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 2020 using data as of September 1, 2021. The entanglement scar coding (Task 2) reports on data for 2019 and compares 2019 findings to previous years. Anthropogenic case study reports (Task 3) describe cases first documented in 2019. The near-real-time matching (Task 4) reports on matching efforts from September 1, 2020 to August 31, 2021. Finally, the visual health coding (Task 5) reports on data through 2019, with some newly added data prior to 2019 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 each of 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 increased and, peaking with 4,919 sightings in 2019, surpassed the number contributed for any past 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 relatively low. Both of these changes have made photographically identifying and cataloging calves from recent years, and collecting genetic samples from them later as juveniles, difficult and make the assessment of survival, entanglement rates, scarring rates, and visual health more challenging. It is particularly important that the genetic sampling work on the calving ground continue in order to link calves to post-calf sightings and thus maintain data on age, parentage and juvenile survival. Calves that have not yet been cataloged may be cataloged years later using genetics or more recent photographs. This past year, we cataloged three calves born in 2009, 2012, and 2015 respectively- a far greater delay in cataloging than was the case in the previous decades. These calves were all cataloged based on photographic matches, but a recent study showed that there are delays of similar length in genetic identifications as well. For those calves that were biopsied as a calf and photographically identifiable, it took five years on average before they were biopsied again, thus delaying their inclusion in the Catalog (Hamilton et al. in press). We continue to work closely with the right whale geneticists at St. Mary's University to: 1) confirm that all samples that were collected are sent to the lab, 2) that those samples are correctly linked to the Catalog database, and 3) help confirm and disseminate genetic identifications when possible.

We faced a couple challenges in the last year that impacted data processing. In November 2020, the team at the Anderson Cabot Center lost our office space in response to the economic impacts of the COVID-19 pandemic on the New England Aquarium. This transition required staff time to relocate all our equipment and files as well as time for our team to adjust to working remotely full time. Another challenge was the continued large number of video sightings submitted to the Catalog. Video sightings take much longer to process as we need to pull still images and information not only to make an identification, but to capture scars, health, and behaviors. Unlike still images, video is currently stored outside of the database on separate servers and this uncoupling of image processing and the database significantly increases processing time. We are in discussions about transitioning DIGITS to a fully web-based system and incorporating video in such a way as to streamline the process substantially.

Since the last catalog report, 3,989 sightings were added to the Catalog, 2,427 identifications confirmed, and 10 new whales added. In addition, 25 whales became presumed dead (i.e. not seen in the past six years) and none were resurrected. These presumed deaths are all whales last seen in 2014 indicating that year was the beginning of a substantial increase in undocumented mortalities. There are currently 771 cataloged whales, 442 of which are presumed to be alive- a decrease of 16 from last year's report. In 2020, there were two dead whales documented compared to the ten recorded in 2019. With the change in right whale distribution, there have been increasing numbers of sightings reported opportunistically: 50 of the 86 contributors in 2020 were individuals, not organizations, many of whom do not normally collect and submit right whale images. These individuals provided over 280 sightings. Tracking down the data and images from many of these sources is challenging and time consuming- especially those only found on social media.

It should be noted that the COVID-19 pandemic impacted the number of right whale sightings collected and submitted to the Aquarium in 2020 due to canceled or delayed surveys. Because the 2020 data are not yet complete, it remains to be seen how many whales were not observed due to the resulting reduction in effort.

We accomplished several Catalog-related projects as well. With support from other sources, we developed an anthropogenic injury web-based portal to review, synthesize, and integrate data on anthropogenic injuries into the DIGITS database. Many of these data sources were formerly housed in multiple formats and locations and were not easily accessible. The web-based portal allows for streamlined entry, access, and extraction of these important data. At the same time, we continued to make adjustments to the existing Catalog database and DIGITS software. These included changes to improve the accuracy and searchability of the data as well as changes to accommodate the anthropogenic injury work.

Scarring data for 2019 showed some improvement compared to prior years with a crude entanglement rate (newly discovered entanglement scars as a proportion of whales seen) of 12.2% and an annual entanglement rate (proportion of adequately photographed whales with new scars) of 18.5%. Both of these rates are below the average crude entanglement rate of 15.5% and the 25% annual entanglement rate documented by Knowlton et al. (2012) for 1980-2009. The proportion of the cataloged population with one or more entanglements remains high at 86.8%, an increase of 0.3% from 2018. In 2019, there were 44 entanglement events, including nine serious entanglements and a continued high proportion of moderate and severe injuries (27%). At 2.5% of all sightings, the nine serious injuries represent a decline from the peak of 4.3% documented in 2018 but still remains a concern as it is double the average rate of 1.2% documented from 1980-2009.

Anthropogenic case studies were developed for one new vessel strike case and five new entanglement cases documented in 2019. These case studies include photographs and life history data, and, for the entanglement cases, rope polymer and diameter information where available. The vessel strike case has a drawing depicting the location of the wound.

Through near-real time matching, we were able to support the team on the calving ground with up-to-date list of whales needing to be darted and mothers considered available to calve, as well as provide matching support for their 62 whales, including several challenging yearlings. We continued our near-real time identification support for two research efforts in Cape Cod Bay and one in the Gulf of St Lawrence. Finally, we rapidly identified five reportedly entangled whales, two dead whales, three newly injured whales, and a new mother discovered on the feeding grounds.

Finally, visual health coding for 4,545 sightings of 380 right whales was completed since the last report, bringing the Visual Health Assessment Database up to date through 2019. Analyses of health scoring over time indicate that the distribution shift of right whales following 2010 temporarily impacted our ability to effectively monitor the health of this population. However, the annual proportion of whales presumed to be alive that were sighted and scored for health has increased since 2015, suggest that shifting survey priorities and strategies have reversed this trend. The proportion of whales with compromised body condition, while still high relative to that of skin, increased just slightly in 2019 and remained below peak levels observed in 2015 and 2016. Lastly, the prevalence of compromised skin condition has been stable since 2017. These updated health data are available to researchers and managers for various efforts, including long term and real time assessments of right whale health. Over the last year, four external requests for visual health data were granted via the North Atlantic Right Whale Consortium for projects investigating links between visual health and entanglements, hormone profiles, and other sublethal stressors. Additionally, there is ongoing work to investigate the utility of drone photography in supporting visual health assessments in habitats where traditional aerial imagery is not sufficient for assessments. Lastly, discussions and strategies to modify the scoring criteria for both body and skin condition parameters to better capture changes in condition are underway.

Task 1: Maintenance of the North Atlantic Right Whale Catalog: 01 January - 31 December 2020

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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 2020 time period and all data reported on are as of September 1, 2021. The database, as of this date, including all data prior to 2021, 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 2020)

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 retroactively entered into the Catalog. Each of these records represents a single, high-quality location for each day a cataloged, tagged whale transmitted a position.

Because NEAq is primarily responsible for photographic identifications, our Catalog reports only describe the status of photographic sightings. As of September 1, 2021, there were a total of 85,617 records from 1935 through 2020: 84,816 associated with photographs where the identification was made primarily through the photographs (even if genetic data were also available), 747 satellite tagged sightings, and 54 sightings with either genetics and no photographs (n=5) or where there were some photographs, but the identification was made primarily through genetics (n=49).

Even with recent fluctuations in the number of right whale sightings contributed to the Catalog, the number of images submitted to the Catalog annually remains high. Each of these digital images has to be reviewed and either deleted or coded for body area and view direction. In addition, the increased use of video cameras in Canada and Unmanned 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 need to review and delete excess images within DIGITS. While time consuming, this is an important step as it improves our matching efficiency.

There have been ongoing problems with timely data submission. Tracking down data and images after the fact is extremely time consuming, and we have to know a sighting exists to do so. One specific example recently is the data for entangled whale #4423 described in the Entanglement section last year. According to the Center for Coastal Studies' (CCS) private disentanglement website, this whale was first seen entangled on April 25, 2019. The NEFSC Atlantic Marine Assessment Program for Protected Species team did not submit images or data to the Catalog until December 2020- 20 months later. There was a similar issue with their sightings from 2007 that were submitted 12 years later. Given the number of people who utilize the Catalog for analyses, the long delays of these important data getting into the Catalog is unfortunate. The data submission issue used to primarily involve sightings of entangled whales, disentanglement events, mortality events, and off-season sightings where the chain of command for data submission was unclear, but now we also have issues tracking down data and images from opportunistic sightings, including those posted on YouTube and Facebook. In some entanglement cases, some images have been emailed, submitted to the CCS, or uploaded to an 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, Dropbox, or thumb drives, there are sometimes large gaps in image sequence numbering 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 this comparison. 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 and confirmed, or deemed unmatchable. The breakdown of the matching status for sightings from 2001 to 2020 is provided in Appendix 1. On average, 98% of each year's sightings are complete for the last two decades. Many of the unmatched sightings in recent years are calves that have yet to be cataloged. Cataloging the 2011 to 2020 calves is proving 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 resulted in fewer juveniles photographed during this period. Combined, these factors have led to a delay in calves being cataloged. As an example, the new whale #4295 that was added this past year and is described under the New Whale section below, was born in 2012, but not cataloged until 2021 because he was not seen for six years after his birth year. This example shows that it may take years, using a combination of photo-identification and genetics data, to link post-calf sightings back to a calf and then catalog that whale. Currently, an average of 71% of the calves born between 2011 and 2020 have been cataloged in contrast to the average of 89% cataloged in the previous nine years (i.e. 2001 to 2010). This delay in cataloging calves impacts our annual matching success and affects the annual count of total individuals seen.

We have completed 97% of the matching for the calendar year 2019 data and 24% for 2020 data (Appendix I). The percentage matched for the 2020 data is lower than the percentage for 2019 in last year's report (30%) and higher than the report prior to that (20%). The large number of 2019 sightings, many of them video, as well as the transition to moving our team to be 100% remote, impacted the data processing. In addition, some of the 2020 data have yet to be submitted. Because of the delays in submission and processing, we focus on confirming at least one sighting of each whale matched by teams in the field for the year we report on. We did this for 2020, although many of the sightings from DFO and Transport Canada, which were submitted in the late spring of 2021, were not processed to the point where sightings could be matched and confirmed. So, although the percentage of sightings matched and confirmed is low, 269 unique individuals have been identified so far for the 2020 right whale year. This number will increase as more data are processed. The details of the 2020 data matching status categorized by observer are reported below and in Table 1 of Section VII.

