating entangled and dead on January 22, 2018 off the Virginia/North Carolina coast at 36.70317°N/74.85000°W. The initial sighting was documented by a NC fisherman from Oregon Inlet (unknown name). Another fisherman from VA reported seeing a live, entangled whale on January 9th, but there are no photographs from that sighting, so it is unknown if that was #3893 before her death. On January 26th, the US Coast Guard flew and relocated the carcass. The Virginia Aquarium responded by boat and attached a telemetry buoy to the carcass so the animal could be later relocated. The carcass was towed to shore on January 28 and a necropsy conducted at Little Island Park, VA. The proximate cause of death was chronic entanglement. The last confirmed sighting of this whale alive and entanglement-free was July 29, 2017 in the Gulf of St. Lawrence.

Unknown ID (unknown age male) - This whale, the carcass of which is referred to as IFAW18-244Eg, was first seen floating dead off the coast of Martha's Vineyard on August 25, 2018 at 41.17636°N/70.44898°W. The sighting was made by an unknown person from the public and not reported directly, but the video was posted on a Cape Cod Times website. Then, on August 27, NOAA-GAR received a report from a recreational vessel of a dead whale carcass floating east of Tom's Neck Point, Martha's Vineyard, MA. Additional photographs of the carcass were forwarded by other reporting parties on the same day (one to USCG and Center for Coastal Studies and also one to Scott Leonard at the Nantucket Marine Mammal Alliance). On August 28, a NOAA team, aboard a USCG vessel out of Woods Hole, took samples of the carcass and attached a telemetry buoy to the flipper. The carcass was deemed not towable due to the lack of flukes. Two days later, the carcass drifted ashore on Monomoy Island, Chatham, MA. A necropsy was performed by the International Fund for Animal Welfare (IFAW). It was determined to be a calf of the year and the initial findings indicate it likely died due to an entanglement. Final results are pending. There were no calves known to be born that year, so it would either be an undetected calf from the year, or a small 1 y.o. from 2017. Two of the 2017 calves can be ruled out because they do not have white bellies; the other three (calves of 1412, 1515, and 2614) cannot yet be ruled out. Genetics may help clarify this whale's identity.

#3515 (13 y.o. female) - This whale, the carcass of which is referred to as IFAW18-281Eg, was first seen floating on Georges Bank, 140 miles east of Cape Cod on October 14, 2018 at 41.3646°N/ 67.0276°W. The NOAA *R/V Bigelow* reported the sighting to the NOAA Stranding hotline just before dusk. The following day, a USCG flight was requested to relocate the carcass with NEFSC observers on board. The carcass was relocated, and the *Bigelow* returned to the carcass and collected data and samples with guidance from IFAW. Due to the state of the carcass and the distance from shore, the animal could not be towed to shore for a full necropsy. However, the photographs of the carcass showed deep impressions from a complex entanglement, and the cause of death was attributed to "a probable severe entanglement". The genetic samples were analyzed and on March 28, 2019, the genetics team from St. Mary's University announced that the sex, haplotype, and genotype (at 13 loci) matched a previous sample from #3515. She was last seen alive on August 12, 2018 in the Gulf of St. Lawrence.

Entanglements

First Reported in 2018

January 22, 2018: #3893 (10 y.o. female) - This entanglement event is described under the Mortalities section above.

May 12, 2018: #4091 (8 y.o. female) - This whale was initially reported entangled about 60 miles east of Chatham, MA. in Great South Channel by the Northeast Fisheries Science Center (NEFSC) aerial survey team. The whale had a single line apparently wrapped around the right flipper with a buoy and trailing line. No line or buoy were visible when she was next seen on January 13, 2019 south of Nantucket, but visibility into the water was not ideal. She may well have shed her gear, but we await another sighting in order to confirm this. Before the May 12 entanglement, she had been last seen gear free just six days earlier on May 6, 2018 in Cape Cod Bay.

July 13, 2018: #3312 (15 y.o. male) - This whale was initially reported entangled east of Miscou, NB Canada in the Gulf of St. Lawrence by the NEFSC aerial survey team. He had been seen gear-free just hours earlier. He had yellowish-green line wrapped around his left flipper, likely going through the mouth and trailing behind him. His tail stock was bloody and raw; he has not been seen since.

July 30, 2018: #3843 (10 y.o. male) - This whale was initially reported entangled 20 miles east of Grand Manan Island in the Bay of Fundy by the Grand Manan Whale and Seabird Research Station. He was towing a low-drag buoy about one body length aft of the flukes. He was thin, with many cyamids infesting his injured tailstock. The Campobello Whale Rescue Team responded that day, and again on August 5th when they were able to cut the line going to whatever was dragging beneath the whale. He was seen almost five months later south of Nantucket with line still coming out of his mouth, but in better overall condition. His last sighting gear-free before the July 30st sighting was on June 7, 2018 in the Gulf of St. Lawrence.

August 20, 2018: #3960 (9 y.o. male) - This whale was initially reported entangled east of Miscou, NB, Canada in the Gulf of St. Lawrence by the joint NEAq/Dalhousie University/Canadian Whale Institute team. The whale appeared to be newly entangled with many wraps in and over the mouth and baleen sticking out the front of the mouth. Over time, with lots of rolling and thrashing, the whale seemed to free itself and swim off at speed. On December 31st, the NEFSC team photographed him south of Nantucket and were able to confirm that he was gear free. His last sighting gear free before the August 20 sighting was two weeks earlier on August 6, 2018 in the Gulf of St. Lawrence.

December 12, 2018: #2310 (25+ y.o. male) - This whale was initially reported entangled 30 miles south of Nantucket, MA by the NEAq aerial survey team. He had a single line through the mouth, with a bitter end visible on one side and line trailing downward on the other side. He was seen again February 3, 2019 in the same area, and then in Cape Cod Bay on April 25th. A disentanglement attempt by CCS in April was not successful. The last known gear-free sighting of this whale before December 12th was on April 18, 2018 in Massachusetts Bay.

Reported Prior to 2018 and Still Entangled by the end of 2018

March 23, 2018: #1142 (41+y.o. female) - This whale was seen 20 miles southwest of Nantucket, MA by the NEFSC aerial survey team. This was her first sighting since her initial entanglement sighting April 1, 2014 off the Delaware coast. She still had a loop of line through the mouth coming together into a wad of knotted line just behind her blowholes- there was no trailing line. The CCS team were able to use an arrow with a cutting tip to nick the line coming out of the right side of the mouth on April 12th on Stellwagen Bank, but the entanglement did not change over the ensuing three months. She was last seen in deteriorating condition in the Gulf of St. Lawrence on July 20, 2018.

First Seen Free of Gear in 2018

Only one right whale was first confirmed free of gear in 2018 and that whale, #3960, is described above, as he was also first seen entangled in 2018.

Entrapments

No right whales were seen entrapped in fishing weirs in 2018.

Significant injuries

Vessel wounds

#4145 (7 y.o. male) - This whale was first seen injured on March 1, 2018 in Cape Cod Bay. He had five, mostly shallow, propeller cuts on the left dorsal fluke, with a scar from the skeg of an engine along side. Nine months later in December, he looked healthy and the deeper cut had resulted in a small chunk out of the trailing edge of his left fluke. His last sighting prior to the injury was in April 2017 in Cape Cod Bay.

Unknown ID (unknown age and sex) - This whale was first seen with four, shallow propeller cuts behind the right blowhole on July 11, 2018 in the Gulf of St. Lawrence. It appears to be a young whale that has not yet been matched to any of the recent calves. Its temporary identifier is G046 and it was darted by our team in the Gulf of St. Lawrence in August 2019. We hope to have a genetic identification by the next Catalog report. It was in poor condition at the last sighting (2019) with gray skin, rake marks by the blowholes, and many orange cyamids on the body. It had last been seen without wounds in April 2017 south of Cape Cod, MA.

Entanglement wounds

#3296 (16 y.o. male) - This whale was first seen with a large section of his right lip missing on February 15, 2018 off the coast of Georgia. He had extensive skin lesions and rake marks around the blowholes and was emaciated. He has not been since and is likely dead. He had last been seen healthy in April 2017 in Cape Cod Bay.

Other injured or unhealthy whales

Unknown ID (unknown age and sex) – This whale was seen emaciated and covered in orange cyamids on November 9, 2018 near Stellwagen Bank east of Boston, MA. Only a small portion of the callosity was photographed. It is unlikely that this whale survived and its identification will likely remain a mystery.

VII. Photographic Contributions

Photos submitted from 63 different organizations or individuals who collected photographs between December 1, 2017 and November 30, 2018 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 63 organizations/people whose photographs were collected between December 1, 2017 and November 30, 2018.

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 percentage of intermatched individuals includes all unidentified calves, making the southeast percentages for this category higher than most regions. 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 / Region	# of Sightings	# of Images	Confirmed	Unconfirmed	Not Matchable	Intermatched	Not Yet Matched	Confirmed Id'd	Other Unique Id'd	Total
ALFA*										
NE	1	5	100.%	0.%	0.%	0.%	0.%	1	0	1
ANSA*										
NE	1	1	0.%	0.%	0.%	0.%	100.%	0	0	0
BC*										
MIDA	1	5	100.%	0.%	0.%	0.%	0.%	1	0	1
BHC										
JL	1	15	0.%	0.%	0.%	0.%	100.%	0	0	0
NE	41	200	12.2%	2.4%	0.%	0.%	85.4%	5	0	5
BIWSC										
BOF	1	13	100.%	0.%	0.%	0.%	0.%	1	0	1
BJ*										
MIDA	1	1	100.%	0.%	0.%	0.%	0.%	1	0	1
BLPE*										
MIDA	1	9	0.%	0.%	0.%	100.%	0.%	0	1	1
BRRO*										
NE	1	2	0.%	0.%	0.%	0.%	100.%	0	0	0
BRWI*										
MIDA	1	1	0.%	0.%	100.%	0.%	0.%	0	0	0
CCG										
EAST	1	0	0.%	0.%	0.%	0.%	100.%	0	0	0
NRTH	61	0	0.%	0.%	0.%	0.%	100.%	0	0	0
CCS										
GSC	7	131	0.%	28.6%	0.%	0.%	71.4%	0	0	0
JL	1	49	0.%	0.%	0.%	0.%	100.%	0	0	0
NE	1,024	15,728	28.1%	9.5%	0.1%	1.5%	60.8%	144	3	147
CHHY*										
SEUS	1	11	0.%	0.%	0.%	0.%	100.%	0	0	0
CMARI										
MIDA	4	53	25.%	0.%	0.%	0.%	75.%	1	0	1
SEUS	16	500	12.5%	6.3%	0.%	0.%	81.3%	2	0	2
CWI										
BOF	1	50	100.%	0.%	0.%	0.%	0.%	1	0	1
CWR										
BOF	1	9	100.%	0.%	0.%	0.%	0.%	1	0	1
DECA*										
SEUS	1	3	0.%	0.%	0.%	0.%	100.%	0	0	0
DFO										
BOF	1	13	100.%	0.%	0.%	0.%	0.%	1	0	1
EAST	7	0	0.%	0.%	0.%	0.%	100.%	0	0	0
NRTH	36	15	0.%	0.%	0.%	0.%	100.%	0	0	0
DOAR*										
NE	3	6	0.%	0.%	33.3%	33.3%	33.3%	0	1	1
DPLY*										
NE	4	17	0.%	0.%	0.%	0.%	100.%	0	0	0

Table 1 (cont.)

Organization / Region	# of Sightings	# of Images	% of Total Sightings: Matched: Confirmed	Unconfirmed	Not Matchable	Intermatched	Not Yet Matched	# of Individuals: Confirmed Id'd	Other Unique Id'd	Total
EAS										
NRTH	2	84	100.%	0.%	0.%	0.%	0.%	1	0	1
EYOR*										
NE	1	16	100.%	0.%	0.%	0.%	0.%	1	0	1
FWRI										
SEUS	5	0	0.%	0.%	0.%	0.%	100.%	0	0	0
GDNR										
SEUS	12	285	83.3%	8.3%	0.%	0.%	8.3%	7	0	7
GMWSRS										
BOF	2	59	100.%	0.%	0.%	0.%	0.%	1	0	1
HDR										
MIDA	10	281	60.%	30.%	0.%	0.%	10.%	6	0	6
HEKR*										
NE	2	8	50.%	0.%	0.%	0.%	50.%	1	0	1
IFAW										
GSC	2	18	0.%	0.%	0.%	100.%	0.%	0	1	1
MIDA	2	1	50.%	0.%	0.%	50.%	0.%	1	1	2
JATO*										
NE	5	15	80.%	0.%	0.%	0.%	20.%	4	0	4
JOCA*										
JL	1	7	100.%	0.%	0.%	0.%	0.%	1	0	1
JUSK*										
NE	1	7	100.%	0.%	0.%	0.%	0.%	1	0	1
KAAC*										
NE	1	1	0.%	0.%	100.%	0.%	0.%	0	0	0
KDSE*										
SEUS	1	3	0.%	0.%	100.%	0.%	0.%	0	0	0
LAHA*										
NE	1	8	0.%	0.%	0.%	0.%	100.%	0	0	0
MADVE*										
NE	3	18	0.%	0.%	0.%	33.3%	66.7%	0	1	1
MAGA*										
NE	2	23	50.%	0.%	0.%	0.%	50.%	1	0	1
MBHFC										
SEUS	1	23	0.%	0.%	0.%	0.%	100.%	0	0	0
MICS										
NRTH	21	0	0.%	0.%	0.%	0.%	100.%	0	0	0
MMAN										
MIDA	1	12	0.%	0.%	0.%	0.%	100.%	0	0	0
NEA										
BOF	8	663	25.%	0.%	0.%	0.%	75.%	2	0	2
GSC	1	11	0.%	100.%	0.%	0.%	0.%	0	0	0
MIDA	64	818	18.8%	17.2%	0.%	1.6%	62.5%	12	1	13
NEA/CWI										
NRTH	273	5,165	61.5%	26.7%	0.%	0.%	11.7%	81	0	81
NEFSC										
GOM	4	65	100.%	0.%	0.%	0.%	0.%	2	0	2
GSC	139	1,259	23.7%	7.2%	0.%	0.%	69.1%	33	0	33
MIDA	61	393	18.%	4.9%	0.%	6.6%	70.5%	11	4	15
NE	406	2,486	11.8%	5.2%	0.%	0.2%	82.8%	38	1	39
NRTH	817	4,523	3.5%	1.5%	0.%	0.4%	94.6%	21	1	22
NEGR*										
BOF	1	35	100.%	0.%	0.%	0.%	0.%	1	0	1
NEHA*										
SEUS	1	11	0.%	0.%	0.%	0.%	100.%	0	0	0
NORM										
MIDA	1	1	0.%	0.%	100.%	0.%	0.%	0	0	0
NWW										
JL	3	6	33.3%	33.3%	0.%	0.%	33.3%	1	0	1

Table 1 (cont.)

Organization / Region	# of Sightings	# of Images	% of Total Sightings: Matched: Confirmed	Matched: Unconfirmed	Not Matchable	Intermatched	Not Yet Matched	# of Individuals: Confirmed Id'd	Other Unique Id'd	Total
OWW										
NRTH	1	14	100.%	0.%	0.%	0.%	0.%	1	0	1
PEFL*										
NE	10	38	80.%	20.%	0.%	0.%	0.%	8	0	8
QLM										
BOF	2	0	0.%	0.%	0.%	0.%	100.%	0	0	0
RAGI*										
JL	2	27	0.%	100.%	0.%	0.%	0.%	0	0	0
RICU*										
NE	12	147	8.3%	8.3%	8.3%	0.%	75.%	1	0	1
SGS										
NE	4	12	0.%	0.%	25.%	0.%	75.%	0	0	0
STAR*										
NE	2	4	50.%	0.%	0.%	0.%	50.%	1	0	1
SWT										
BOF	1	2	100.%	0.%	0.%	0.%	0.%	1	0	1
TC										
NRTH	5	80	60.%	0.%	40.%	0.%	0.%	3	0	3
TI										
BOF	1	6	100.%	0.%	0.%	0.%	0.%	1	0	1
TT-NYDEC										
MIDA	4	88	50.%	0.%	0.%	0.%	50.%	2	0	2
TTOR										
MIDA	2	11	0.%	100.%	0.%	0.%	0.%	0	0	0
UNK										
MIDA	4	46	25.%	0.%	0.%	75.%	0.%	1	1	2
URI										
MIDA	2	14	0.%	100.%	0.%	0.%	0.%	0	0	0
USCG										
GOM	1	15	100.%	0.%	0.%	0.%	0.%	1	0	1
MIDA	1	5	100.%	0.%	0.%	0.%	0.%	1	0	1
USFWS										
GSC	1	4	0.%	0.%	0.%	100.%	0.%	0	1	1
VAQF										
MIDA	2	56	100.%	0.%	0.%	0.%	0.%	1	0	1
WHOI										
MIDA	1	4	0.%	100.%	0.%	0.%	0.%	0	0	0
NE	60	0	0.%	0.%	0.%	0.%	100.%	0	0	0
Totals	**3,192**	**33,715**								

VIII. Catalog Related Publications and Reports

Since the last Catalog report on October 31, 2018, the following reports and publications that utilize data from the Catalog have been either published or submitted.

Brown MW, Zani MA, Howe KR, Hamilton PK, Knowlton AR, Kraus SD. 2018. Research, Monitoring and Conservation of the North Atlantic Right Whale (Eubalaena glacialis) in the southern Gulf of St. Lawrence and the Bay of Fundy- 2018. Report to Irving Oil. 48 pp.

Corkeron P, Hamilton P, Bannister J, Best P, Charlton C, Groch K, Findlay K, Rowntree V, Vermeulen E, and Pace R. 2018. The recovery of North Atlantic right whales, Eubalaena glacialis, has been constrained by human-caused mortality. R. Soc. open sci. 5: 180892. http://dx.doi.org/10.1098/rsos.180892

Davies KTA, Brown MW, Hamilton PK, Knowlton AR, Taggart CT, and Vanderlaan ASM. 2019. Variation in North Atlantic right whales (Eubalaena glacialis) occurrence in the Bay of Fundy, Canada, over three decades. Endang Species Res 39:159-171. https://doi.org/10.3354/esr00951

Ganley LC, Brault S, and Mayo CA. 2019. What we see is not what there is: estimating North Atlantic right whale Eubalaena glacialis local abundance. Endangered Species Research, 38, 101-113.

Gowan TA, Ortega-Ortiz JG, Hostetler JA, Hamilton PK, Knowlton AR, Jackson KA, George RC, Taylor CR, and Naessig PJ. 2019. Temporal and demographic variation in partial migration of the North Atlantic right whale. Scientific Reports 9:353. DOI:10.1038/s41598-018-36723-3

Graham KM, Burgess EA, Rolland RM. 2019. Validation of steroid hormone immunoassays for blubber in the North Atlantic right whale (Eubalaena glacialis). Report to Fisheries and Oceans Canada: Ocean Ecology Section for contract # F5211-180767

Hamilton PK and Kraus SD. 2019. Frequent encounters with the seafloor increase right whales' risk of entanglement in fishing groundlines. Endang Species Res 39: 235–246

Kenney RD. 2018. What if there were no fishing? North Atlantic right whale population trajectories without entanglement mortality. Endang Species Res 37:233-237 https://doi.org/10.3354/esr00926

Pettis HM. 2018. Monitoring injured North Atlantic right whales: December 2018 report. A report to the Volgenau Foundation. 10 pp.

Pettis HM, Pace RM, Schick RS, and Hamilton PK. 2018. North Atlantic Right Whale Consortium 2018 annual report card. Report to the North Atlantic Right Whale Consortium, November 2018. 17 pp.

Sharp SM, McLellan WA, Rotstein DS, Costidis AM, Barco SG, Durham K, Pitchford TD, Jackson, KA, Daoust PY, Wimmer T, Couture EL, Bourque L, Frasier T, Frasier B, Fauquier D, Rowles TK, Hamilton PK, Pettis H, and Moore MJ. 2019. Gross and histopathologic diagnoses from North Atlantic right whale (Eubalena glacialis) mortalities between 2003 and 2018. Dis Aquat Org 135:1-31. https://doi.org/10.3354/dao03376

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Frasier, T.R., Hamilton, P.K., Brown, M.W., Kraus, S.D., White, B.N. 2010. Reciprocal exchange and subsequent adoption of calves by two North Atlantic right whales. Aquatic Mammals. 36(2): 115-120.

Hamilton, P.K., Knowlton, A.R, and Marx, M.K. 2007. Right Whales Tell Their Own Stories: The Photo-Identification Catalog. *In* Kraus, SD and Rolland, RM (eds). The Urban Whale: North Atlantic Right Whales at the Crossroads. Harvard University Press. 514 pp.

Knowlton, A. R., and Kraus, S. D. 2001. Mortality and Serious Injury of Northern Right Whales (*Eubalaena glacialis*) in the Western North Atlantic Ocean. J. Cetacean Res. Manage., (Special Issue) 2), 193-208.

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, 2018 as of September 4, 2019.

A detailed breakdown of the matching status of all sightings from 1999 to 2018. 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 2018 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
1999	119		1950	94	2163	94.50%	94.50%
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	57		2118	231	2406	97.63%	97.63%
2004	19	1	1706	113	1839	98.97%	98.91%
2005	7		3261	140	3408	99.79%	99.79%
2006	22		2679	101	2802	99.21%	99.21%
2007	46		3602	120	3768	98.78%	98.78%
2008	13		4011	135	4159	99.69%	99.69%
2009	60		4521	117	4698	98.72%	98.72%
2010	24		3143	68	3235	99.26%	99.26%
2011	61	1	3310	107	3479	98.25%	98.22%
2012	62	1	2006	58	2127	97.09%	97.04%
2013	96		1745	64	1905	94.96%	94.96%
2014	109	2	2209	82	2402	95.46%	95.38%
2015	102	3	1604	65	1774	94.25%	94.08%
2016	52	7	2127	25	2211	97.65%	97.33%
2017	127	11	2837	152	3127	95.94%	95.59%
2018	2517	248	680	8	3453	27.11%	19.92%

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	Catch all area for unusual eastern sightings
			ESS	East Scotian Shelf
GOM	O	Gulf of Maine, North of Cape Anne other than Jeffreys Ledge (Mt. Desert Rock, etc.)	GB	George's Bank
			GMB	Grand Manan Banks
			GOM	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	Delaware Bay
			DEL	Delaware
			MD	Maryland
			NC	North Carolina
			NJ	New Jersey
			NY	New York
			SC	South Carolina
			SNE	Southern New England
			VA	Virginia
NE	M	New England (Cape Cod and Massachusetts Bays)	CCB	Cape Cod Bay
			MB	Massachusetts Bay
NRTH	N	North of 46 degrees	CFG	Cape Farwell Grounds
			GSL	Gulf of St. Lawrence
			ICE	Iceland
			NRTH	Catch all for all other northern sightings
RB	R	Roseway Basin	RB	Roseway Basin
SEUS	S	Southeast (Georgia, Florida, Gulf of Mexico)	FL	Florida
			GA	Georgia
			GMEX	Gulf of Mexico
UNK	X	No region or area listed	UNK	Unknown

Appendix III. Abbreviations for 63 data contributors from December 1, 2017 through November 30, 2018.
"*" indicates the sighting was contributed by an individual, not an organization.

Abbreviation	Primary Contact	Organization Name (if applicable)
ALFA*	Alexander Falk	
ANSA*	Andy Sanford	
BC*	Brian Chmielecki	
BHC	Laura Howes	Boston Harbor Cruises
BIWSC	Shelley Barnaby (Longergan)	Briar Island Whale & Seabird Cruises
BJ*	Billy Johnson	
BLPE*	Blair Perkins	
BRRO*	Bruce Robertson	
BRWI*	Brian Will	
CCG		Canadian Coast Guard
CCS	Brigid McKenna	Center for Coastal Studies
CHHY*	Charity Hyatt	
CMARI	Melanie White	Clearwater Marine Aquarium Research Institute
CWI	Moe Brown	Canadian Whale Institute
CWR	Mackie Greene	Campobello Whale Rescue
DECA*	Dennis Canfield	
DFO	Stephanie Ratelle, Pam Emery and others	Department of Fisheries and Oceans & Bedford Institute of Oceanography/Ocean and Ecosystem Sciences Division
DOAR*	Donna Ardizzoni	
DPLY*	Doug Lyon	
EAS	Rannveig Grétarsdóttir	Elding Adventures at Sea
EYOR*	Eyal Oren	
FWRI	Katie Jackson and Tom Pitchford	Florida Wildlife Research Institute/ FL. Fish & Wildlife Conservation Commission
GDNR	Clay George	Georgia Dept. of Natural Resources
GMWSRS	Andrew Westgate and Heather Koopman	Grand Manan Whale and Seabird Research Station
HDR	Mark Cotter	HDR Environmental
HEKR*	Heather Coates-Krawitz	
IFAW	Misty Niemeyer	International Fund for Animal Welfare
JATO*	Jayne Todd	
JOCA*	John Cannon	
JUSK*	Justin Skaife	
KAAC*	Kathrine Accomando	
KDSE*	Kim and Dan Sells	

Appendix III. (cont.)

Abbreviation	Primary Contact	Organization Name (if applicable)
LAHA*	Larry Handler	
MADVE*	Martin Del Vecchio	
MAGA*	Mark Garfinkel	
MBHFC	Michael Bailey	Ms. B Fishing Haven & Eco Charters
MICS	Christian Ramp	Mingan Island Cetacean Study
MMAN	Scott Leonard	Marine Mammal Alliance Nantucket
NEA	Monica Zani	New England Aquarium
NEA/CWI	Monica Zani	New England Aquarium and Canadian Whale Institute
NEFSC	Lisa Conger, Tim Cole, Allison Henry and others	Northeast Fisheries Science Center
NEGR*	Neil Green	
NEHA*	Neal Hart	
NORM	Julia Willmott	Normandeua Assoiciates Inc.
NWW	Amy Warren	Newburyport Whale Watch
OWW		Oshan Whale Watch
PEFL*	Peter Flood	
QLM	Danielle Dion	Quoddy Link Marine
RAGI*	Ray Gilbert	
RICU*	Rick Cuzner	
SGS	Randy Sigler	Sigler Guide Service
STAR*	Steve Arena	
SWT	Peter Wilcox	Sea Watch Tours
TC	Stephanie Ratelle (DFO)	Department of Fisheries and Oceans/Atlantic Science Enterprise Centre
TI	Stephen Robinson	Top of the Island Boat Tours
TT-NYDEC	Ann Zoidis	Tetratech
TTOR	Tony Lima	The Trustees of Reservations
UNK		Private individuals- images pulled from social media. Unsuccessful in locating the observer.
URI	Christopher Orphanides	University of Rhode Island
USCG		U.S. Coast Guard
USFWS		U.S. Fish and Wildlife Service
VAQF	Sue Barco	Virginia Marine Science Museum
WHOI	Michael Moore	Woods Hole Oceanographic Institution

Task 2: Final Report on 2017 Right Whale Entanglement Scar Coding Efforts

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Overview

This report summarizes right whale entanglement scarring analyses for 2017 using sightings from the North Atlantic Right Whale Consortium (NARWC). The goal is to compare the frequency and rate of 2017 scarring levels to those of 2010-2016 (data provided in previous reports) as well as to the prior 30 years of data, as reported by Knowlton et al. (2012). As part of this annual review, we have categorized each new entanglement event by injury severity levels (minor, moderate, and severe as defined in Knowlton et al. (2016; see Appendix 1)) and compared 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 are provided.