Each year, we undertake a variety of other catalog related tasks, which are necessary to make the Catalog run smoothly and to better leverage the data within. This past year we made modifications to the database and DIGITS software to minimize data entry error and to streamline anthropogenic injury assessment and tracking. Previously, when entering vessel strike or entanglement cases, the pre-injury date, injury detection date, number of days between the two sightings, sex, and age of the whale at detection were all manually calculated and typed in. Now, the data entry interface provides the user with a dropdown of all of that whale's sightings and allows them to click on the pre-injury and injury detection sightings. The software automatically determines the rest (age, sex, time between sightings). This has eliminated calculation and entry errors.

This past year, we also developed an anthropogenic data web interface to view the data entered in DIGITS and enter additional data related to each event. The goal of this project was to have all data relating to anthropogenic injuries available in one place. Currently, data on these cases can be found in the Catalog database, annual Catalog reports, excel spreadsheets (monitoring cases), Bycatch.org (entanglement case studies), and necropsy reports. The new anthropogenic injury portal allows much of the information to be pulled from these various sources. For whales with attached gear, there are entry fields that describe gear type, entanglement complexity, whether there are constricting wraps, how much gear was trailing the whale, whether there are multiple anchor points, whether any of the gear was retrieved and if so, where it is stored, what fishery the gear came from, what part(s) of the gear were involved (endline, groundline, netting etc.), the rope diameter, and any gear marking information. If a whale is determined gear-free, the date of that confirmation is automatically displayed based on the sighting behaviors in the database. For vessel strike cases, information about whether a forensic assessment has been done, and estimated vessel size involved has also been added. The web page also displays whether there was medical intervention, the location of the pre-injury and injury detection sightings, whether the whale is known to have died and if so, whether a necropsy was performed, what its necropsy case number was, and if a cause of death was determined. The data entered in via the web portal is linked back to DIGITS tables of anthropogenic events to further improve the utility of these data. In the coming year we plan to share this new database and web portal to interested parties and begin the process, with stakeholder input, of developing visual displays and data exports of these data for broader use.

This past year, we performed 21 exports of Catalog data to investigators who submitted data-use applications through the North Atlantic Right Whale Consortium. These exports were for a variety of investigations. We also undertook a large digitization project since the last Catalog report. We digitized 47 of the Aquarium's audio tapes of right whale sounds and 43 Hi 8 right whale video tapes from the past 30 years. These files are now on servers that are backed up nightly- providing both security and better access to this important historic data.

Finally, a word about the use of artificial intelligence (AI) for managing the Catalog. We continue to coordinate with FlukeBook's right whale AI team and plan to perform periodic image exports to help them train their model as we have in the past. Users can access their right whale matching system either directly or through the Catalog public website (see "The public catalog and the E catalog" section below). The use of their system may speed up matching for many aerial and some shipboard images, but it is unlikely that it will ever be able to compare aerials to shipboards and vice versa- a requirement for right whale photo-identification given the use of both platforms for right whale research. In short, it will help provide some preliminary identifications (all of which need to be confirmed by a human), but it is important to remember that identifications are only one small component of the Catalog work. The Catalog has to be maintained in such a way as 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 health and anthropogenic scarring. The staff will also continue to match all shipboard images, catalog new animals, track links to the genetics database, and confirm that any match initially made by AI 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, we do not expect AI will ever be able maintaining the high level of detail that manual inspections provide for the Catalog data. That level of details 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- 2020 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, 2020)

a. Summary of sightings

(n= 84,816)

Assessment Complete (95%)		Assessment Incomplete (5%)	
Matched: Confirmed	77,052	Matched: Unconfirmed	434
Not Matchable	3,143	Intermatched	454
		Not Yet Matched	3,733

Since the last catalog report, there have been 2,427 sightings added to the Catalog and 3,989 identifications confirmed.

b. Summary of cataloged whales

(n=771)

All Whales

	Male	Female	Unknown	**Total**
Gender	370 (48.0%)	325 (42.1%)	76 (9.9%)	771
	Adult	Juvenile	Unknown	**Total**
Age Class in 2020	636 (90.9%)	57 (8.1%)	7 (1.0%)	700*

* Totals for gender and age class differ because 71 cataloged whales died before 2020 and, therefore, did not have an age class recorded in 2020. An additional one *cataloged* whale died in 2020, but had age class records in 2020 and so is included here.

Presumed Living in 2020

	Male	Female	Unknown	**Total**
Gender	248 (56.1%)	171 (38.7%)	23 (5.2%)	442
	Adult	Juvenile	Unknown	**Total**
Age Class in 2020	383 (86.6%)	52 (11.8%)	7 (1.6%)	442

Known Dead (cataloged whales only)

	Male	Female	Unknown	**Total**
Gender	29 (40.3%)	43 (59.7%)	0	72
	Adult	Juvenile	Unknown	**Total**
Age Class at Death	44 (61.1%)	25 (34.7%)	3 (4.2%)	72

One cataloged whale died in 2020 and is included in the age row in "All Whales" above. The remaining 71 dead whales are not included in that tally.

Presumed Dead as of 2020

	Male	Female	Unknown	**Total**
Gender	93 (36.2%)	111 (43.2%)	53 (20.6%)	257

Catalog data- 2020 only (this is for the "right whale year", which includes data from December 1, 2019 through November 30, 2020)

Explanations of area abbreviations can be found in Appendix II. The numbers and percentages below do not match Appendix I because those results are for the calendar year, not the right whale year. Not all 2020 data have been received and/or entered, so the numbers below will change in the future.

a. Summary of sightings- 2020

(n= 1,790)

Assessment Complete (28.0%)		Assessment Incomplete (72.0%)	
Matched: Confirmed	481	Matched: Unconfirmed	377
Not Matchable	21	Intermatched	139
		Not Yet Matched	772

b. Distribution of sightings

Five Main Right Whale Areas					
BOF	**CCB**	**FL/GA**	**GSC**	**RB**	
5	445	311	5	5	
Other SEUS and Mid-Atlantic Areas					
GMEX	**NC**	**NJ**	**NY**	**SC**	
17	22	7	2	4	
Other Northeast Areas					
GB	**GMB**	**GOM**	**JL**	**MB**	**SNE**
200	1	1	3	54	182
Other Areas North and East					
GSL					
526					

c. Summary of identified whales

With 28.0% of all 2020 sightings for the right whale year matched and confirmed, 269 individual right whales have been identified (note: the 28.0% matched reported here differs from the 24.8% matched reported in Appendix I because the latter is for the 2020 *calendar* year). The numbers in section d below are noticeably low for GSL as we have not fully processed those data. Also, section d includes some of the same individuals between areas; zeros in that section indicate that no whale from that area has been identified yet. Another 17 whales have been partially identified: one cataloged whale, 16 calves from various years, and no whales of unknown age.

	Male	Female	Unknown	**Total**
Gender	153 (56.9%)	106 (39.4%)	10 (3.7%)	269

	Adult	Juvenile	Unknown	**Total**
Age Class in 2020	228 (84.8%)	38 (14.1%)	3 (1.1%)	269

d. Distribution of identified whales

Five Main Right Whale Areas						
	BOF	**CCB**	**FL/GA**	**GSC**	**RB**	
	1	117	23	1	0	
Other SEUS and Mid-Atlantic Areas						
	GMEX	**NC**	**NJ**	**NY**	**SC**	
	2	9	2	2	0	
Other Northeast Areas						
	GB	**GMB**	**GOM**	**JL**	**MB**	**SNE**
	52	0	0	1	19	79
Other Areas North and East						
	GSL					
	5					

Summary of deaths, resurrections, and new whales cataloged in 2020
(Details provided in Sections V, VI, and VII)

a.)	Whales Presumed Dead	25
b.)	Whales Resurrected	0
c.)	Whales Added to Catalog*	
	i. In 2020	2
	ii. In 2021	8
d.)	Confirmed Deaths	
	i. Cataloged whales	1
	ii. Carcasses not ID'd to Catalog	1

* These figures are since the last report, not just for the year 2020.

III. Computerized Database Status

Sighting effort data

All of the NEAq survey data from December 1, 2019 to November 30, 2020 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 exported and sent to Dr. Kenney twice since the last report. The data were sent on December 8, 2020. Dr. Kenney returned the data with questions or issues on February 25, 2021. Mr. Hamilton reviewed the 60 potential errors that needed to be investigated on April 15, 2021: all were investigated, the solution noted for those that could be resolved, and the record corrected, where necessary, in the live Catalog database. Thirty-two of the issues were related to just two survey days with incorrect data exports. Mr. Hamilton uploaded the final data on August 24, 2021. The data were exported again on August 5, 2021. Dr. Kenney did an initial comparison and returned the data with questions or issues on August 10, 2021. He was expecting survey data from NEFSC 2020 and the Early Warning System from the southeast from 2021, so planned to do another round of referencing once those data came in. Mr. Hamilton reviewed the five potential errors that needed to be investigated on August 11, 2021: all were investigated, the solution noted for those that could be resolved, and the record corrected, where necessary, in the live Catalog database. By September 1, 2021, Mr. Hamilton was waiting to receive the final data from the comparison, so the current URI comparison data in the Catalog are from the December 8, 2020 data export.

Catalog database

Since the creation of DIGITS (Digital Image Gathering and Information Tracking System) in 2005, the database and software interface whose development was funded by the National Science Foundation (NSF), 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 1.7 terabytes in size.

NEAq maintains detailed drawings of each whale that provide a summary of all matching features for that individual at a glance. These composites are drawn directly in Adobe Photoshop Elements. The old hand-drawn composites were scanned in and both the old and new composites are updated in Photoshop as needed to provide matchers with the most up-to-date visual summary of each whale. A contractor used to do these drawings, but now one of our staff is fully trained. A total of 12 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.

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.

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. Over the last several years, we've hired Parallax to make some improvements to the DIGITS software. The first round of those improvements was completed in September 2021. Some are briefly mentioned above in reference to the new anthropogenic injury web portal, but all will be described in detail in next year's report.