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 details of 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 2017 and any new, pre-2017 sightings added to the catalog since the 2018 report. Scar coding was also performed for any new whales added to the catalog with sightings up to and including 2017. In addition to calculations of annual population entanglement rates and detection of new entanglement interactions, explanations are provided below for several analyses that are described in the papers mentioned above and presented in this report for the 2017 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., 2016/2017) 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 interaction 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 entanglement interaction (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 a review of the draft 2017 Atlantic Large Whale Entanglement Report (Morin et al. 2019) which includes an assessment of gear type and country of origin for all whales with gear attached. 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-1980-2017 (only 7 events pre-1980), as well as those that were documented in 2017 only, are provided below:

- Total number of animals reviewed in all years: **746**
    - # of batches analyzed (one batch equals all sightings of an individual grouped within each area/season in a given year) – all years: **19,012**
    - 2017 batches analyzed: **691**
- Number of separate entanglement interactions all years pre-1980-2017: **1,545**
    - 2017 interactions: **62**
- Percentage of population entangled at least once: 642/746 **86.1%**
    - # of females in the population through 2017: **313**
    - % of females entangled at least once: 275/313 **87.9%**
    - # of males in the population through 2017: **357**
    - % of males entangled at least once: 334/357 **93.6%**
    - # of unknown sex in the population through 2017: **76**
    - % of unknown sex entangled at least once: 33/76 **43.4%**

An additional 14 events were added from previous years: one in 2006; two in 2013; one in 2014; three in 2015; and seven in 2016. 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 2017; 2) recent identifications of older sightings; 3) recently added better quality images of animals which provided evidence that a certain scar visible prior to 2017 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 2010-2017 period ranged from 11.0% to 22.1% with an annual rate average of 16.7%, slightly above the 30-year average. For 2017, this rate was 17.1%, 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	432	64	14.8%
2011	443	98	22.1%
2012	379	57	15.0%
2013	291	32	11.0%
2014	376	63	16.8%
2015	260	38	14.6%
2016	322	66	20.5%
2017	**362**	**62**	**17.1%**

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 interaction 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).

For all two-year periods from 2009/2010 through 2015/2016, all the periods except for 2014/2015 were above the average of 25%. And for 2016/2017, this pattern persisted with 26.6% of adequately photographed individuals bearing evidence of new entanglement injuries or gear (Table 2).

Table 2. *Annual entanglement rate*

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%**

Timeframes of entanglement
The timeframe of entanglement detection (i.e. the maximum timeframe within which the interaction 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 75% of the entanglement detections were determined within a one-year timeframe, respectively. In 2012, this percentage increased to 80% (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 62% of the cases detected within one-year. 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	64	24 (37%)	21 (33%)	14 (22%)	3 (5%)	2 (3%)	
2011	98	35 (36%)	40 (40%)	13 (13%)	5 (5%)	2 (2%)	4 (4%)
2012	57	27 (47%)	18 (32%)	4 (7%)	4 (7%)	3 (5%)	1 (2%)
2013	32	7 (22%)	10 (30%)	7 (22%)	4 (13%)	4 (13%)	
2014	63	14 (22%)	17 (27%)	14 (22%)	8 (13%)	8 (13%)	2 (3%)
2015	38	9 (24%)	12 (31%)	7 (18%)	3 (8%)	6 (16%)	1 (3%)
2016	66	17 (26%)	16 (24%)	20 (30%)	2 (3%)	11 (17%)	
2017	**62**	**24 (38%)**	**15 (24%)**	**6 (10%)**	**11 (18%)**	**6 (10%)**	

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 interactions 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 = 64	3 (5%)	30 (47%)	29 (45%)	2 (3%)	35% 179/511
2011 n = 98	7 (7%)	51 (52%)	34 (35%)	6 (6%)	35% 178/511
2012 n = 57	1 (2%)	36 (63%)	17 (30%)	3 (5%)	31% 160/512
2013 n = 32	2 (6%)	10 (31%)	20 (63%)	0 (0%)	30% 153/514
2014 n = 63	2 (3%)	19 (30%)	42 (67%)	0 (0%)	30% 141/514
2015 n = 38	1 (3%)	12 (31%)	23 (61%)	2 (5%)	26% 135/517
2016 n = 66	4 (6%)	18 (27%)	43 (65%)	1 (2%)	23% 119/510
2017 n = 62	**0 (0%)**	**25 (40%)**	**33 (53%)**	**4 (7%)**	**20% 95/479**

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 2010-2016, all years have been above this average rate with a range from 1.4% to 3.8% and in 2017, the rate increased to 3.9% 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 2017.

In 2017, there were 14 whales with serious entanglements: nine carrying gear and five with severe injuries. Of the nine with attached gear, two (#3603, an 11- year old female and #4504, a 2 year old female) were found dead. One of the remaining seven was unable to be disentangled

(#4094, a seven-year old female) and is likely dead; three were unable to be disentangled (#1317, a 34 year old male; #3245, a fifteen year old male; #4146, a six year old female) but they apparently shed their gear and were seen alive in 2018; and three were disentangled (#3530, a 13 year old male; #4123, a 6 year old male; #4510, a 3+ year old female) and were seen alive in 2018. Although six of the nine entangled whales appear to have survived at least one year, their health will be monitored using the visual health assessment developed by Pettis et al. (2004) to assess whether their entanglements result in a decline in health. Of the five whales with severe injuries, the fate of all but one (#4140) is uncertain as each of the four were in compromised condition at their last sighting. (Table 5; Figure 1).

Table 5. *Serious entanglements (whales with gear or severe injuries only).*

	2010	2011	2012	2013	2014	2015	2016	**2017**
With attached gear	5	11*	5*	3	7*	4*	7	**9**
Severe injuries only	1	3	6	1	7	3	5	**5**
% of all sighted individuals with serious entanglements (gear + severe injuries)	1.4% (6/421)	3.2% (14/437)	2.9% (11/374)	1.4% (4/294)	3.8% (14/367)	2.7% (7/256)	3.8% (12/319)	**3.9% (14/362)**
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)**

* 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 three decades (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 2010-2017 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 22-44%). 2017 was on the high end of this range at 42% (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 have been updated.*

Year (# of events)	Minor	Moderate	Severe
2010 (n = 64)	42 (0); 66%	16 (0); 25%	6 (5); 9%
2011 (n = 99)*	69 (2); 70%	23 (5); 23%	7 (4); 7%
2012 (n = 58)*	44 (1); 76%	5(1); 9%	9 (3); 15%
2013 (n = 32)	21 (0); 66%	8 (1); 25%	3 (2); 9%
2014 (n = 65)*	42 (0); 64%	9 (0); 14%	14 (7); 22%
2015 (n = 40)+	25 (0); 62%	8 (0); 20%	7 (4); 18%
2016 (n = 66)	37 (0); 56%	17 (1); 26%	12 (6); 18%
2017 (n = 62)	**36 (1); 58%**	**16 (3); 26%**	**10 (5); 16%**

* *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 nine cases with attached gear, seven (#1317, 3530, 3603, 4094, 4123, 4504, and 4510) were able to be attributed to Canadian snow crab gear based on specific gear characteristics. One case was attributed as unknown Canadian gear (#3245) and one case was attributed to unknown U.S. gear (#4146) (Morin et al. 2019).

For scarring cases involving no gear, 15 cases occurred within a six-month period as shown in Table 7. Three of these likely occurred in U.S. waters, three in Canadian waters, and for the remaining nine, country of origin could not be determined.

With all gear and scarring-only cases combined, 24% (15 of 62 cases) could be attributed to likely country of origin - 11 occurred in Canadian waters, 4 occurred in U.S. waters, and the remaining 47 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, SNE = southern New England, MB = Massachusetts Bay, GSL = Gulf of St Lawrence, 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
3640	24-Apr-17	30-Apr-17	6	Adult male; MINOR	CCB	SNE	US
1419	29-Jun-17	21-Jul-17	22	Adult male; MINOR	GSL	GSL	Canada
2753	29-Jun-17	25-Jul-17	26	20 year old female; MODERATE	GSL	GSL	Canada
4194	30-Apr-17	27-May-17	27	6 year old male; MINOR	CCB	JL	US
1820	10-May-17	27-Jun-17	48	Adult male; SEVERE	GSL	GSL	Canada
3101	30-Apr-17	08-Jul-17	69	16 year old female; MINOR	MB	GSL	Unknown
4040	24-Apr-17	05-Jul-17	72	Unknown age female; MINOR	CCB	GSL	Unknown
3139	23-Apr-17	04-Jul-17	72	16 year old female; SEVERE	CCB	SNE	US
2642	24-Apr-17	05-Jul-17	72	21 year old female; MODERATE	CCB	GSL	Unknown
4633	04-May-17	02-Aug-17	90	1 year old female; MODERATE	CCB	GSL	Unknown
2010	17-Apr-17	21-Jul-17	95	27 year old male; MINOR	CCB	GSL	Unknown
3808	23-Apr-17	01-Aug-17	100	9 year old female; MINOR	CCB	BOF	Unknown
3623	12-Apr-17	21-Jul-17	100	11 year old male; MODERATE	CCB	GSL	Unknown
1971	17-Apr-17	29-Jul-17	103	28 year old male; SEVERE	CCB	GSL	Unknown
4617	23-Apr-17	18-Aug-17	117	1 year old female; MODERATE	CCB	GSL	Unknown

Discussion

Results from our 2017 scarring assessment indicate a total of 62 entanglement interactions including 14 serious entanglements (the highest documented serious entanglement rate over a 38-year period at 3.9%), a continued high proportion of moderate and severe injuries (42%), and a continuing decline in the juvenile population (down to 20%) likely attributable to both documented and undetected entanglement events.

The situation for right whales in 2017 took a very bad turn with the highest number of mortalities (n = 17) ever documented in a given year, including two that died from entanglement (Daoust et al. 2017). It was also a year with multiple, live whale entanglements (n = 7). Most of these mortalities and entanglements took place in the Gulf of St. Lawrence as many right whales have shifted into this unprotected habitat during the spring, summer, and fall months. While three of these live entangled whales were able to be disentangled, one of the disentanglements resulted in the tragic death of our friend and colleague, Captain Joe Howlett. This terrible event underscores the urgent need to address the entanglement issue in order to make disentanglement an unnecessary approach for saving this species, as well as other large whales throughout the world. In addition, recent analyses by Pace et al. (2017) and Pettis et al. (2018) show that the right whale population is declining quickly, with most of this decline attributable to human impacts (Sharp et al. 2019; Corkeron et al. 2018).

Although many of the entanglements in 2017 where gear was attached are known to have occurred in the Gulf of St. Lawrence, based on the results of our 2017 scarring assessment, the problem is broader and more concerning than the documented deaths and live whale entanglements indicate. Our findings from 2017 indicate that the pattern of increasing serious entanglement detections over 30 years (Knowlton et al. 2012; 2016) has continued and worsened as the rate of serious entanglements has continued to grow. Although some of this increase in serious entanglements is clearly related to the distribution shift into the Gulf of St. Lawrence and the overlap with heavy snow crab gear, there remain many unknowns about where most of these entanglements occur; yet there is still evidence that entanglements are occurring in U.S. waters as well. Data indicate entanglements in both nearshore and offshore lobster and crab gear, as well as gillnet gear. As mitigation efforts to address the snow crab gear threat in the Gulf of St. Lawrence were initiated towards the end of the 2017 fishing season, and continued into 2018 and 2019, we had hoped to see a concurrent drop in complex entanglements and severe injuries linked with this heavy gear. However, despite static and dynamic closures in that high use area in 2018 and 2019, live whale entanglements in snow crab gear, and severe injuries known to have occurred in that area, have continued and remain a serious concern for this species. We continue to be concerned that limited closures and dynamic management in the Gulf of St. Lawrence will not resolve this challenging issue. Until gear is changed to ropeless or to “whale release” ropes of 1700 lb. breaking strength, right whales, and other large whales, will be particularly vulnerable to this fishery.

Other fixed-gear fisheries in both countries also put right whales at risk. It is encouraging that NOAA Fisheries is undertaking rulemaking to address lobster and crab gear fisheries in the Gulf of Maine and southern New England where entanglements have also been documented. Addressing gillnet gear, as well as other fixed-gear fisheries in the U.S. and Canada, will be essential to ensuring a holistic approach to mitigating a threat that occurs over the broad range of right whale distribution.

In summary, this assessment of 2017 entanglement interactions shows the highest rate of serious entanglements yet documented in this 38-year study, with an increasing frequency observed in Canadian gear. The continued reality is that fishing gear entanglements occurring in both countries are decimating this small population at an unsustainable rate. The work of U.S. and Canadian fishery managers, in tandem with fishermen, scientists and engineers, will hopefully expedite changes in fishing practices broadly to prevent extinction of this species.

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__Figure 1.__ Severe injuries caused by entanglement (no attached gear) documented in 2017 (listed in order of catalog #). Note: CCS = Center for Coastal Studies, NMFS = National Marine Fisheries Service, NEAq = New England Aquarium.

Catalog #	Sex	Birth year	Date of entanglement detection (date seen prior)	Age at entanglement detection	Location when detected/Observer
1412	Female	Unknown	12 Apr 2017 (22 Jun 2003)	33+ years old	Cape Cod Bay/CCS

Description:
Prior to 2017, this scarcely seen 33+ year old reproductive female had only been documented off Iceland, the Cape Farewell Grounds, and Jeffreys Ledge. In 2017, she was seen with her third known calf in Cape Cod Bay and Great South Channel. She had extensive scarring on the peduncle including one wound that appeared to go into muscle and was unhealed. Because she is so rarely seen (previous sighting was in 2003), it is impossible to narrow down a timeframe in which the entanglement occurred. She was noted as thin but this is typical for females with a calf. Her skin condition was noted as good.

Left insertion and dorsal peduncle

Dorsal peduncle

Catalog #	Sex	Birth year	Date of entanglement detection (date seen prior)	Age at entanglement detection	Location when detected/Observer
1820	Male	Unknown	27 Jun 2017 (10 May 2017)	30+ years old	Gulf of St Lawrence/NMFS

Description:
This adult male was seen with severe, raw entanglement injuries around the peduncle and insertions. His skin was noted to be in poor condition although his body condition was ok. He was seen in 2018 and the scars have healed although his skin condition still appears poor.

Left peduncle and insertion

Catalog #	Sex	Birth year	Date of entanglement detection (date seen prior)	Age at entanglement detection	Location when detected/Observer
1971	Male	1989	29 Jul 2017 (17 Apr 2017)	28 years old	Gulf of St Lawrence/NMFS

Description:
This adult male was seen with severe, raw entanglement injuries around the peduncle. He was also coded with poor skin condition in 2017. When he was seen in 2018, his skin condition still appeared poor, and the wounds were not fully healed.

Dorsal peduncle and insertions

Dorsal peduncle and insertions

Catalog #	Sex	Birth year	Date of entanglement detection (date seen prior)	Age at entanglement detection	Location when detected/Observer
3050	Male	Unknown	19 Apr 2017 (19 Apr 2016)	17+ years old	Southern New England/NEAq

Description:
This adult male was observed with moderate to severe entanglement injuries on the dorsal peduncle and insertions. Imagery was too poor to assess health. He has not been sighted since 2017.

Dorsal flukes and insertions

Catalog #	Sex	Birth year	Date of entanglement detection (date seen prior)	Age at entanglement detection	Location when detected/Observer
3139	Female	2001	4 Jul 2017 (23 Apr 2017)	16 years old	Southern New England/Opportunistic and NEAq

Description: This 16-year-old reproductive female was observed with severe injuries on the peduncle and insertions and a deep, angled injury over the back and forward part of the peduncle. These injuries occur over a severe dorsal peduncle injury acquired when she was a calf in 2001. She was noted to be thin with poor skin condition in July 2017 and, although she was coded in poor health in April 2017 before this new injury, her health appeared to have declined even further by July. She has not been seen since 2017.

Dorsal peduncle and body

Dorsal peduncle and left tail stock

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 interaction 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 interaction. 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.

New England Aquarium

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

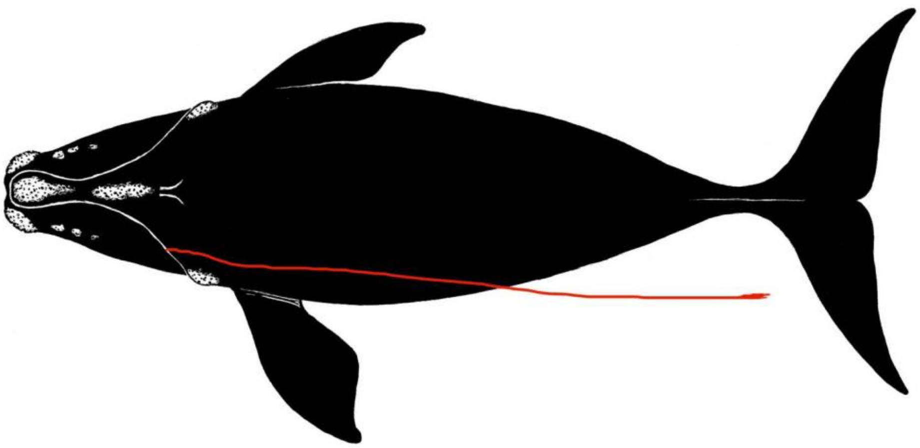
This assessment describes the layout of gear on a whale and does not take into account associated wounds. The configuration of gear on whale is generally used to assess the need for intervention, indicates how the whale may have become entangled, and may be used to make predictions about the fate of 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

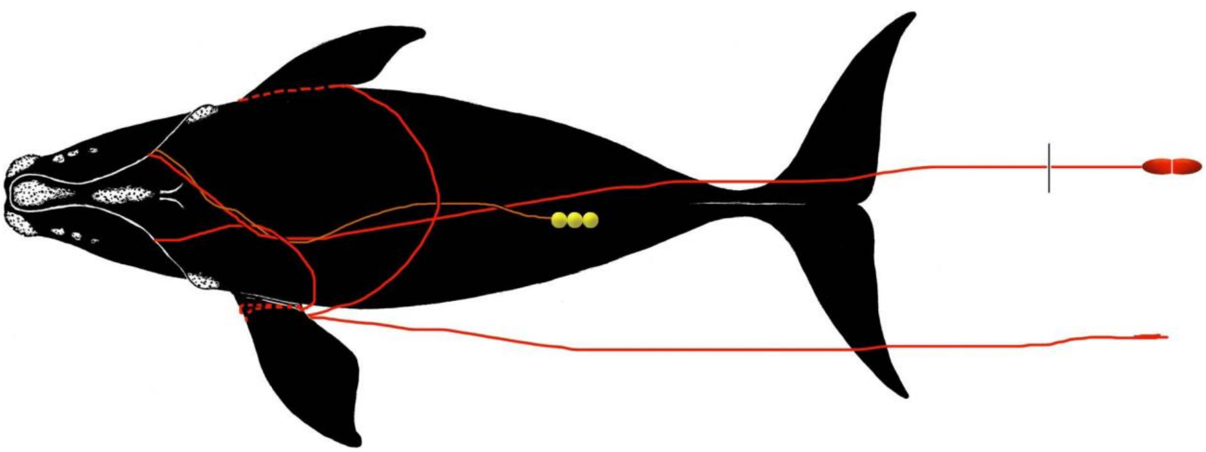
Low risk cases were those involving no tight wraps, only one attachment point, gear trailing less than one body length, and no heavy gear attached. In these cases, gear was often shed.

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, 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 2018 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 2017 events, there are now 124 case studies posted.

For 2017, we have created nine entanglement case studies. We also reviewed five 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 one case study for the 2017 timeframe. No forensic assessments were done for these whales. 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 Ib with case studies provided in Appendix IIb.

Future steps

We've 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 that 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 nine newly completed cases studies for right whale entanglements ordered by whale number.

EGNO	Retrieved Gear?	Country of origin/gear type	Date first observed entangled	Date prior	Age	Sex
1317	No	Canada/Snow crab	8 Jul 2017	(23 Apr 2017)	34	Male
3245	No	Canada/Unknown	28 Aug 2017	(25 Aug 2017)	15	Male
3530	Yes	Canada/Snow crab	5 Jan 2017	(14 Aug 2016)	13	Male
3603	No	Canada/Snow crab	21 Jun 2017	(11 Jun 2017)	11	Female
4094	No	Canada/Snow crab	19 Jul 2017	(23 Apr 2017)	7	Female
4123	No	Canada/Snow crab	10 Jul 2017	(8 Jul 2017)	6	Male
4146	No	U.S./Lobster	23 Apr 2017	(12 Apr 2017)	6	Female
4504	Yes	Canada/Snow crab	19 Sep 2017	(29 Jul 2017)	2	Female
4510	Yes	Canada/Snow crab	5 Jul 2017	(25 Jun 2017)	3+	Female

Appendix Ib. List of one newly completed case study for a right whale with vessel strike injuries.

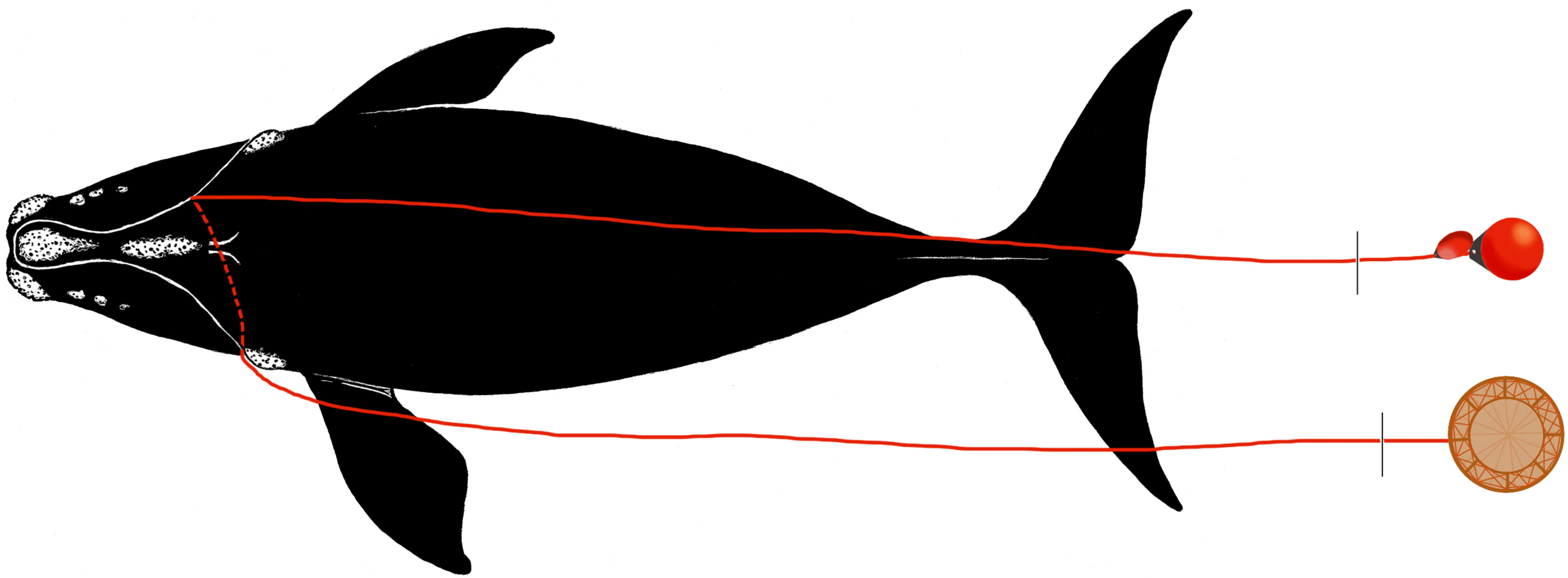
EGNO	Country of origin/vessel size	Date first observed with injuries	Date prior	Age	Sex
2145	Unknown/Small	7 Oct 2017	(14 Apr 2017)	26	Female

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

Species	Right Whale	Whale ID	1317

Date first observed entangled (date seen prior without gear)	8 Jul 2017 (23 Apr 2017)				
Sex	Male	Birth year	1983	Age at entanglement	34

Case study ID	CCS	NMFS		GEAR ID
	WR-2017-09	E09-17		
Gear sample collected?	Yes	Gear type	Canadian snow crab	

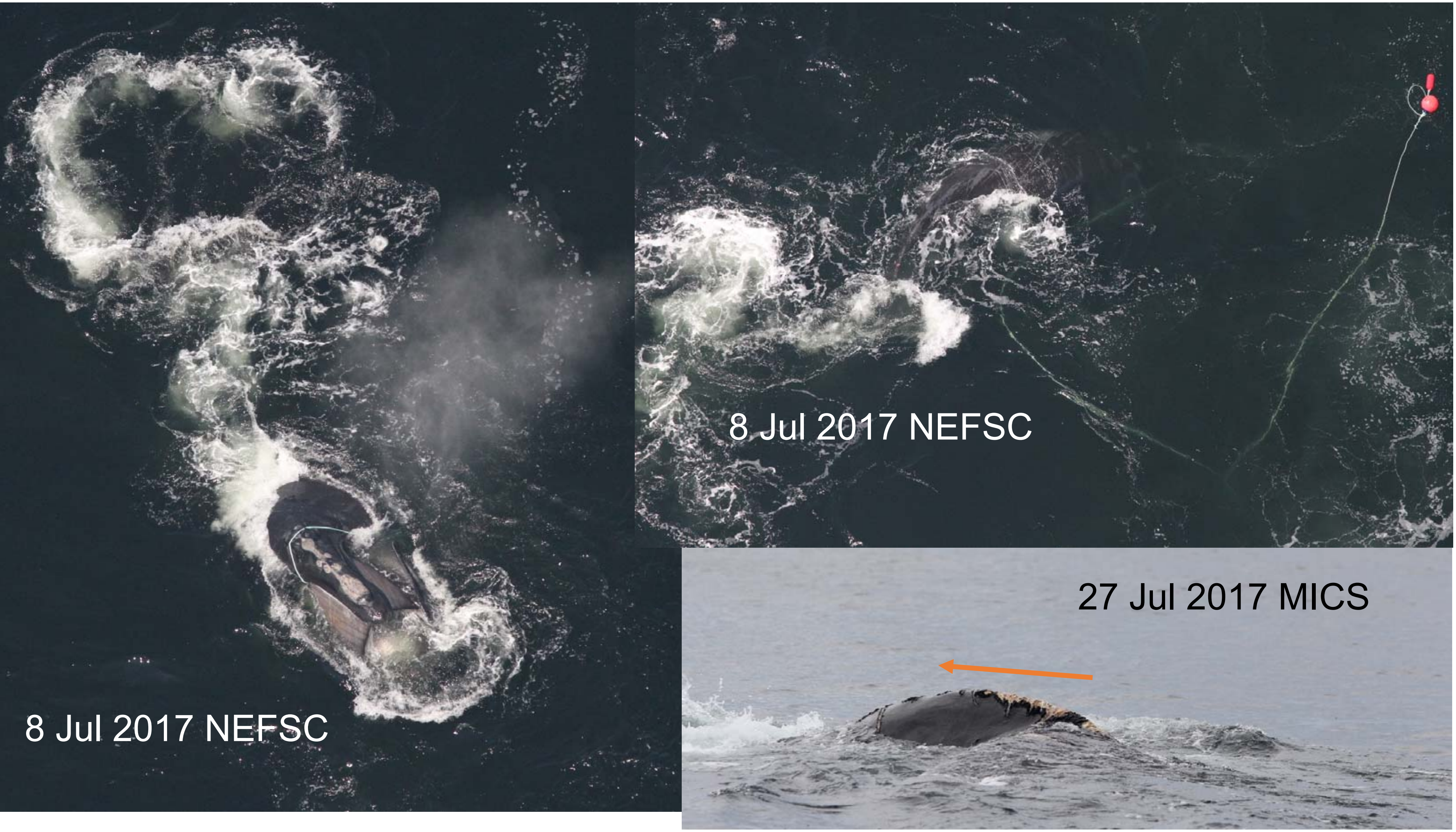


Reproductive prior to/after entanglement detection	Yes/				
Entanglement injury severity	Severe				
Entanglement configuration risk	Low				
Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	None	None	Unknown	None	High
Duration of time carrying gear	Minimum 1 day, maximum 91 days				
Disentangled?	No				
Status	Alive, last seen in 2018				
Number of prior entanglements	4				