Since the last Catalog report, the Citrix license was renewed at a considerable increase in cost (four times the cost of the previous renewal). As a reminder, Citrix allows DIGITS users to access the system from any device, and allows contributors to download their own data at any time. Citrix has changed their model of how they do business and no longer sell perpetual licenses. If one doesn't renew their subscription license annually, the next upgrade will force them into a more expensive subscription model. Subscription licenses have to be renewed each year at a higher cost and, if not renewed, the product will cease to function. This adds approximately $2,000 on to the already expensive cost of server maintenance and back up. We are in discussions to modify the DIGITS software to be completely web-based in which case the Citrix software will no longer be necessary. The move to a fully web-based solution is likely a couple of years away.

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). They track every documented scars and anthropogenic injury events (7 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

This Catalog website (www.neaq.org/rwcatalog) utilizes the live DIGITS data, and therefore requires minimal upkeep (since sightings data are automatically updated every time a match is confirmed). Images are updated when new "primary" images are selected for matching purposes. Any image that is flagged as a primary image in DIGITS is also visible on the website. In 2020, using funds from a private foundation, we completed the redesign of the website to improve its overall look and function, and to allow for a direct link between the FlukeBook website where some automated matching is now available. The updated website has an improved interface with the ability to zoom in on images and to perform more detailed searches for whales. It was also restructured to allow a link to a specific whale- a feature that was not available before. This allows potential matches detected by FlukeBook's AI to link directly to a Catalog page; any potential match found on FlukeBook can be inspected on the Catalog website with the click of a button. There have been more than 8,800 navigations of the Catalog website.

Additional web resources for the Catalog can be found on the Anderson Cabot Center for Ocean Life at the New England Aquarium's website (https://www.andersoncabotcenterforoceanlife.org). This website has background information on right whales, detailed information on how to photo-identify them, and photographic examples of all the different matching features that we use during photo-identification. The website was revamped in 2019.

In 2012, we developed a new external catalog called the E Catalog. This Catalog was created to help experienced researchers identify individual right whales while at sea. It is an electronic, off-line catalog that contains images of all cataloged whales and some intermatch whales. The E Catalog is updated twice a year (June/July and November/December) and is exported using the DIGITS software. A Dropbox link is sent to approximately eight team leaders covering each of the main right whale habitats. In 2018, the E Catalog set-up routine was modified to function in the new SQL 2016 environment. The E Catalog is now only compatible with Windows 8 or higher.

IV. New Animals

Calves are only made into new animals and assigned a Catalog number if their identifying features are photographed well enough to be subsequently matched. A "new" non-calf whale is "created" (i.e. given a number and classified within the Catalog) when no matches with existing cataloged animals can be found and when enough good quality photographs exist for it to be matched to subsequent sightings. It can take 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 to an identified mother and known to have been lost without any carcass found that could definitively be linked to the calf of that mother. 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. We choose this 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 10 new whales added to the Catalog: two in 2020 and eight (so far) in 2021. All of them were calves from past years born in: 2009 (n=1), 2012 (n=1), 2015 (n=1), 2017 (n=2), 2019 (n=3), and 2020 (n=2). It is interesting to note that all but two of these calves are solely, or primarily, seen around Cape Cod, MA (although two of the ten died and thus have no post-calf sightings).

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

Added in 2020

Catalog No.	Sex	Birth Year	Mother	Father
4593*	Male	2015	3693	
4712*	Female	2017	1412	

Added in 2021

Catalog No.	Sex	Birth Year	Mother	Father
3988*	Male	2009	1817	
4295*	Male	2012	3995	
4730	Male	2017	1012	
4903	Unknown	2019	2503	
4904	Female	2019	1204	
4991	Female	2019	2791	
5010+	Unknown	2020	2360	
5060+	Male	2020	3560	

"*" indicates a narrative is provided below
"+" indicates the whale died as a calf

#3988 (11 y.o male) - This whale was first seen January 5, 2009 off the coast of Florida with his mother, #1817. He was last seen September 5, 2009 in the Bay of Fundy. The photographs of this whale were of marginal quality and we had hoped to see him again to determine if we could re-identify him with confidence and thus add him to the Catalog.

This past year, after considerable discussion amongst our team, we decided that we could confidently say he did not match any whales cataloged since 2009, nor have his genetics matched any whale since. A genetic sample has been obtained from this whale.

#4295 (8 y.o male) - This whale was first seen May 19, 2012 125 miles east of Provincetown, MA, just north of Georges Bank with his mother, #3995. That was his only sighting that year. He was next seen six years later in March 2018 south of Cape Cod. All of his subsequent sightings have been southeast of Nantucket- his last, in May 2019, more than 80 miles from shore. A genetic sample has been obtained from this whale.

#4593 (5 y.o male) - This whale was first seen January 12, 2015 off the coast of Florida with his mother, #3693. The pair's last sighting that year was off Florida on February 8. Since his birth, he has been seen almost exclusively in the waters south of the Cape and Islands. A genetic sample has been obtained from this whale.

#4712 (3 y.o female) - This whale was first seen April 12, 2017 in Great South Channel. She was one of the three calves that was not seen in the southeast that year. Her mother #1412, named Iceland, is rarely seen, with sighting gaps as long as 14 years and some sightings on the Cape Farewell Grounds and off Iceland. Interestingly, unlike her mother, #4712 has been seen consistently since her year of birth- almost always around Cape Cod. 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. The number of new whales above that are only seen around Cape Cod underscores the need to collect genetic samples in this area to make these important linkages to past calves. Due to the changes in right whale distribution in the summer months, many of the recent calves are not well-photographed and are also seen less frequently when they are one- or two-year-olds, making them harder to identify with confidence. Excluding the 45 calves that remain in limbo (some going back as far as 1991), there are five 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 2019, there have been a total of 45 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 45 resurrections represent 17% of the 261 presumed deaths during that time period. Many of these mistakenly presumed dead classifications occurred primarily due to gaps in sighting effort in Great South Channel and Roseway Basin, and these gaps were filled in from 2004 to 2006. Great South Channel and Gulf of Maine effort have remained relatively high since 2004, although there has been some decrease in effort in recent years. For this reason, there were only five resurrections between 2005 and 2015. In the five 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 (79 presumed deaths from 2016 to 2020, compared to 36 for the previous five years). Given the large number of *known* mortalities in the last five years and the Pace et al. (2017) model results in recent years, this increase in presumed mortality almost certainly reflects true, undetected mortalities.

The presumed dead assessment has a number of flaws. Although a whale becomes presumed dead in a given year, it does not mean that the whale actually died in that year. A whale that is classified as presumed dead in 2020 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) reviewed the time between the first sighting of a dead whale and the last sighting of that whale 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 simply as a crude, but easily calculated, assessment that counts the number of cataloged whales last seen alive six or more years ago.

In 2020, 25 animals were classified as presumed dead (seven of them calving females) and no whales were resurrected. This is the highest number of presumed deaths in a given year on record and indicates that 2014 was the beginning of a more rapid decline in the population. 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.

<u>*Presumed dead*</u>

> **#1131** (35+ y.o. male) - This whale, named Snowball, was first seen in the Great South Channel in September 1979. He was seen regularly over the years and had visited all of the major habitats. He sired no calves as far as we know. Prior to his disappearance, his longest sighting gap was four years. His last sighting was June 29, 2014 in Roseway Basin. He was entangled and in poor health at the time. He was emaciated and covered in

orange cyamids and likely did not survive long. He had last been seen gear-free four years earlier. A genetic sample is on file for this whale.

#1140 (37+ y.o. female) - This whale, named Wart, was first seen in the Great South Channel in May 1981. She was seen regularly over the years and had visited all of the major habitats. She gave birth to at least seven calves between 1982 and 2013. She was satellite tagged in 1990 and tracked for six weeks as she and her calf swam around the Gulf of Maine and down to New Jersey before returning to the Bay of Fundy (Mate et al. 1997). She was seen entangled in March of 2008 and, after many disentanglement attempts, some partially successful, was seen free of the gear in May 2010. She gave birth three years later to her seventh calf in January in or around Cape Cod Bay. This is one of only two documented northern births. Prior to her disappearance, her longest sighting gap was four years. Her last sighting was March 23, 2014 in Cape Cod Bay; there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#1162 (34+ y.o. male) - This whale was first seen in Roseway Basin in August 1980. He disappeared for 10 years until he was seen there again in 1991. He was seen more consistently after that with sighting gaps of only one to three years. For the next 14 years he was seen almost solely in the Bay of Fundy or in Roseway before he transitioned to Jeffreys Ledge and later the Gulf of St Lawrence. His genetic sample did not profile well, so it is unknown whether or not he sired any calves. His last sighting was September 7, 2014 in the Gulf of St Lawrence. He was in good condition at the time, though his skin was not smooth and black. A genetic sample is on file for this whale, but, because it did not profile well, this whale should be sampled again if re-sighted.

#1321 (31+ y.o. female) - This whale, named Mono, was first seen in Roseway Basin in September 1983. She was seen every year or two until she gave birth to her first of five calves in 1991. After that, she was primarily seen off the southeast U.S. and had sighting gaps of five to six years. Her last sighting was March 22, 2014 off the Florida coast with a calf; there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#1323 (31+ y.o. male) - This whale was first seen in Roseway Basin in July 1983. He was seen almost exclusively there through the 1980’s, almost exclusively in the Bay of Fundy in the 1990’s, and frequently in Great South Channel in the 2000’s. He was seen every single year from 1988 onward. He was seen off Georgia in 2011, 2013, and 2014- unexpected for an adult male. He sired no calves as far as we know. His last sighting was January 20, 2014 off Florida; there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#1511 (33+ y.o. male) - This whale was first seen in May 1981 in Great South Channel. Most of his sightings over the years occurred there, or in the Bay of Fundy or Roseway Basin. He sired at least one calf- Lucky, born in 1991. Prior to his disappearance, his longest sighting gap was eight years. His last sighting was April 9, 2014 in Cape Cod Bay; there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#1617 (41+ y.o. male) - This whale, named Orangepeel, was first seen in April 1973 in Cape Cod Bay. He wasn't seen again for 13 years. He is one of the only whales in the visual health assessment database to have been coded as emaciated and survive; he was considered emaciated in 1994 and 1998. He sired at least three calves during his life. His last sighting was August 24, 2014 twenty miles east of Frenchboro, Maine; there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#1625 (28+ y.o. male) - This whale was first seen in August 1986 in Roseway Basin. He was seen almost every year afterwards- mostly in the feeding habitats in and around the Gulf of Maine. He was first seen in the Gulf of St Lawrence in 2006 and, after that, he was primarily seen there or in Cape Cod Bay. He sired no calves as far as we know. His last sighting was March 18, 2014 in Cape Cod Bay; there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#1632 (28+ y.o. female) - This whale, named Catspaw, was first seen September 1986 in Roseway Basin. She was seen offshore over the next two years before disappearing for 12 years. She was resighted in 2000 and then seen every year from 2002 through 2014. She had four calves between 2002 and 2013. Her last sighting was March 4, 2014 in Cape Cod Bay; there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#1981 (25 y.o. male) - This whale, named Croc, was first seen in August 1989 in the Bay of Fundy with his mother Punctuation. He was seen every year afterwards except for one three-year gap between 1990 and 1993. He was mostly seen in the Bay of Fundy, Great South Channel, and off the southeastern U.S. In 2009, he started using the Cape Cod Bay habitat where all of his sightings in 2013 and 2014 occurred. He sired at least two calves. His last sighting was April 18, 2014 in Cape Cod Bay; there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#1990 (25+ y.o. unknown sex) - This whale was first seen in August 1989 in Roseway Basin. It has relatively few sightings in the Catalog. It was not seen again for 14 years until it was resighted in the Gulf of Maine about 50 miles east of Provincetown, MA in June 2003. It was seen around that area for the next three years, then seen in Jeffreys Ledge in 2006 and 2009. Its next and final sighting was January 16, 2014 in Massachusetts Bay; there were no outward indications of ill health at the time. There is no genetic sample on file for this whale.