Entanglement configuration	Single line through mouth and over rostrum
Anchoring points	Mouth
Gear configuration confidence	High
Remaining questions	Gear shed; length of buoy line not reported
Comments	Blood in water from injuries at tail stock, prob recent

Polymer type		
Gear component		End line and crab pot (per DFO)
Rope diameter (inches)		
Breaking strength (lbs)	Tested	
	New	

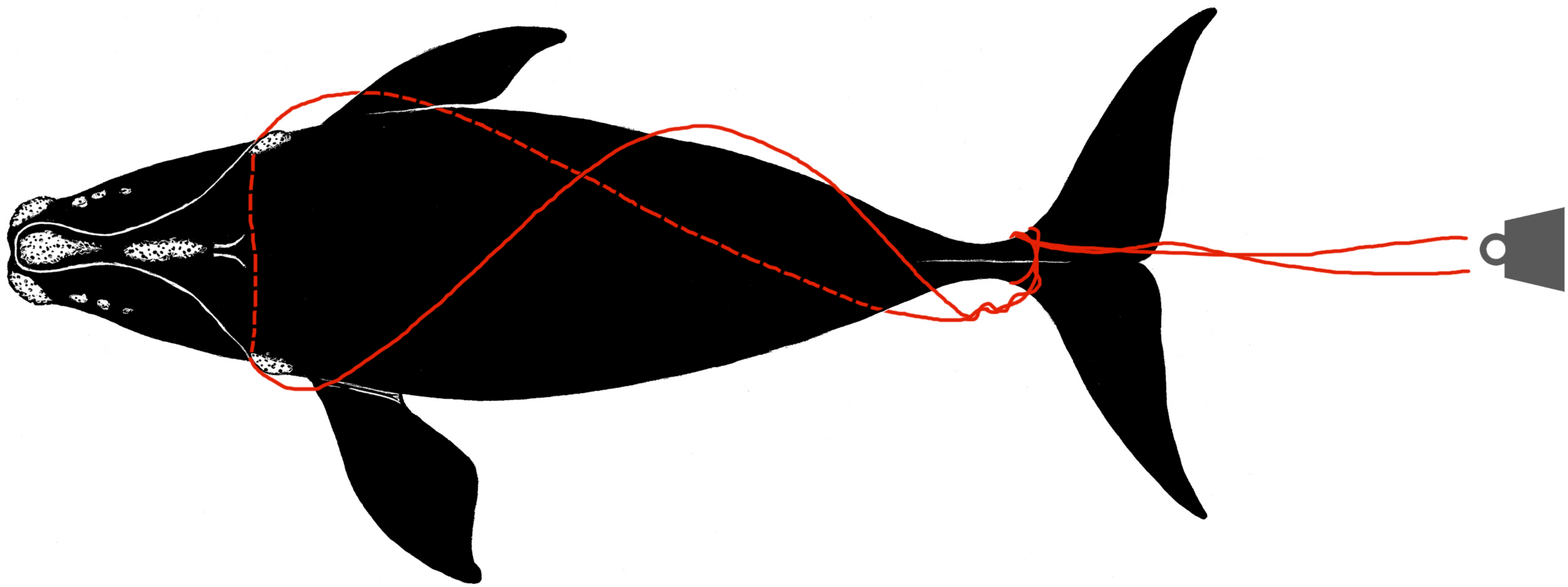
This case study was developed at the New England Aquarium with financial support from NOAA Fisheries. Whale data were provided by the North Atlantic Right Whale Consortium (www.narwc.org). All images are listed with appropriate credit information and taken under permit. Retrieved gear is assessed and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


8 Jul 2017 NEFSC
8 Jul 2017 NEFSC
27 Jul 2017 MICS

Species	Right Whale	Whale ID	3245

Date first observed entangled (date seen prior without gear)	28 Aug 2017 (25 Aug 2017)		
Sex	Male	Birth year	2002
Age at entanglement	15		

Case study ID	CCS	NMFS	GEAR ID
	WR-2017-27	E28-17	
Gear sample collected?	No	Gear type	Canadian - unknown



Reproductive prior to/after entanglement detection	
Entanglement injury severity	Moderate
Entanglement configuration risk	High

Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	None	None	Unknown	None	Medium

Duration of time carrying gear	Minimum 1 day, maximum 3 days
Disentangled?	No
Status	Alive, last seen in 2018
Number of prior entanglements	1

Entanglement configuration	Line through mouth and around peduncle
Anchoring points	Mouth, tail
Gear configuration confidence	High
Remaining questions	Weight may have been attached
Comments	Gear shed; entangled in Gulf of St Lawrence

Polymer type		
Gear component		
Rope diameter (inches)		Noted as larger diameter rope
Breaking strength (lbs)	Tested	
	New	

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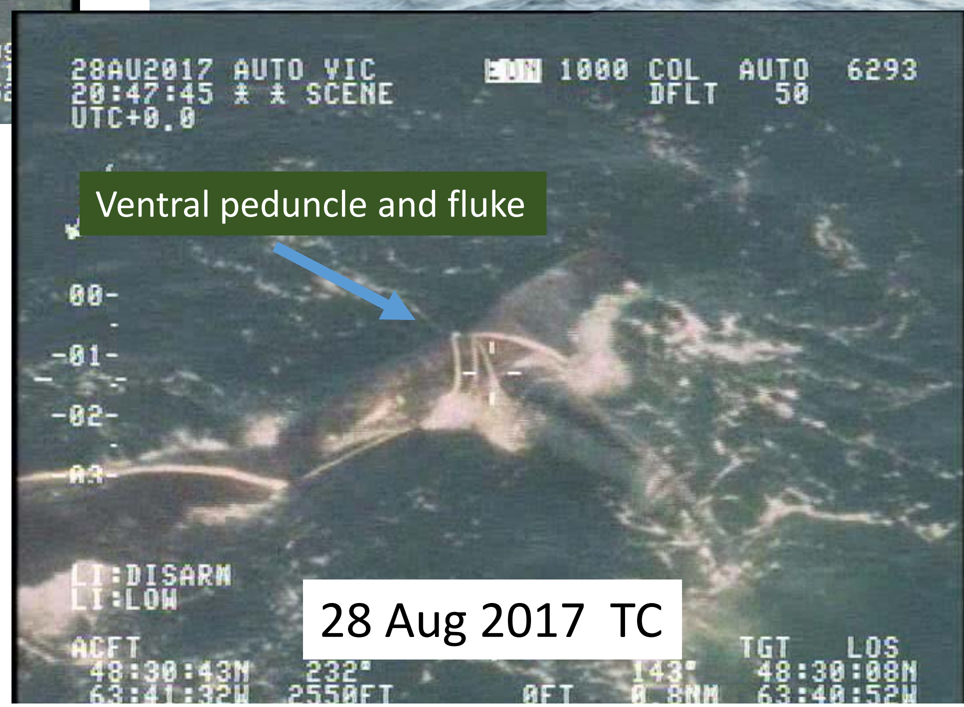
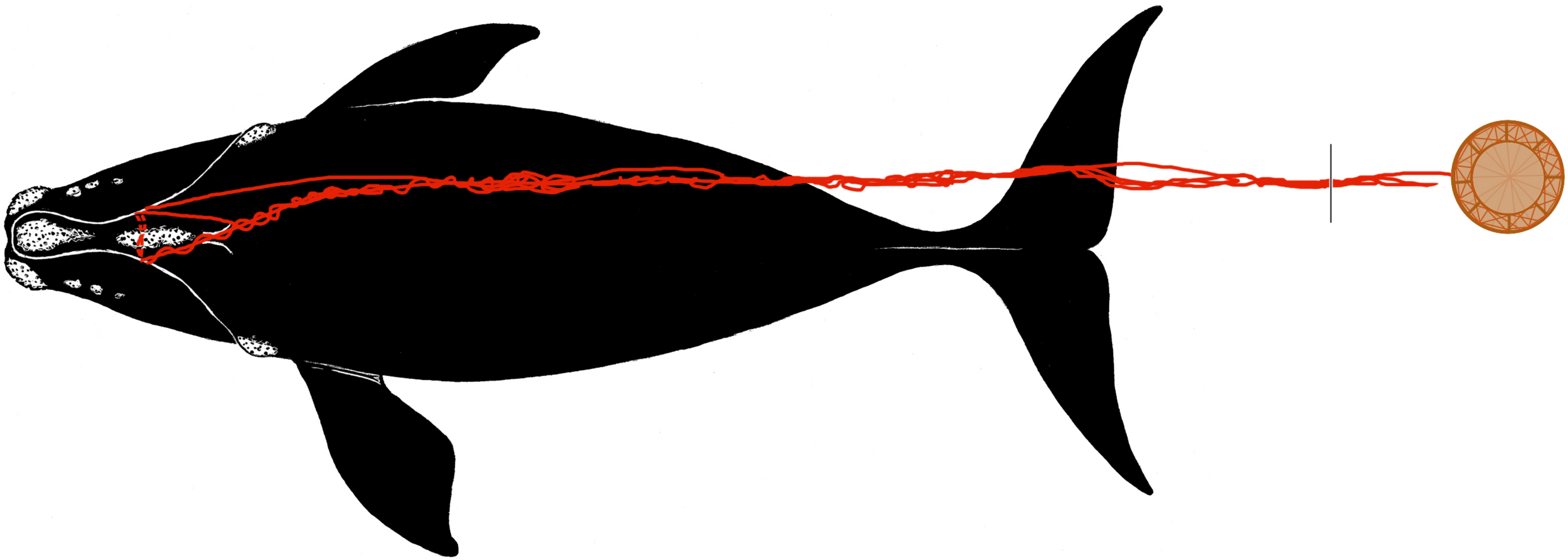
28 Aug 2017 TC



Species	Right Whale	Whale ID	3530

Date first observed entangled (date seen prior without gear)	5 Jan 2017 (14 Aug 2016)				
Sex	Male	Birth year	2004	Age at entanglement	13

Case study ID	CCS	NMFS	GEAR ID
	WR-2017-02	E02-17	
Gear sample collected?	Yes	Gear type	Canadian snow crab



Reproductive prior to/after entanglement detection					
Entanglement injury severity	Severe				
Entanglement configuration risk	High				
Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	Unknown??	Low	Unknown	Low	High
Duration of time carrying gear	Minimum unknown, maximum 143 days				
Disentangled?	Yes				
Status	Alive, last seen in 2019				
Number of prior entanglements	2				

Entanglement configuration	Two lines exiting either side of mouth forming a bridle and trailing behind whale at depth
Anchoring points	Mouth
Gear configuration confidence	High
Remaining questions	None
Comments	451 ft of endline and crab pot recovered

Polymer type		Rope assessment in progress
Gear component		Endline and crab pot
Rope diameter (inches)		
Breaking strength (lbs)	Tested	
	New	

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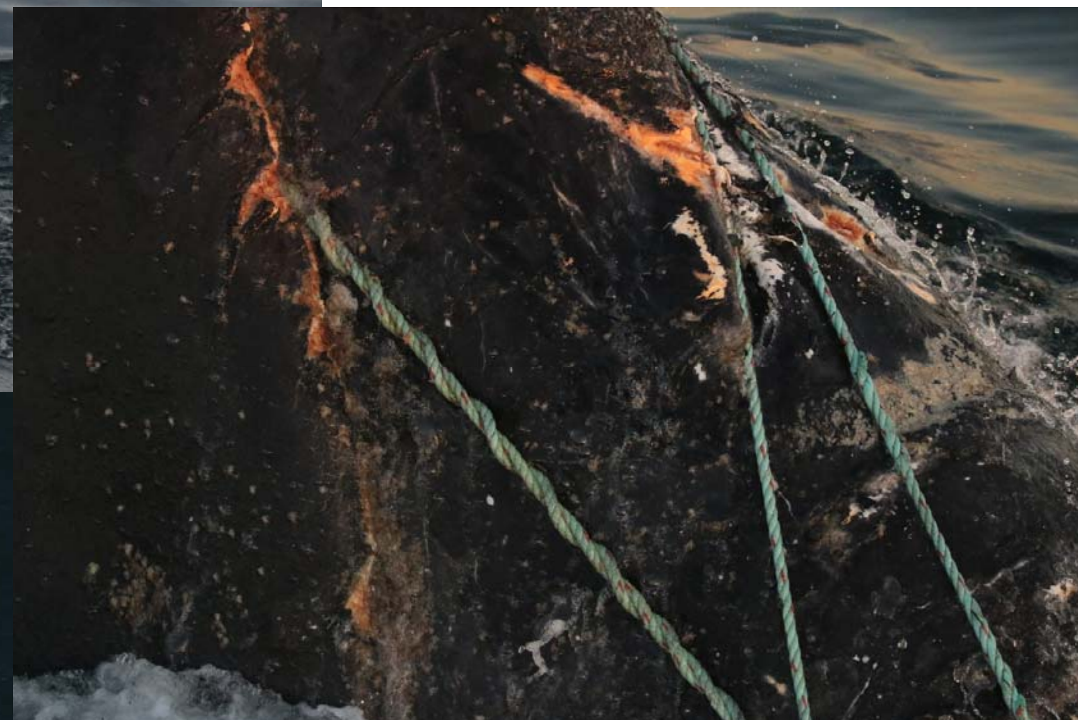
5 Jan 2017 GDNR



5 Jan 2017 FWRI

Species	Right Whale	Whale ID	3603

Date first observed entangled (date seen prior without gear)	21 Jun 2017 (23 Apr 2017)		
Sex	Female	Birth year	2006
Age at entanglement	11		

Case study ID	CCS	NMFS	GEAR ID
		E05-17	
Gear sample collected?	No, except buoy #s	Gear type	Canadian snow crab

No drawing available

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

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

Duration of time carrying gear	Minimum 1 day, maximum 10 days
Disentangled?	No
Status	Dead
Number of prior entanglements	2

Entanglement configuration	Multiple ropes with buoys attached through mouth, around both flippers and across ventrum
Anchoring points	Mouth, flippers
Gear configuration confidence	Low
Remaining questions	At least 2 sets of gear, maybe 4.
Comments	Found anchored in gear, dragged first gear 8 miles

Polymer type		
Gear component		Buoys and end line
Rope diameter (inches)		
Breaking strength (lbs)	Tested	
	New	

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22 June 2017 NOAA/NEFSC

Species	Right Whale	Whale ID	4094

Date first observed entangled (date seen prior without gear)	19 Jul 2017 (23 Apr 2017)				
Sex	Female	Birth year	2010	Age at entanglement	7

Case study ID	CCS	NMFS	GEAR ID
	WR-2017-13	E13-17	
Gear sample collected?	No	Gear type	Canadian snow crab

No drawing available

Reproductive prior to/after entanglement detection				Yes/No	
Entanglement injury severity				Severe	
Entanglement configuration risk				High	
Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	Medium	Medium	Unknown	High	High
Duration of time carrying gear	Minimum 1 day, maximum 86 days				
Disentangled?	No				
Status	Likely dead - not seen since 2017				
Number of prior entanglements	2				

Entanglement configuration	Single line through mouth and trailing about 1 body length to a poly buoy
Anchoring points	Mouth
Gear configuration confidence	[2ǿ
Remaining questions	Unclear if weighted gear attached aft of buoy
Comments	Whale in poor condition, deep injuries at tail

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

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19 July 2017 NOAA/NEFSC

Species	Right Whale	Whale ID	4123

Date first observed entangled (date seen prior without gear)	9 Jul 2017 (8 Jul 2017)				
Sex	Male	Birth year	2011	Age at entanglement	6

Case study ID	CCS	NMFS	GEAR ID	
	WR-2017-10	E10-17		
Gear sample collected?	No	Gear type	Canadian snow crab	

No drawing available

Reproductive prior to/after entanglement detection					
Entanglement injury severity	Moderate				
Entanglement configuration risk	High				
Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	Unknown	None	Unknown	Low	Medium
Duration of time carrying gear	Minimum 2 days, maximum 3 days				
Disentangled?	Yes - July 10, 2017				
Status	Alive, last seen in 2018				
Number of prior entanglements	1				

Entanglement configuration	Multiple wraps of endline and buoy around body with weighted gear heading to seafloor
Anchoring points	Unsure if mouth and/or flippers involved
Gear configuration confidence	Low
Remaining questions	
Comments	Whale appeared to be semi-anchored

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

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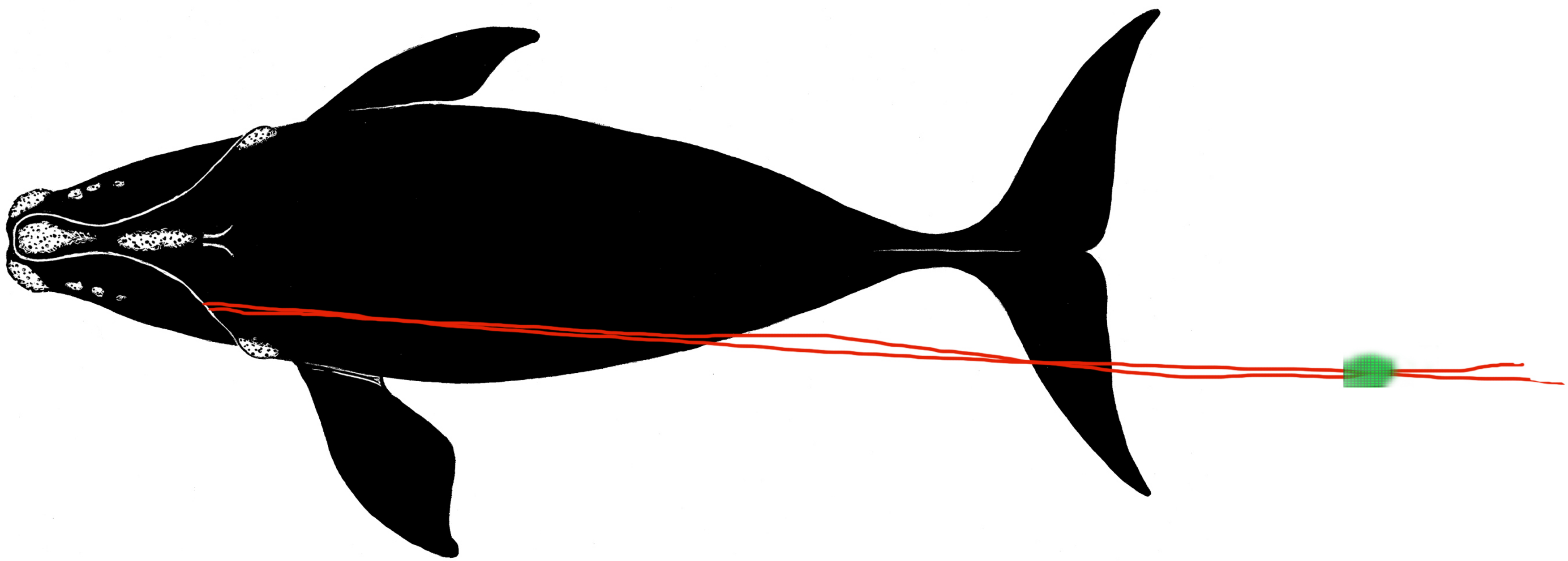
10 July 2019 NOAA/NEFSC

Species	Right Whale	Whale ID	4146

Date first observed entangled (date seen prior without gear)	23 Apr 2017 (12 Apr 2017)		
Sex	Female	Birth year	2011
Age at entanglement	6		

Case study ID	CCS	NMFS	GEAR ID
	WR-2017-03	E03-17	
Gear sample collected?	No	Gear type	US lobster



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

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

Duration of time carrying gear	Minimum 1 day, maximum 12 days
Disentangled?	No
Status	Alive, last seen in 2018
Number of prior entanglements	1

Entanglement configuration	Line caught left side of mouth and trailing ~1 body length. Whale moving fast in Cape Cod Bay, fresh scars on tail.
Anchoring points	Mouth
Gear configuration confidence	High
Remaining questions	
Comments	Gear eventually shed

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

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23 April 2017 CCS

Species	Right Whale	Whale ID	4504

Date first observed entangled (date seen prior without gear)	15 Sep 2017 (29 Jul 2017)		
Sex	Female	Birth year	2015
Age at entanglement	2		

Case study ID	CCS	NMFS	GEAR ID
		E31-17	
Gear sample collected?	Yes	Gear type	Canadian snow crab

No drawing available

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	Medium	Unknown

Duration of time carrying gear	Minimum 1 day, maximum 47 days
Disentangled?	No
Status	Dead
Number of prior entanglements	0

Entanglement configuration	Three lines through mouth and two wraps around body and flippers; may have drowned in gear
Anchoring points	Mouth, flipper
Gear configuration confidence	Low
Remaining questions	Old pot but new ropes - not sure if derelict or active
Comments	499 ft line in 3 sections of 3/4 in and 7/8 in

Polymer type		Uncertain but will presume polypro/polyester (weakest)
Gear component		End line and crab trap
Rope diameter (inches)		3/4 (0.7848); 7/8 (0.875)
Breaking strength (lbs)	Tested	
	New	8 500; 10 225

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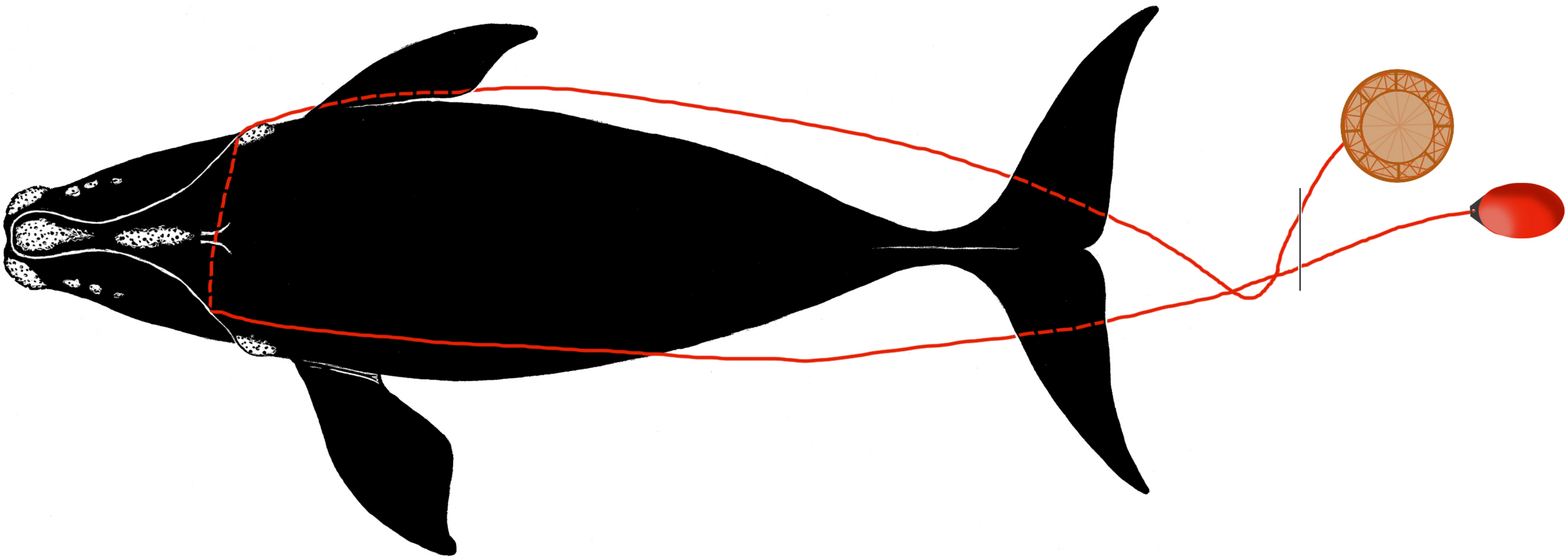
15 Sep 2017 DFO


19 Sep 2017 Unk

Species	Right Whale	Whale ID	4510

Date first observed entangled (date seen prior without gear)	5 Jul 2017 (25 Jun 2017)		
Sex	Female	Birth year	
Age at entanglement	3+		

Case study ID	CCS	NMFS	GEAR ID
	WR-2017-06	E06-17	
Gear sample collected?	Yes	Gear type	Canadian snow crab



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

Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	Unknown	Low	Unknown	Unknown	Medium

Duration of time carrying gear	Minimum 1 day, maximum 9 days
Disentangled?	Yes
Status	Alive, last seen in 2018
Number of prior entanglements	0

Entanglement configuration	Rope and buoy exiting left mouth and fouled on line out of right mouth and going to weight at depth; anchored/dragging gear
Anchoring points	Mouth
Gear configuration confidence	High
Remaining questions	
Comments	Extensive rope burn on body, raw wounds at tail

Polymer type		
Gear component		End line and crab trap (per DFO)
Rope diameter (inches)		
Breaking strength (lbs)	Tested	
	New	

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5 July 2017 NEA/CWI

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

Species	**Right Whale**
Whale ID #	**2145**
Necropsy/Other ID #	

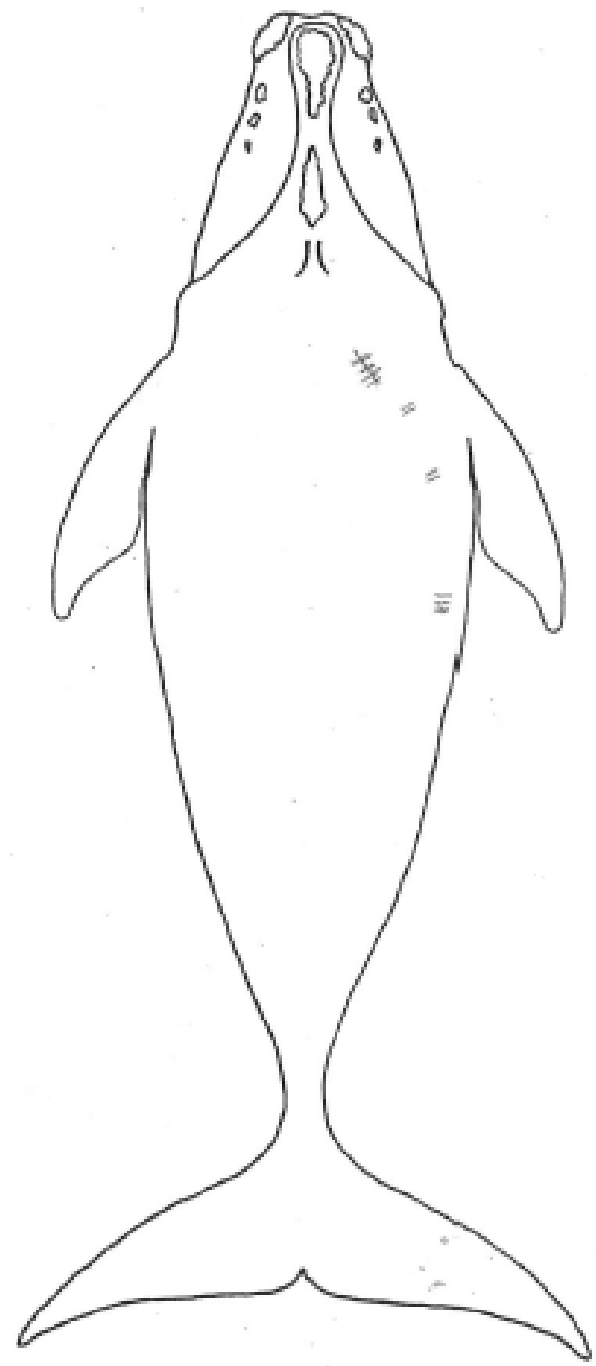
Sex	Female
Birth Year	1991

Age at Detection w/ Injury	26
Date First Detected w/ Injury	7 Oct 2017
Date Seen Prior w/o Injury	(14 Apr 2017)

Reproductive Prior Injury Detection	Yes
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? - not seen since 2017
MMPL Vessel Size Category	
Vessel Size Range	Analysis has not been done
Max Wound Length (cm)	

Vessel Related Comments	Several small propeller cut series on right shoulder.
Whale Related Comments	Whale thin and in poor condition but seems to be unrelated to this interaction as she had shown signs of delcine beginning in 2016.