#2330 (21+ y.o. female) - This whale, named Celeste, was first seen in July of 1993 in Cape Cod Bay. She was seen primarily in the Bay of Fundy and off the southeastern U.S., although she was seen in all major habitats except the Gulf of St Lawrence at least once. She gave birth to three calves between 2004 and 2013. Her last sighting was July 18, 2014 in Roseway Basin; there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#2710 (17 y.o. female) - This whale, named Arc, was first seen in December 1996 with her mother Stumpy off the Georgia coast. She was seen many times each year and every year through 2010. After that, she was only seen twice – both times in 2014. She had two calves between 2006 and 2010. Her last sighting was as the focal female of a 35+ whale surface active group on the northeast peak of Georges Bank on July 1, 2014. The group was only found because the Department of Fisheries and Oceans was helping to search for an entangled whale that had been seen in the area a few days earlier. There were no outward indications of ill health at her last sighting. A genetic sample is on file for this whale.

#2830 (16+ y.o. male) - This whale was first seen in April 1998 south of Cape Cod. He was seen primarily in the Bay of Fundy, and Cape Cod Bay to a lesser extent, through 2005. After that, he was seen more widely including all the offshore habitats and Jeffreys Ledge, but settled into being primarily a Cape Cod Bay whale from 2011 to 2014. He sired no calves as far as we know. His last sighting was June 23, 2014 in Great South Channel; there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#3279 (12 y.o. male) - This whale was first seen in January 2002 of the coast of Florida with his mother, #1179. He was seen every year after until 2014 with the exception of 2013. He was primarily seen off the southeastern U.S. or the areas around Cape Cod. His last sighting was September 17, 2014 in the Bay of Fundy. He was entangled with rope going through his mouth and wrapping over his head, cutting into the rostrum forward of the blowholes. A genetic sample collected in February 2000 was thought to be from this whale, but in 2013, it was determined that the sample was *not* from #3279. For this reason, there is no genetic sample on file for this whale.

#3294 (22+ y.o. female) - This whale, named Equator, was first seen in August 2002 in the Bay of Fundy. She was seen every year between 2002 and 2014, almost solely off the southeast U.S. or in Cape Cod or Massachusetts Bays. She was found entangled in December 2008 and, after a partial disentanglement that month, was seen gear free the following February. She gave birth to her first and only calf in 2013. Her last sighting was April 18, 2014 in Cape Cod Bay. Besides the severe scarring from the previous entanglement, there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#3648 (8 y.o. male) - This whale was first seen in February 2006 off the Georgia coast with his mother Rudolph. He was seen every year afterwards except for 2013. Until 2012, he was mostly seen in the Bay of Fundy and off the southeastern U.S. with a few sightings in Great South Channel. He was only seen in Cape Cod Bay in 2012 and 2014. His last sighting was March 1, 2014 in Cape Cod Bay; there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#3692 (8+ y.o. female) - This whale was first seen in April 2006 in the Cape Cod Bay. She was seen every year between 2006 and 2014, mostly in Cape Cod Bay, though she was also seen in several offshore habitats. She gave birth to her first and only calf in

2013. Her right fluke blade was cut by a propeller in the winter of 2013 and the outside 3rd of the fluke fell off in 2014. Her last sighting was April 12, 2014 in Massachusetts Bay. She looked somewhat thin at the time, but there were no other outward indications of ill health at the time. There is *no* genetic sample on file for this whale.

#3770 (7 y.o. male) - This whale was first seen in March 2007 in Great South Channel with his mother #1242. His mother is rarely seen and had a 16-year sighting gap. Her calf has proved to be much more sightable; he has been seen every year since his birth except for 2013. He has been seen in all the critical habitats with no clear pattern or preference. His last sighting was April 2, 2014 about 25 miles south of Nantucket Island; there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#3794 (7 y.o. female) - This whale was first seen in January 2007 off the Florida coast with her mother, Swerve. She was seen every year since her birth except for 2013, mostly off the southeastern U.S. Her last sighting was August 28, 2014 in the Bay of Fundy; there were no other outward indications of ill health at the time. A genetic sample is on file for this whale.

#4001 (4 y.o. male) - This whale was first seen in December 2009 off the Georgia coast with his mother, Aphrodite. He was seen every year since his birth – mostly in the southeast U.S., Cape Cod Bay, and the Bay of Fundy. He was seen entangled on September 4, 2014 in the Bay of Fundy with a tight wrap of line over his head. His last sighting was October 12, 2014 in Massachusetts Bay. He was still entangled with the line cutting into the head forward of the blowholes. A genetic sample is on file for this whale.

#4010 (4 y.o. male) - This whale was first seen in February 2010 off the Florida coast with his mother, Arc (both he and his mother were last seen in 2014). He was seen every year since his birth except 2013– mostly in the Bay of Fundy and Cape Cod Bay. His last sighting was August 8, 2014 in the Bay of Fundy; there were no other outward indications of ill health at the time. A genetic sample is on file for this whale.

#4160 (3 y.o. male) - This whale was first seen in December 2010 off the Florida coast with his mother, Gannet. He was subsequently seen in 2011 and 2014. In July 2011, he was photographed with substantial, fresh entanglement wounds. He was alone that day and the next, and when his mother was next seen in September, she also was alone and had fresh entanglement wounds as well. Although only speculation, it is possible that both Gannet and #4160 were entangled at the same time between April 25 and July 19, 2011. His last sighting was August 20, 2014 in Roseway Basin; his wounds appeared healed and, besides some moderately poor skin condition, there were no other outward indications of ill health. A genetic sample is on file for this whale.

#4394 (1 y.o. male) - This whale was first seen in January 2013 off the Georgia coast with his mother, Equator (like mother/calf pair Arc and #4010 above, both #4394 and his mother Equator were last seen in 2014). He and Equator were in Cape Cod Bay in April and May of that year. He returned to the southeast the following year where his last sighting occurred on February 10, 2014 off the Georgia coast. He appeared thin at the time. A genetic sample is on file for this whale.

#4401 (calf of the year, unknown sex) - This whale was first seen in January 2014 off the Florida coast with his mother, Half Note. Half Note has consistently had problems nursing her calves since 2005. Her last four calves, including #4401, have all become very thin on the calving ground before disappearing. Whale #4401 was last seen on February 22, 2014 off the Georgia coast. He was emaciated at the time and likely died shortly afterward. Half Note was seen alone March 11th and many times after that in 2014. There is no genetic sample on file for this whale.

Resurrected

No whales were resurrected in 2020.

VI. Mortalities, Entanglements, and Significant Injuries

Overview

There were two mortalities discovered in 2020 and a summary of those cases is presented below. Three right whales were confirmed first seen entangled in 2020. In addition to these confirmed cases, there were two other reported cases that could not be confirmed due to either poor photographic evidence (February 9, 2020 off North Carolina) or lack of photographs (March 16, 2020 on Georges Bank, WR-2020-02). These cases are *not* reported on below. One whale that had been entangled in previous years was seen still entangled in 2020 and no whales were first seen gear-free in 2020. There were four cases of significant, non-lethal injuries caused by propellers or entanglements in 2020. 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

#5060 (calf, male) - The carcass of this whale, the 2020 calf of Snow Cone (#3560), which is referenced as MMSC-20-104, was found floating dead on June 25, 2020 approximately 5 miles east of Elberon, N.J. He had propeller wounds from two separate vessel strikes visible on the head and body. The carcass was identified by the callosity, size, and scars on both sides of the head. On June 27, the carcass was towed to Sandy Hook, N.J. and necropsied the following day. The mortality report lists the proximate cause of death as a combination of sharp and blunt trauma from two vessel strikes. The last confirmed sighting of this whale alive was with his mother on April 6, 2020 off Cape Lookout, N.C.

Unknown ID (neonate, male) - This whale, the carcass of which is referred to as CALO20-90 (Field ID), SER20-00585 (NMFS Regional), and SE-2020-1229534 (National Database), was first seen on the beach south of the north end of Core Banks, N.C. on November 20, 2020. A necropsy was performed the following day. Initial findings suggest that the whale died during birth. Genetics were collected and it may be possible to narrow down who the mother may be, but it is unlikely that we will be able to determine her identity with any certainty.

Entanglements

First Reported in 2020

February 24, 2020: #3180 (19 y.o. female) - This whale, named Dragon, was first seen entangled February 24, 2020 about 45 miles southeast of Nantucket Island off Cape Cod, MA. The event was assigned a CCS case number of WR-2020-01. She had a bullet buoy lodged in her mouth with some trailing line. It appeared that she could not close her mouth and she was emaciated and her skin covered with orange cyamids. She has not been seen since and likely died shortly after her initial sighting entangled. Before the February 24 entanglement, she had been last seen gear-free on April 11, 2019 in Cape Cod Bay.