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College of the Atlantic   7 Oct 2017

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

Prepared by:
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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, 2018 to August 30, 2019. The biopsy portion of this task initially focused primarily on the southeast U.S., but has since expanded. Last year, there were dedicated biopsy efforts on the calving ground off the southeastern U.S. (although very few were sighted), in Cape Cod Bay in the spring, and in the Gulf of St. Lawrence and Bay of Fundy in the summer. 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 provided year-round for sick, injured, entangled, or dead right whales allows necropsy teams to be alerted to any individual-specific data that should be collected from dead whales and provides information on the last time a whale was seen alive/healthy/gear-free, potentially indicating where the harmful event took place. 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 2018/2019 season was sent to all survey teams on November 15, 2018, along with a list of all right whales that needed to be biopsied (i.e. have a skin sample collected for genetic analysis). Further, copies of a newly exported E Catalog were hand delivered to survey team leaders on November 8, 2018.

For the southeast, images of 16 unique whales were reviewed. We were able to match/confirm all to the Catalog. 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. Six of the seven calves of the year were biopsied on the calving ground (the seventh was biopsied in Cape Cod Bay in the spring). None of the nine non-mother/calf pairs needed to be biopsied. A list of biopsied animals is included as Appendix II.

We also performed rapid matching for darting efforts in Cape Cod Bay and the Gulf of St Lawrence. Either on the boat or within a day or two of the sightings, we matched 32 of the 41 sightings collected during the joint Northeast Fisheries Science Center/New England Aquarium biopsy effort in Cape Cod Bay. This was extremely helpful in targeting darting candidates among the multitude of whales in the Bay. There were two successful dartings (three others occurred when the NEAq team was not on the boat).

In the Gulf of St. Lawrence, both Mingan Island Cetacean Studies (MICS) and the NEAq/Canadian Whale Institute teams were ready to biopsy. For the former effort, we matched the first sighting of each of the four whales they saw in 2019, and then the MICS team were able to intermatch the re-sightings of those whales. One whale needed to be re-darted, but he was only seen on their last day on the water, so no darting attempt was made. For the latter effort, we rapidly matched 510 of the 544 NEAq/CWI sightings for a total of 110 unique individuals. Out of the 110 whales, four needed to be darted and five others needed to be re-darted. We were able to successfully dart three whales: two that had eluded us for years and one young whale that we hope will genetically match a calf from recent years. The Gulf of St. Lawrence matching was facilitated by a list of whales seen in the Gulf by the NEFSC aerial survey team.

Entangled or Entrapped Whales
During this contract period, there were five newly entangled live right whales, three previously entangled, and no entrapped right whales (Table 1).

Table 1. List of three previously entangled whales and five newly entangled or entrapped whales that were first reported between September 1, 2018 and August 31, 2019 for which matching attempts or confirmations were made quickly.

Date	**Incident**	**ID**	**Location and comments**	**ID Date**	**Darted previously?**
12/12/18	First entangled	2310	Southeast of Nantucket	12/20/18	Yes
12/30/18	Still entangled	3843	South of Nantucket, first entangled 7/30/18	12/31/18	Yes
01/13/19	Still entangled	4091	South of Nantucket, first entangled 5/12/18, 2019 images shared 1/23/19	01/23/19	Yes
04/25/19	First entangled	4423	Great South Channel	04/25/19	Yes
06/29/19	First entangled	4440	Gulf of St. Lawrence	06/29/19	Yes
07/04/19	First entangled	3125	Gulf of St. Lawrence	07/20/19	Yes
07/04/19	Still entangled	4423	Gulf of St. Lawrence, First entangled 4/25/19	07/05/19	Yes
08/06/19	First entangled	1226	Gulf of St. Lawrence	08/06/19	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 10 dead right whales (Table 2).

Table 2. List of matching efforts on 10 sightings of dead whales that were first reported between September 1, 2018 and August 31, 2019.

Date	Incident	ID	Location and comments	ID Date	Darted previously?
10/14/2018	Dead	3515	Georges Bank, decomposed, later genetically identified as #3515		Yes
06/04/19	Dead	4023	Gulf of St. Lawrence, "#1", matched within 30 minutes of notification	06/04/19	Yes
06/20/19	Dead	1281	Gulf of St. Lawrence, "#2"	06/20/19	Yes
06/24/19	Dead		Off Glace Bay, Cape Breton, N.S., "#8", images not sent until July 18		Unknown
06/25/19	Dead	1514	Gulf of St. Lawrence, "#3"	06/25/19	Yes
06/25/19	Dead	3815	Gulf of St. Lawrence, "#4"	06/25/19	Yes
06/26/19	Dead	3329	Gulf of St. Lawrence, "#5"	06/27/19	Yes
06/27/19	Dead	3450	Gulf of St. Lawrence, "#6"	06/28/19	Yes
07/18/19	Dead	3421	Gulf of St. Lawrence, "#7"	07/21/19	Yes
07/21/19	Dead		East of Cape Breton, N.S., "#9", can't definitively determine if the same as #8		Unknown

Injured or Sick Whales

In addition to the entangled whales above, there were three sightings of injured or sick whales for which rapid identification attempts were made during the reporting period (Table 3). Two were caused by entanglements and one was of unknown cause. Additionally, there were many unhealthy looking whales in the Gulf of St. Lawrence during the 2019 summer, which were also rapidly identified.

Table 3. List of sick or injured whales, other than those seen entangled in fishing gear, that were reported between September 1, 2018 and August 31, 2019 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?
09/11/18	Injured	4601	Off Cape Breton with pilot whales	9/11/2018	Yes
11/09/18	Sick		Off Stellwagen Bank, only a portion of callosity photographed, emaciated and covered in orange cyamids		
07/04/19	Injured	1971	Canadian Coast Guard Cutter LeBlanc reported injured whale as possibly entangled whale #4440	07/04/19	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. Some of the interesting rapid match results for opportunistic sightings during the contract period include:

1) A lone whale (#3301- adult male) head pushing in September 2018 in the Bay of Fundy, previously seen in the Gulf of St Lawrence in July;
2) Mogul (#3845- adult male) seen in June off the coast of France--he swam to Iceland in 2018;
3) A right whale (#2304- adult male) in the Bay of Fundy on May 17th, which is very early and farther north than almost any other historical sighting;
4) An adult male (#3245) seen off Hilton Head, SC on December 23rd;
5) Two whales seen in the southeastern Bay of Fundy six weeks before any were seen by dedicated surveys in and around the Grand Manan Basin (adult female #3808 on July 5 and juvenile female #4191 on July 8)--neither were seen in the Bay again;
6) A whale (#3392- adult male) seen ~50 miles southwest of the Grand Manan Basin in August by a whale watch boat and then north of the Basin five days later.

These sightings capture some of the unusual movements of right whales that have become more common in recent years.

Discussion

Our matching support for the calving ground was minimal this year with only sixteen animals seen. Nevetheless, field teams appreciate the list of potential mothers, which helps them identify cows quickly and thus know if a genetic sample is needed from them.

It was another challenging year for dead whales. We were able to identify seven of the ten within hours and alert the necropsy team that one (#1281- Punctuation) could have been pregnant. All of the identifications were challenging, as little to no callosity information was initially available. In only one case was a portion of the callosity seen (#1281 floating on her side). All others were belly up and required skilled matching based on ventral scars or belly patterns. There were only a few, poor-quality images for carcasses #8 and #9 – unfortunately not enough detail present to match them to each other (or confirm they were not the same carcass), let alone match them to the Catalog. Finally, the carcass of #3515 was very decomposed when first discovered and that match was attributed solely to genetics.

The real-time matching in Cape Cod Bay for the biopsy effort was further leveraged by supplying identifications to the WHOI team doing drone work. That team prefers to target specific individuals, particularly whales for which they have body measurements from other habitats or years. For the Gulf of St. Lawrence, there were additional real-time matches made to help colleagues distinguish entangled whales. The lines on two of the entangled whales were only visible from a plane and colleagues on the water were confused by multiple whales with fresh entanglement scarring thinking they were one of these two entangled whales. There were multiple occasions, including aiding a disentanglement team, that we were asked to make quick matches to address this confusion.

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 Alison Henry (Northeast Fisheries Science Center); Brigid McKenna (Center for Coastal Studies); Ester Quintana and Orla O'Brien (New England Aquarium); Christian Ramp (Mingan Island Cetacean Studies); Shelley Longergan (Brier Island Whale and Seabird Cruises); Laura Howes (Boston Harbor Cruises); Danielle Dion (Quoddy Link Marine); and Andrew Westgate and Laurie Murrison (Grand Manan Whale and Seabird Research Station).

Appendix I. List of 16 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	1204	>37	2013	Y	N	Calf seen at first sighting	2019-01-17-FWRI Eg A	18-Jan-19
2	2503	14	2014	Y	Y	Calf darted 2/8/19	2018-12-12-S2S-GA Eg A	13-Dec-18
3	2791	>32	2009	Y	Y	Calf darted 1/18/19	2018-12-17-S2S-GA Eg C	18-Dec-18
4	3270	>17	2011	Y	Y	Calf darted 2/22/19	2019-02-14-S2S-GA Eg-A	15-Feb-19
5	3317	16	2016	Y	Y	Calf darted 2/5/19	2018-12-17-S2S-GA Eg A	18-Dec-18
6	3370	>16	2009	Y	Y	Calf darted 2/18/19	2019-01-01-FWRI-A Eg D	02-Jan-19
7	4180	>9	N/A	N	Y	Calf darted 2/7/19	2019-02-05-MRC Eg A	06-Feb-19

Other whales

Count	Whale ID	Age	Sex	Darted?	Comments	Confirmed sighting	Date confirmed
1	2743	22	M	Y	Swelling on right side	2019-02-08-FWRI-A Eg A	09-Feb-19
2	3245	17	M	Y		2018-12-29-FWRI Eg A	30-Dec-18
3	3343	16	M	Y		2018-12-29-FWRI Eg D	30-Dec-18
4	3450	>15	F	Y		2018-12-07-RINE Eg A	31-Dec-18
5	3640	>13	M	Y		2018-12-29-FWRI Eg C	30-Dec-18
6	3808	11	F	Y		2018-12-12-S2S-GA Eg B	13-Dec-18
7	3815	11	F	Y		2018-12-29-FWRI Eg B	30-Dec-18
8	3892	11	M	Y		2018-12-23-S2S-GA Eg A	24-Dec-18
9	3904	10	F	Y		2018-12-17-S2S-GA Eg B	18-Dec-18

Appendix II. List of six right whales biopsied off the southeastern U.S. from December 1, 2018 to March 31, 2019.

Count	Whale	Biopsied as:	Date Confirmed
1	2019 calf of 2791	2019-01-18-FWRI-V-Eg B	19-Jan-19
2	2019 calf of 3317	2019-02-05-GDNR-Eg B	06-Feb-19
3	2019 calf of 4180	2019-02-07-FWRI-V-Eg B	08-Feb-19
4	2019 calf of 2503	2019-02-08-FWRI-V-Eg B	09-Feb-19
5	2019 calf of 3370	2019-02-18-FWRI-V-Eg B	20-Feb-19
6	2019 calf of 3270	2019-02-22-FWRI-V-Eg B	23-Feb-19

Task 5: Final Report on 2017 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 2018. 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, one year of health data (2017) was analyzed and the VHA Database is considered complete through 2017.

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 743 batches consisting of 40,048 images from 3,075 sightings of 368 individual right whales were evaluated and scored for visual health parameters for this update (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).

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
1956	1	1	**1**
1958	1	1	**1**
2008	5	5	**5**
2013	3	9	**1**
2014	5	27	**3**
2015	17	39	**10**
2016	24	180	**15**
2017	687	2813	**360**
Total	743	3075	368*

*The total number of right whales assessed during this update was 368, including repeat samples of individual whales in multiple years

Database Overview
The updated VHA Database contains 18,985 batches consisting of 68,072 sightings from 1935-2017. The number of batches and associated sightings available to be assessed has varied annually (Figure 1, sample period 1980-2017 shown).

The percentage of sightings photographed by aerial and shipboard platforms has changed over time (Figure 2), with an increasing trend in aerial sightings. Between 1980–1999, 83% of right whale sightings were observed via shipboard platforms. Since then, only 43% 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 shipboard sightings increased in 2016 to more than 50% of the sightings for the first time since 2006, but in 2017 that proportion once again dipped below 50%. In fact, 2017 represents the highest proportion of aerial sightings (68.1%) in this study period. Though relatively insignificant in number, sightings of right whales from land and drone are represented in the database (total of 634 and 82 of 67,993 sightings, respectively, from 1980-2017).

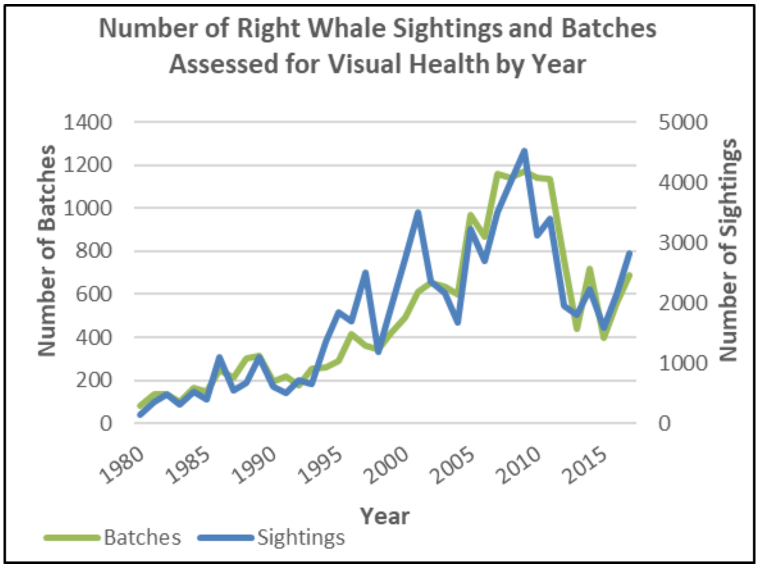

Figure 1. Count of North Atlantic right whale sightings and batches by year in the Visual Health Assessment Database 1980-2017.

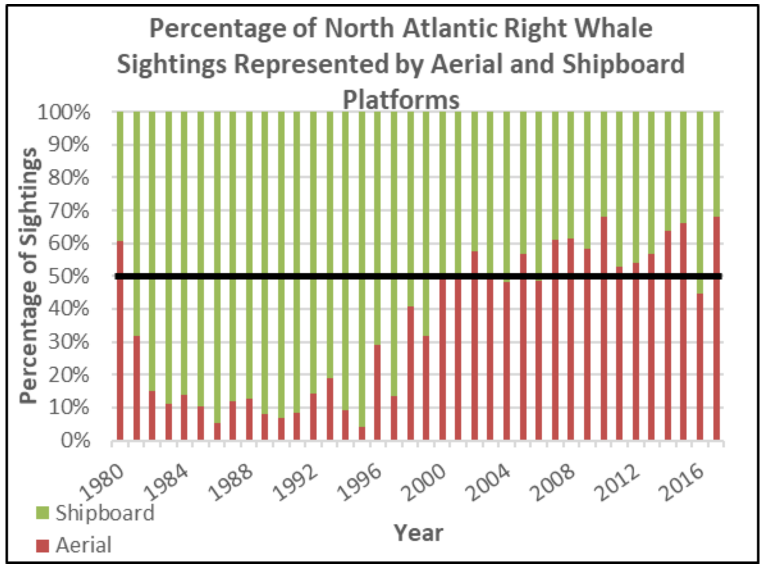

Figure 2. Percentage of North Atlantic right whale sightings scored for VHA represented by aerial and shipboard platforms between 1980- 2017. 50% line included in black. Land and drone based sightings are excluded from this analysis as they represent a relatively insignificant number of annual sightings (634 and 82 of 67,993 sightings, respectively, assessed between 1980-2017 were land based).

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 2017, the annual percentage of presumed alive right whales with scored skin condition ranged from 37.9–82.4%. The percentage of presumed alive right whales with scored body condition was consistently lower than that of skin condition and ranged from 22.2–70.3% annually.

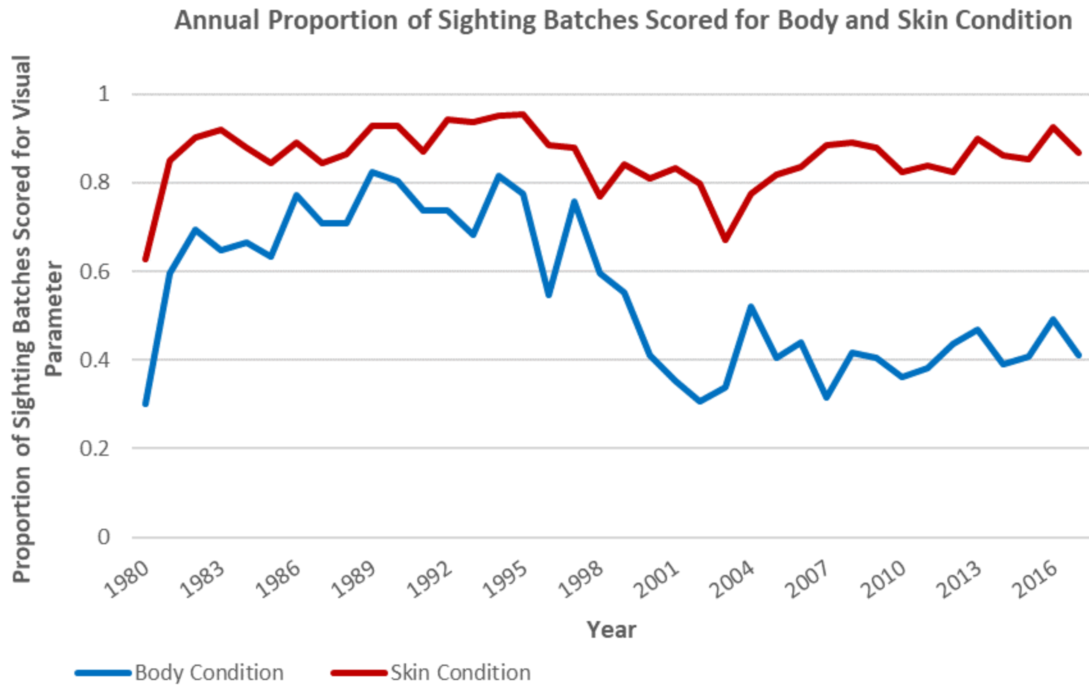

Figure 3. Annual proportion of right whale sighting batches that were successfully scored for skin and body condition, 1980-2017.

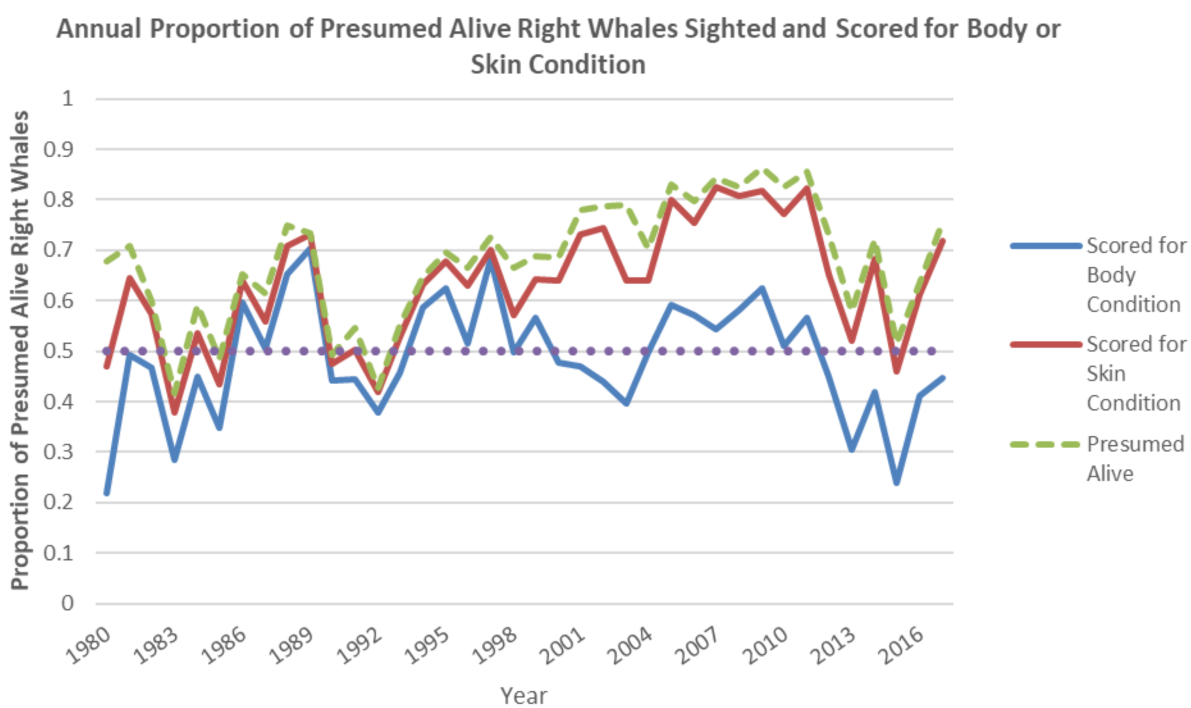

Figure 4. Annual proportion of presumed alive right whales that were seen and scored for skin and body condition by year, 1980-2017. Dashed line represents 50% presumed alive population.

The incidence of compromised skin and body condition detected visually in North Atlantic right whales varied by year with peak incidences 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.

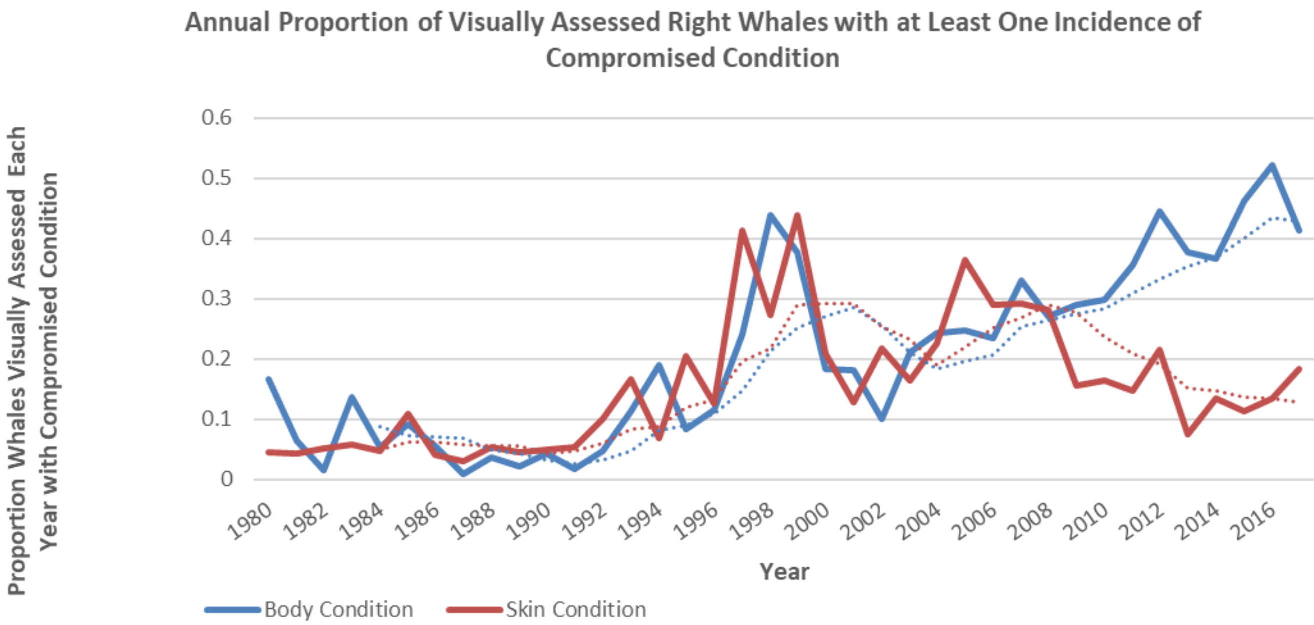

Figure 5. Annual proportion of right whales with compromised skin and body condition. Incidence was defined as at least one sighting batch for an individual right whale scored as compromised for skin or body condition by year, 1980-2017. Reproductive females were excluded from the body condition analysis in each of their calving years. Stippled lines represent 5-year rolling average.

Discussion

Visual health data for 368 right whales (up from 324 in 2016) 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. Assess limpet tagged whale visual health before and after tagging
2. Determine the potential role of body condition in right whale carcass detection rates
3. Use VHA data as predictors in a state-space mark-recapture model for survival and reproduction

Additionally, the VHA Database is currently being used to inform Bayesian model estimates of entanglement impact on right whale survival and reproduction.

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 2017. 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 and 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). 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 increased in both 2016 and 2017, 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 understanding changes in individual and population wide health over time, but also to adequately monitoring 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 two 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, and to more thoroughly assess body condition.

For much of the study period between 1980-2017, the fluctuations in the incidence 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 2017, 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 worth noting, and encouraging to see, that the incidence of compromised body condition did decrease in 2017 compared to spikes in 2015 and 2016. If right whales are finding habitats that remain stable in quality prey resources inter-annually, we would expect that this decreasing trend continue.

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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