October 11, 2020: #4680 (4 y.o. male) - This whale was first seen entangled on October 11, 2020 about three miles east of Sea Bright, N.J. It was given a CCS case number of WR-2020-17. In a sad coincidence, he is Dragon's calf from 2016- both of them entangled in the same year. The entanglement involved at least two wraps over the rostrum. He was in extremely poor condition and had a large open wound on his left shoulder. Like his mother Dragon, he has not been seen since and likely died shortly after his initial sighting entangled. Before this entanglement, he had been last seen gear-free on December 29, 2019 south of Nantucket.

October 19, 2020: #3920 (11 y.o. male) - This whale, named Cottontail, was first seen entangled on October 19, 2020 about 10 miles south of Nantucket while survey teams were searching for entangled whale #4680. He had several lines wrapping over and imbedded in his rostrum and over 100 feet of line trailing behind him. The entanglement was given a CCS case number of WR-2020-18. The CCS disentanglement team was nearby at the time and were able to attach a telemetry buoy and remove 100 feet of line. Over the ensuing weeks, the GPS on the telemetry buoy tracked his progress around southern New England and into the Gulf of Maine. By the end of October, the tag had broken free. He was next seen off Melbourne Beach, FL on February 18, 2021. Another telemetry buoy was attached to the gear and he was tracked for about 24 hours before the tag stopped transmitting. His carcass was discovered February 27 floating off Myrtle Beach, SC. Before this entanglement, Cottontail had been last seen gear-free on March 16, 2020 30 miles south of Nantucket.

Reported Prior to 2020 and Still Entangled by the End of 2020

January 18, 2020: #3466 (16 y.o. male) - This whale was first seen entangled on December of 2019 south of Nantucket. He had several strands of yellow rope passing through the mouth and then coming together in a wad behind the flukes. He was then seen multiple times south of Nantucket from January 18 to January 31, 2020. His condition and the entanglement configuration had not changed. He was not seen again for

15 months until April 7, 2021 when he was seen north of Block Canyon completely gear-free. He appeared in good condition at the time.

First Seen Free of Gear in 2020

No whales were first seen free of gear in 2020.

Significant injuries

#1017 (40+ y.o., male) – This whale was first seen injured on February 29, 2020 in Cape Cod Bay. He had 20+ shallow propeller cuts along his right flank. He had last been seen uninjured October 29, 2019 in the Gulf of St Lawrence.

#4539 (5 y.o., male) – This whale was seen on April 5, 2020 in Cape Cod Bay with a wound around his right blowhole and right coaming and minor propeller wounds on his right side. He had last been seen uninjured October 21, 2019 in the Gulf of St Lawrence.

#5010 (calf, unknown sex) – This calf of Derecha, #2360, was already mortally wounded from propeller cuts on its head when it was first sighted on January 8, 2020 off the Florida coast. It was seen alive over a weeklong period before it disappeared. Derecha was not seen again until March of 2021.

#2020 calf of 3101 (calf, unknown sex) – This whale was first seen with at least two wounds of moderate severity and unknown origin on its right side on July 16, 2020 in the Gulf of St Lawrence. It had last been seen without the injuries on June 14 in the Gulf.

VII. Photographic Contributions

Photos submitted from 86 different organizations or individuals who collected photographs between December 1, 2019 and November 30, 2020 that have been partially or completely processed and integrated into the Catalog database. Since not all data from these contributors have been processed, tallies of sightings and images contributed may change. Table 1 provides a summary for each contributor, including:

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

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

Table 1: List of 86 organizations/individuals whose photographs were collected between December 1, 2019 and November 30, 2020.

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

			% of Total Sightings					# of Individuals		
			Matched							
Organization / Region	# of Sightings	# of Images	Confirmed	Unconfirmed	Not Matchable	Intermatched	Not Yet Matched	Confirmed Id'd	Other Unique Id'd	Total
ACOE										
SEUS	2	5	0.%	0.%	100.%	0.%	0.%	0	0	0
ANSA*										
NE	4	7	0.%	0.%	0.%	0.%	100.%	0	0	0
APEM										
MIDA	1	1	100.%	0.%	0.%	0.%	0.%	1	0	1
AS										
SEUS	35	484	51.4%	31.4%	0.%	17.1%	0.%	3	1	4
BEMU*										
MIDA	1	7	100.%	0.%	0.%	0.%	0.%	1	0	1
BHC										
MIDA	1	3	0.%	0.%	0.%	0.%	100.%	0	0	0
BHWW/AW										
GOM	1	7	0.%	0.%	0.%	0.%	100.%	0	0	0
BIHA*										
SEUS	2	3	0.%	0.%	100.%	0.%	0.%	0	0	0
BIWSC										
BOF	1	4	0.%	0.%	0.%	0.%	100.%	0	0	0
BRHO*										
MIDA	2	53	100.%	0.%	0.%	0.%	0.%	2	0	2
BWRI										
SEUS	6	0	0.%	0.%	0.%	50.%	50.%	0	3	3
CAFI*										
NE	1	4	0.%	0.%	0.%	0.%	100.%	0	0	0
CBPWP										
NRTH	6	106	33.3%	66.7%	0.%	0.%	0.%	1	0	1
CC										
SEUS	2	9	0.%	0.%	0.%	50.%	50.%	0	1	1
CCS										
GOM	5	70	60.%	40.%	0.%	0.%	0.%	3	0	3
GSC	3	51	33.3%	33.3%	0.%	0.%	33.3%	1	0	1
JL	1	18	100.%	0.%	0.%	0.%	0.%	1	0	1
MIDA	59	1,012	72.9%	23.7%	0.%	3.4%	0.%	40	2	42
NE	403	6,162	37.2%	41.2%	0.%	3.7%	17.9%	124	6	130
CHBE*										
GSC	1	13	0.%	0.%	0.%	0.%	100.%	0	0	0
CHJO*										
SEUS	1	1	0.%	0.%	0.%	0.%	100.%	0	0	0
CMARI										
SEUS	80	1,358	51.3%	16.3%	0.%	32.5%	0.%	15	7	22
CWI										
BOF	1	36	100.%	0.%	0.%	0.%	0.%	1	0	1
DACH*										
SEUS	2	21	100.%	0.%	0.%	0.%	0.%	2	0	2

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
DALI*										
SEUS	2	27	50.%	0.%	0.%	50.%	0.%	1	1	2
DAMY*										
SEUS	2	26	50.%	50.%	0.%	0.%	0.%	1	0	1
DAPR*/DR										
NE	1	9	0.%	0.%	0.%	0.%	100.%	0	0	0
DASH*										
NE	2	6	0.%	0.%	100.%	0.%	0.%	0	0	0
DFO										
NRTH	388	270	0.%	2.6%	0.%	2.6%	94.8%	0	5	5
RB	5	0	0.%	0.%	0.%	0.%	100.%	0	0	0
DRHE*										
MIDA	2	24	50.%	0.%	50.%	0.%	0.%	1	0	1
EDGR*										
SEUS	10	257	20.%	30.%	0.%	50.%	0.%	2	4	6
FBC										
SEUS	2	29	100.%	0.%	0.%	0.%	0.%	2	0	2
FWRI										
SEUS	88	1,381	60.2%	4.5%	0.%	35.2%	0.%	14	7	21
GDNR										
SEUS	64	770	3.1%	0.%	0.%	32.8%	64.1%	2	8	10
GLBE*										
NE	1	28	100.%	0.%	0.%	0.%	0.%	1	0	1
GOWH										
MIDA	1	51	100.%	0.%	0.%	0.%	0.%	1	0	1
GREMM										
NRTH	1	31	100.%	0.%	0.%	0.%	0.%	1	0	1
GUMA*										
NRTH	4	59	50.%	25.%	0.%	0.%	25.%	2	0	2
HEBE*										
GOM	1	30	0.%	100.%	0.%	0.%	0.%	0	0	0
IQMWWC										
BOF	1	2	100.%	0.%	0.%	0.%	0.%	1	0	1
JAHI*										
MIDA	1	4	0.%	0.%	100.%	0.%	0.%	0	0	0
JELO*										
SEUS	1	3	0.%	0.%	100.%	0.%	0.%	0	0	0
JOBL*										
SEUS	2	16	100.%	0.%	0.%	0.%	0.%	2	0	2
JRD*										
NRTH	1	2	0.%	100.%	0.%	0.%	0.%	0	0	0
JSWW										
MIDA	1	37	0.%	100.%	0.%	0.%	0.%	0	0	0
JUDO*										
MIDA	2	19	0.%	50.%	0.%	50.%	0.%	0	1	1
KEBU*										
NE	3	0	0.%	0.%	0.%	0.%	100.%	0	0	0
MABI*										
SEUS	1	26	100.%	0.%	0.%	0.%	0.%	1	0	1
MADE*										
MIDA	2	16	0.%	50.%	0.%	50.%	0.%	0	1	1
MAGA*										
NE	2	7	50.%	0.%	0.%	0.%	50.%	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
MAPA*										
NE	7	94	0.%	28.6%	28.6%	0.%	42.9%	0	0	0
MIBO*										
SEUS	2	2	0.%	0.%	100.%	0.%	0.%	0	0	0
MIBU*										
JL	2	2	0.%	0.%	100.%	0.%	0.%	0	0	0
MIDE*										
SEUS	2	46	100.%	0.%	0.%	0.%	0.%	2	0	2
MIHE*										
SEUS	2	20	100.%	0.%	0.%	0.%	0.%	2	0	2
MISO*										
NRTH	2	4	50.%	0.%	0.%	50.%	0.%	1	1	2
MMSC										
MIDA	1	26	100.%	0.%	0.%	0.%	0.%	1	0	1
NATO*										
SEUS	2	6	0.%	0.%	100.%	0.%	0.%	0	0	0
NEA										
GOM	6	73	33.3%	33.3%	0.%	0.%	33.3%	2	0	2
MIDA	12	203	58.3%	33.3%	0.%	0.%	8.3%	6	0	6
SEUS	2	16	0.%	50.%	0.%	50.%	0.%	0	1	1
NEFSC										
GOM	189	2,164	30.7%	37.%	0.%	1.1%	31.2%	47	2	49
GSC	1	3	0.%	100.%	0.%	0.%	0.%	0	0	0
MIDA	104	1,261	39.4%	34.6%	0.%	2.9%	23.1%	37	2	39
NIHA*										
NRTH	117	0	0.%	0.%	0.%	0.%	100.%	0	0	0
NMBBP/DR										
MIDA	2	15	50.%	0.%	0.%	50.%	0.%	1	1	2
NORM										
MIDA	1	1	0.%	0.%	100.%	0.%	0.%	0	0	0
ORD/SS										
MIDA	5	20	80.%	0.%	20.%	0.%	0.%	3	0	3
PAMO*										
BOF	1	2	0.%	0.%	100.%	0.%	0.%	0	0	0
PEFL*										
NE	61	1,171	3.3%	14.8%	0.%	3.3%	78.7%	2	2	4
PVDV*										
MIDA	2	15	0.%	50.%	0.%	50.%	0.%	0	1	1
QLM										
BOF	1	23	0.%	100.%	0.%	0.%	0.%	0	0	0
REPI*										
NRTH	7	38	14.3%	85.7%	0.%	0.%	0.%	1	0	1
RIBA*										
SEUS	2	15	100.%	0.%	0.%	0.%	0.%	2	0	2
RINE*										
MIDA	2	16	50.%	0.%	50.%	0.%	0.%	1	0	1
ROMA*										
SEUS	2	5	0.%	100.%	0.%	0.%	0.%	0	0	0
SAEN*										
MIDA	1	18	100.%	0.%	0.%	0.%	0.%	1	0	1
SAMA*										
SEUS	2	24	0.%	100.%	0.%	0.%	0.%	0	0	0
SCHA*										
MIDA	2	14	50.%	0.%	0.%	50.%	0.%	1	1	2

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
SEFSC/AMPS										
MIDA	2	57	100.%	0.%	0.%	0.%	0.%	2	0	2
SMT										
NE	4	15	0.%	0.%	0.%	0.%	100.%	0	0	0
TT-NYDEC										
MIDA	2	58	100.%	0.%	0.%	0.%	0.%	2	0	2
TYAD*										
SEUS	2	13	50.%	50.%	0.%	0.%	0.%	1	0	1
TYSH*										
MIDA	3	23	0.%	0.%	0.%	33.3%	66.7%	0	1	1
TYZE*										
SEUS	2	15	50.%	50.%	0.%	0.%	0.%	1	0	1
UNCW										
MIDA	2	37	0.%	0.%	0.%	100.%	0.%	0	1	1
UNK										
MIDA	1	4	100.%	0.%	0.%	0.%	0.%	1	0	1
USCG										
MIDA	1	3	100.%	0.%	0.%	0.%	0.%	1	0	1
VAQF										
MIDA	1	5	100.%	0.%	0.%	0.%	0.%	1	0	1
VIPA*										
NE	4	19	0.%	0.%	0.%	0.%	100.%	0	0	0
VO										
SEUS	2	33	0.%	50.%	0.%	0.%	50.%	0	0	0
WACO*										
SEUS	2	20	0.%	50.%	0.%	50.%	0.%	0	1	1
WESH										
SEUS	2	22	50.%	50.%	0.%	0.%	0.%	1	0	1
WHOI										
NE	6	85	100.%	0.%	0.%	0.%	0.%	6	0	6
Report Totals	1,790	18,271								

VIII. Catalog Related Publications and Reports

Since the last Catalog report on October 31, 2020, the following reports and publications that utilize data from the Catalog have been either published or submitted:

Fortune, S.M.E., M.J. Moore, W.L. Perryman, and A.W. Trites. 2020. Body growth of North Atlantic right whales (Eubalaena glacialis) revisited. Marine Mammal Science 1–15. https://doi.org/10.1111/mms.12753

Gowan, T.A., N.J. Crum, and J.J. Roberts. 2021. An open spatial capture-recapture model for estimating density, movement, and population dynamics from line-transect surveys. Ecology and Evolution [Early View] https://doi.org/10.1002/ece3.7566

Graham, K.M., E.A. Burgess, and R.M. Rolland. 2021. Stress and reproductive events detected in North Atlantic right whale blubber using a simplified hormone extraction protocol. Conservation Physiology 9(1): coaa1 33.

Hamilton, P.K., Frasier, B.A., Conger, L.A., George, R.C., Jackson, K.A., Frasier, T.R. In Press. Genetic identifications challenge our assumptions of physical development and mother-calf associations and separation times: A case study of the North Atlantic right whale (Eubalaena glacialis). Journal of Mammalogy Special Issue 102-1.

Henry AG, Garron M, Morin D, Reid A, Ledwell W, TVN Cole TVN. 2021. Serious Injury and Mortality Determinations for Baleen Whale Stocks along the Gulf of Mexico, United States East Coast, and Atlantic Canadian Provinces, 2014-2018. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 21-07; 62 p. Available from: https://www.fisheries.noaa.gov/new-england-mid-atlantic/northeast-fisheries-science-center-publications

Moore, M.J., T.K. Rowles, D.A. Fauquier, J.D. Baker, I. Biedron, J.W. Durban, P.K. Hamilton, A.G. Henry, A.R. Knowlton, W.A. McLellan, C.A. Miller, R.M. Pace, III, H.M. Pettis, S. Raverty, R.M. Rolland, R.S. Schick, S.M. Sharp, C.R. Smith, L. Thomas, J.M. van der Hoop, and M.H. Ziccardi. 2021. Assessing North Atlantic right whale health: Threats, and development of tools critical for conservation of the species. Diseases of Aquatic Organisms 143:205-226.

Pace, R.M. III, R. Williams, S.D. Kraus, A.R. Knowlton, and H.M. Pettis. 2021. Cryptic mortality of North Atlantic right whales. Conservation Science and Practice 3(2):e346.

Pettis HM. 2021. Monitoring injured North Atlantic right whales: January 2021 report. A report to the Volgenau Foundation. 10 pp.

Pettis HM, Pace RM, and Hamilton PK. 2021. North Atlantic Right Whale Consortium 2020 annual report card. Report to the North Atlantic Right Whale Consortium, January 2021. 22 pp.

Quintana-Rizzo, E., S. Leiter, T.V.N. Cole, M.N. Hagbloom, A.R. Knowlton, P. Nagelkirk, O. O'Brien, C.B Kahn, A.G. Henry, P.A. Duley, L.M. Crowe, C.A. Mayo, and S.D. Kraus. 2021. Residency, demographics, and movement patterns of North Atlantic right whales Eubalaena glacialis in an offshore wind energy development area in southern New England, USA. Endangered Species Research 45:251-268. https://doi.org/10.3354/esr01137

Stewart, J.D., J.W. Durban, A.R. Knowlton, M.S. Lynn, H. Fearnbach, J. Barbaro, W.L. Perryman, C.A. Miller, and M.J. Moore. 2021. Decreasing body lengths in North Atlantic right whales. Current Biology 31(14):3174-3179.E3..

IX. References

Anderson, M. S., Forney, K. A., Cole, T. V., Eagle, T., Angliss, R. P., Long, K., Barre, L., Van Atta, L., Borggaard, D., Rowles, T., Norberg, B., Whaley, J., and Engleby, L. 2008. Differentiating Serious and Non-Serious Injury of Marine Mammals: Report of the Serious Injury Technical Workshop, 10-13 September 2007, Seattle, Washington.

Hamilton, P.K., Frasier, B.A., Conger, L.A., George, R.C., Jackson, K.A., Frasier, T.R. In Press. Genetic identifications challenge our assumptions of physical development and mother-calf associations and separation times: A case study of the North Atlantic right whale (Eubalaena glacialis). Journal of Mammalogy Special Issue 102-1.

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.

Mate, B.R., Nieukirk, S.L. and Kraus, S.D. 1997. Satellite-monitored movements of the northern right whale. The Journal of wildlife management 61(4):1393-1405.

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, 2020 as of September 1, 2021.

A detailed breakdown of the matching status of all sightings for the *calendar* years 2001 to 2021. 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 2020 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
2001	166		3603	214	3983	95.83%	95.83%
2002	119		2452	154	2725	95.63%	95.63%
2003	55		2120	231	2406	97.71%	97.71%
2004	19		1708	114	1841	98.97%	98.97%
2005	7		3261	140	3408	99.79%	99.79%
2006	23		2682	101	2806	99.18%	99.18%
2007	36		3610	125	3771	99.05%	99.05%
2008	13		4033	118	4164	99.69%	99.69%
2009	36		4545	117	4698	99.23%	99.23%
2010	25		3143	68	3236	99.23%	99.23%
2011	44		3327	108	3479	98.74%	98.74%
2012	48		2020	59	2127	97.74%	97.74%
2013	55		1784	65	1904	97.11%	97.11%
2014	100		2217	87	2404	95.84%	95.84%
2015	62		1636	76	1774	96.51%	96.51%
2016	19		2162	30	2211	99.14%	99.14%
2017	53		2914	158	3125	98.30%	98.30%
2018	53		3664	116	3833	98.62%	98.62%
2019	144	2	4569	204	4919	97.07%	97.03%
2020	1000	432	458	15	1905	47.51%	24.83%

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 86 data contributors from December 1, 2019 through November 30, 2020.
"*" indicates the sighting was contributed by an individual, not an organization.

Abbreviation	Organization Name (if applicable)	Primary Contact
ACOE		Army Corps of Engineers
ANSA*	Andy Sanford	
APEM	John McCarthy	APEM Limited
AS	Jim Hain	Associated Scientists at Woods Hole
BEMU*	Ben Murphy	
BHC	Laura Howes	Boston Harbor Cruises
BHWW/AW	Julianne Taylor	Bar Harbor Whale Watch/Allied Whale
BIHA*	Bill Harris	
BIWSC	Shelley Barnaby (Longergan)	Briar Island Whale & Seabird Cruises
BRHO*	Brian Horsley	
BWRI	Jamison Smith	Blue World Research Institute
CAFI*	Catlin Fitzmaurice	
CBPWP	Elizabeth Zwamborn	The Cape Breton Pilot Whale Project
CC	Chris Slay	Coastwise Consulting
CCS	Brigid McKenna	Center for Coastal Studies
CHBE*	Chris Berry	
CHJO*	Christa Johnson	
CMARI	Melanie White	Clearwater Marine Aquarium Research Institute
CWI	Moe Brown	Canadian Whale Institute
DACH*	David Chidsey	
DALI*	David Litz	
DAMY*	Danny Myer	Landmark Properties
DAPR*/DR	Dan Proulx	
DASH*	Dalia Shilas	
DFO	Stephanie Ratelle & AndrewWright	Department of Fisheries and Oceans
DRHE*	Drew Hegarty	
EDGR*	Ed Gerstein	Florida Atlantic University
FBC	Capt Vic Vazquez	FishyBizness Charters, LLC
FWRI	Katie Jackson	Florida Fish and Wildlife Conservation Commission

Appendix III. (cont.)

Abbreviation	Organization Name (if applicable)	Primary Contact
GDNR	Clay George	Georgia Dep. of Natural Resources
GLBE*	Glen Bernard	
GOWH	Artie Rashlich	Gotham Whale
GREMM	Michel Moisan	Groupe de recherche et d'éducation sur les mammifères marin
GUMA*	Guylaine Marchand	
HEBE*	Henry Becton	
IQMWWC	Nicole Leavitt	Island Quest Marine Whale and Wildlife Cruises
JAHI*	James Hickman	
JELO*	Jeremy Lormis	
JOBL*	Josh Blaylock	
JRD*	Jesse Roy-Drainville	
JSWW	Danielle Brown	Jersey Shore Whale Watch
JUDO*	Justin Domogauer	
KEBU*	Keegan Burke	
MABI*	Mark Bias	
MADE*	Marsh Deane	
MAGA*	Mark Garfinkel	
MAPA*	Matt Padulo	
MIBO*	Michael Bohrn	
MIBU*	Miraj Budak	
MIDE*	Michael DeSanctis	
MIHE*	Mike Henry	
MISO*	Mike Soucy	
MMSC	Bob Schoelkopf	Marine Mammal Stranding Center
NATO*	Nathan Todnem	
NEA	Monica Zani & Orla O'Brien	New England Aquarium
NEFSC	Allison Henry & Lisa Conger	Northeast Fisheries Science Center
NIHA*	Nick Hawkins	
NMBBP/DR	Monty Reed	North Myrtle Beach Patrol

Appendix III. (cont.)

Abbreviation	Organization Name (if applicable)	Primary Contact
NORM	Julia Willmott	Normandeua Associates Inc.
ORD/SS	Laura Morse	Orsted Energy/Smultea Consulting
PAMO*	Pat Mowat	
PEFL*	Peter Flood	
PVDV*	Philip Vender Vossen	
QLM	Danielle Dion	Quoddy Link Marine
REPI*	Renaud Piniaux	
RIBA*	Rick Barberi	
RINE*	Richard Neal	Frying Pan Tower
ROMA*	Robert Martinez	
SAEN*	Sarah Ensey	
SAMA*	Sandra MacMillan	
SCHA*	Scott Hartley	
SEFSC/AMPS	Lance Garrison	Southeast Fisheries Science Center
SMT	Courtney Dunn	Smith Marine Towing
TT-NYDEC	Ann Zoidis	Tetratech
TYAD*	Tyler Adams	
TYSH*	Ty Sharrow	
TYZE*	Tyler Zern	
UNCW	Bill McLellan	University of North Carolina-Wilmington
UNK		Unknown observer
USCG		U.S. Coast Guard
VAQF	Sue Barco	Virginia Marine Science Museum
VIPA*	Vi Patek	
VO		Vantage Observing
WACO*	Walter Coker	
WESH		WESh Channel 2 (Orlando, FL)
WHOI	Michael Moore	Woods Hole Oceanographic Institution

Task 2: Final Report on 2019 Right Whale Entanglement Scar Coding Efforts

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Overview

This report summarizes right whale entanglement scarring analyses for 2019 using sightings and photographs from the North Atlantic Right Whale Consortium (NARWC) Identification Database. The goal was to compare the frequency and rate of scar detections in 2019 to those of 2010-2018 (data provided in previous reports) as well as to the prior 30 years of data (1980-2009), as reported by Knowlton et al. (2012). As part of this annual review effort, we have categorized each new entanglement event in terms of injury severity levels of minor, moderate, and severe as defined in Knowlton et al. (2016; see Appendix 1) and compared frequency at these levels to prior years. Additionally, two-page case studies for all whales with attached gear and a one-page case study for all whales with severe injuries and no attached gear were developed.

For this report, we opted not update the prior years as we intend to conduct a new assessment with the aim of publishing a peer-reviewed paper describing the last 10 years of data using the methodology described in the Knowlton et al. (2012) paper. Because this reassessment needs to be done on the full 40-year dataset using the new Anthropogenic Events Database, we did not want to delay getting the 2019 results reported. 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 that are reported in near real-time). As we develop our plans for this next paper, we anticipate integrating information on where entanglements have definitely occurred or may have been occurring over the past 40 years to see if there has been any shift in patterns.

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 2019 and any new, pre-2019 sightings added to the catalog since the 2020 report that described 2018 scarring events. Scar coding was also carried out for any new whales added to the catalog with sightings up to and including 2019. In addition to calculations of annual population entanglement rates and detection of new entanglement events, explanations are provided below for several analyses that are described in the papers mentioned above and presented in this report for the 2019 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.,

2018/2019) were analyzed. For an animal to be considered adequately photographed, clear images showing the entire area of the dorsal peduncle or one of the fluke insertion areas were required in both years to allow for inter-year comparisons. For calves and one-year-olds, the peduncle area had to be well-photographed in only the second year to be included. Lastly, any whale that had evidence of an entanglement event in Year 2 elsewhere on the body that would have been detectable from photographs in Year 1 or an entanglement that was known to have occurred within Year 2 of the two-year timeframe was also included.

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

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

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

Entanglement locations
Determining the location where entanglements may have occurred was evaluated in two ways. First was via an inquiry with NOAA Fisheries about the draft 2019 Atlantic Large Whale Entanglement Report for those whales with gear attached – although it was not available for review, NOAA Fisheries was able to provide information on gear type and country of origin where available (David Morin, pers comm.); second was a review of short timeframe scarring events (<6 months, i.e. 180 days) 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-1980-2019 (only 7 events pre-1980) and those that were documented in 2019 only are provided below:

- Total number of animals reviewed in all years: **771**
  - # of batches analyzed (one batch equals all sightings of an individual grouped within each area/season in a given year) – all years: **20,817**
  - 2019 batches analyzed: **892**
- Number of separate entanglement events detected - all years pre-1980-2019: **1,708**
  - 2019 events: **44**
    - Female – 15

    - Male – 28
    - Unknown sex - 1
- Percentage of population entangled at least once: 669/771 **86.8%**
    - # of females in the population through 2019: **325**
    - % of females entangled at least once: 289/325 **88.9%**
    - # of males in the population through 2019: **370**
    - % of males entangled at least once: 348/370 **94.1%**
    - # of unknown sex in the population through 2019: **76**
    - % of unknown sex entangled at least once: 32/76 **42.1%**

An additional 42 events were added from previous years – one each in 1988, 1994, 1997, 2006, two in 2009, one in 2010, one in 2011, two in 2012, two in 2014, four in 2015, nine in 2016, seven in 2017, and 10 in 2018. 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 2019; 2) recent identifications of older sightings; 3) recently added better quality images of animals which provided evidence that a certain scar visible prior to 2019 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 2010-2019 period ranged from 10.9% to 22.4% with an annual rate average of 16.5%, slightly above the 30-year average. For 2019, this rate was 12.2% indicating a detectable drop in crude entanglement rate from the average over the 2010-2019 time period (Table 1).

Table 1. *Crude entanglement rate. Note: years prior to 2019 not updated.*

Year	# of individuals sighted	# of newly detected entanglements	Percentage
2010	422	66	15.4%
2011	438	98	22.4%
2012	376	58	15.4%
2013	302	33	10.9%
2014	373	65	17.4%
2015	276	39	14.1%
2016	329	72	21.9%
2017	378	68	18.0%
2018	347	59	17.0%
2019	**361**	**44**	**12.2%**

Annual rate of entanglement

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

Although Table 2 has not been updated for the years prior to 2018/2019 for this report, the previous scarring report indicated that all but one year (2014/2015) were above the average of 25%. 2018/2019 is below the historical average with 18.5% of adequately photographed individuals showing signs of entanglement occurrence by 2019.

Table 2. *Annual entanglement rate (years prior to 2018/2019 not updated)*

Year	Adequately photographed	Entangled by year 2	Entanglement rate
2009/2010	197	52	26.4%
2010/2011	194	77	39.7%
2011/2012	137	44	32.1%
2012/2013	50	15	30.0%
2013/2014	83	28	33.7%
2014/2015	87	17	19.5%
2015/2016	100	34	34.0%
2016/2017	158	42	26.6%
2017/2018	178	54	30.3%
2018/2019	**211**	**39**	**18.5%**

Timeframes of entanglement

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

For 2010 and 2011, 70% and 76% of the entanglement detections were determined within a one-year timeframe, respectively. In 2012, this percentage increased to 79% (Table 3) showing further improvement in the ability to detect events quickly. However, in 2013-2016, this percentage dropped with just over 50% events detected within a one-year timeframe. This pattern improved somewhat in 2017 with 59% of the cases detected within one-year. In 2018, this improved dramatically with 80% sighted within a one-year timeframe. And in 2019, this increased to 90%. 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: years prior to 2019 not updated.*

	# of events	<6 mo	< 1 year	< 2 years	< 3 years	>3 years	Unknown timeframe
2010	65	24 (37%)	22 (33%)	14 (22%)	3 (5%)	2 (3%)	
2011	98	35 (36%)	40 (40%)	13 (13%)	5 (5%)	2 (2%)	4 (4%)
2012	58	27 (47%)	19 (32%)	4 (7%)	4 (7%)	3 (5%)	1 (2%)
2013	33	8 (24%)	10 (31%)	7 (21%)	4 (12%)	4 (12%)	
2014	65	15 (23%)	17 (27%)	15 (23%)	8 (12%)	8 (12%)	2 (3%)
2015	39	9 (23%)	13 (33%)	7 (18%)	3 (8%)	6 (15%)	1 (3%)
2016	72	19 (26%)	17 (24%)	22 (30%)	2 (3%)	12 (17%)	
2017	68	25 (37%)	15 (22%)	8 (12%)	12 (18%)	7 (10%)	1 (1%)
2018	59	21 (36%)	26 (44%)	6 (10%)	2 (3%)	2 (3%)	2 (3%)
2019	**44**	**27 (61%)**	**13 (29%)**	**3 (7%)**	**0 (0%)**	**1 (<1%)**	**0 (0%)**

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 2013-2017 data, this pattern shifted with only 33% to 41% of entanglement events involving calves or juveniles (Table 4). In 2018 and 2019, 22% and 23% of events involved juveniles respectively. Of concern is the steady decline of the proportion of calves and juveniles in the population from 2010 through 2019. 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; Pace et al. 2021).

Table 4. Entanglement events by age group. Note: years prior to 2019 not updated.

	Calf	Juvenile (1-8 years old)	Adult (>8 years old)	Unknown age	% of 0-8 yo in population presumed alive
2010 n = 65	3 (5%)	31 (47%)	29 (45%)	2 (3%)	35% 181/512
2011 n = 98	7 (7%)	51 (52%)	34 (35%)	6 (6%)	35% 181/514
2012 n = 58	1 (2%)	37 (64%)	17 (29%)	3 (5%)	32% 166/516
2013 n = 33	3 (9%)	10 (30%)	20 (61%)	0 (0%)	30% 158/520
2014 n = 65	2 (3%)	20 (31%)	43 (66%)	0 (0%)	28% 147/520
2015 n = 39	1 (3%)	13 (33%)	23 (59%)	2 (5%)	27% 143/524
2016 n = 72	7 (10%)	21 (29%)	43 (60%)	1 (2%)	25% 131/522
2017 n = 68	0 (0%)	28 (41%)	35 (52%)	5 (7%)	21% 108/505
2018 n = 59	0 (0%)	13 (22%)	41 (69%)	5 (9%)	16% 79/479
2019 n = 44	**2 (5%)**	**8 (18%)**	**32 (72%)**	**2 (5%)**	**15% 70/475**

Serious entanglements: Whales carrying gear or with severe entanglement wounds only
Knowlton et al. (2012) combined the number of animals carrying gear (independent of injury severity) with the number of animals with severe entanglement wounds (without attached gear) and divided that total by the number of animals seen in a given year to determine the percentage of 'serious entanglements' for all years. The result for 1980-2009 showed an annual average serious entanglement rate of 1.2% (range 0.0 – 3.0%; SD = +/- 0.8%) (Appendix 2). For 2010-2017, all years have been above this average rate with a range from 1.4% to 3.8%. In 2018, the rate increased to 4.3% making it the highest year over this 39-year study. In 2019, this rate dropped to 2.5% which remains more than double the average rate from 1980-2009 (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 2019.

In 2019, there were nine whales with serious entanglements: five carrying gear and four with severe injuries and no attached gear. Of the five with attached gear, one (#1226, a 40+ year old male) was first seen entangled on August 6, 2019 in the Gulf of St Lawrence and found dead on September 16, 2019 off of Fire Island, NY but the gear was no longer present. Three of the remaining four were either partially or fully disentangled - #3125, an 18-year old male was first seen entangled on July 4, 2019 in the Gulf of St Lawrence. After the New England Aquarium team and collaborators were able to attach a satellite telemetry buoy to the trailing gear on July 19, 2019, he was the subject of two disentanglement efforts as he travelled from the Gulf of St Lawrence to waters off of Massachusetts. He was in very poor condition and is likely dead despite these efforts; #4423, a 5-year-old male, was first seen entangled in the Great South Channel on April 25, 2019 and partially disentangled in the Gulf of St Lawrence on July 11, 2019 with the remaining gear shed by October 28, 2019; and #4440, a 5-year-old male first seen entangled in the Gulf of St Lawrence on June 29, 2019 and disentangled on July 16, 2019. Both #4423 and #4440 will be monitored to see if their condition improves. The fourth whale, #3466, a 15-year-old male, was first seen entangled on December 21, 2019 in southern New England and was later seen gear free in April 2021 indicating he had shed the gear.

Of the four whales with severe injuries only, all of them have been seen in 2020 and their condition has not shown any clear decline. They will continue to be monitored.

Table 5. *Serious entanglements (whales with gear or severe injuries only). Years prior to 2019 not updated.*

	With attached gear	Severe injuries only	% of all sighted individuals with serious entanglements (gear + severe injuries/sighted)	Total (dead/potentially dead)
2010	5	1	1.4% (6/422)	3 (2/1)
2011	11*	3	3.2% (14/438)	5 (1/4)
2012	5*	6	2.9% (11/376)	6 (2/4)
2013	3	1	1.3% (4/302)	3 (1/2)
2014	7*	7	3.8% (14/373)	9 (2/7)
2015	4*	3	2.5% (7/276)	2 (0/2)
2016	7	5	3.6% (12/329)	10 (2/8)
2017	9	5	3.7% (14/378)	14 (2/12)
2018	6	8	4.3% (15/347)	6 (3/3)
2019	**5**	**4**	**2.5% (9/361)**	**2 (1/1)**

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

Entanglement injury severity

Above we described whales with 'serious entanglements' as any whale carrying gear or with severe wounds only. Here, we tabulate the severity of the wounds resulting from *all* the entanglement events in a given year. Entanglement injury severity was divided into three categories (minor, moderate, severe; see Appendix 1 for criteria) based on extensiveness and depth of the wounds. Knowlton et al. (2016) showed that moderate and severe entanglement injury rates have increased significantly over the three decades analyzed (1980-2009) with increasing rates noted in each year from 1997 onward and with statistically significant increases noted from 2000 onward. Although the recent data from 2010-2019 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 34% (range 24-42%). 2019 was below the average with 27% (Table 6). The proportion of 2019 cases resulting in severe injuries remained at a relatively high level at 18% (2010-2019 range: 7-24%; 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: Years prior to 2019 not updated.*

Year (# of events)	Minor	Moderate	Severe
2010 (n = 65)	42 (0); 65%	17 (0); 26%	6 (5); 9%
2011 (n = 99)*	69 (2); 70%	23 (5); 23%	7 (4); 7%
2012 (n = 59)*	45 (1); 76%	5(1); 9%	9 (3); 15%
2013 (n = 33)	22 (0); 67%	8 (1); 24%	3 (2); 9%
2014 (n = 67)*	44 (0); 66%	9 (0); 13%	14 (7); 21%
2015 (n = 41)+	26 (0); 63%	8 (0); 20%	7 (4); 17%
2016 (n = 72)	42 (0); 58%	18 (1); 25%	12 (6); 17%
2017 (n = 68)	40 (1); 59%	16 (3); 24%	12 (5); 17%
2018 (n = 59)	37 (1); 63%	8 (0); 13%	14 (5); 24%
2019 (n = 44)	**32 (1); 73%**	**4 (0); 9%**	**8 (4); 18%**

* *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 five cases with attached gear, one (#1226) was attributed to Canadian unknown gear type, one (#3125) was consistent with Canadian snow crab gear, and the remaining three were unknown country of origin (David Morin, pers comm).

For scarring cases involving no gear, 24 cases occurred within a six-month period as shown in Table 7. Seven of these likely occurred in US waters, eight in Canadian waters, and for the remaining nine, country of origin could not be determined.

With all gear and scarring-only cases combined, 39% or 17 of 44 cases could be attributed to likely country of origin - 10 occurred in Canadian waters, seven occurred in U.S. waters, and the remaining 27 cases could not be attributed to country of origin.

Table 7. *Entanglement scarring only cases determined to have occurred within a 6-month (180-day) time period with age or minimum age, sex, injury severity, injury time frame, and their likely country of origin. Note: BOF = Bay of Fundy , CCB = Cape Cod Bay, FL = Florida, GA = GA, SNE = southern New England, GB = Georges Bank, GSL = Gulf of St Lawrence, ICE = Iceland, SNE = southern New England.*

EGNo	Injury Age	Minimum Age	Gender	Severity	Injury Time Frame (days)	Pre-Injury Date	Pre-Injury Area	Detection Date	Detection Area	Likely Country of Origin
3892	11		M	Minor	5	2019-07-11	GSL	2019-07-16	GSL	Canada
1506	34		M	Minor	9	2019-08-09	GSL	2019-08-18	GSL	Canada
2027	29		M	Minor	13	2019-05-15	SNE	2019-05-28	SNE	US
1507	34		M	Minor	18	2019-07-19	GSL	2019-08-06	GSL	Canada
3380		16	M	Severe	26	2019-06-15	GSL	2019-07-11	GSL	Canada
3301	16		M	Severe	34	2019-08-26	GSL	2019-09-29	BOF	Canada
1271		41	M	Moderate	36	2019-06-10	GSL	2019-07-16	GSL	Canada
3350	16		M	Minor	37	2019-03-01	CCB	2019-04-07	CCB	US
4991	0		F	Minor	38	2019-01-18	FL	2019-02-25	GA	US
4640	3		F	Minor	39	2019-04-29	CCB	2019-06-07	GB	US
4080	9		F	Minor	41	2019-03-19	CCB	2019-04-29	CCB	US
2510		24	M	Minor	52	2019-08-25	GSL	2019-10-16	GSL	Canada
3510	14		M	Severe	57	2019-04-11	CCB	2019-06-07	GSL	Unknown
2930		20	M	Moderate	64	2019-06-15	GSL	2019-08-18	GSL	Canada
2705	22		M	Minor	82	2019-04-11	CCB	2019-07-02	GSL	Unknown
1042		39	M	Minor	94	2019-04-07	CCB	2019-07-10	GSL	Unknown
4991	0		F	Minor	105	2019-02-25	GA	2019-06-10	GSL	Unknown
4546	4		F	Moderate	109	2019-04-07	SNE	2019-07-25	SNE	US
1307		45	M	Minor	118	2019-03-13	SNE	2019-07-09	GSL	Unknown
4633	3		F	Minor	145	2018-08-21	GSL	2019-01-13	GB	Unknown
4042	9		M	Minor	170	2018-07-16	GSL	2019-01-02	GB	Unknown
4720		2	X	Minor	175	2018-08-20	GSL	2019-02-11	SNE	Unknown
3845	11		M	Minor	176	2018-07-23	ICE	2019-01-15	GB	Unknown
4308	6		F	Moderate	180	2019-03-13	CCB	2019-09-09	SNE	US

Discussion

Results from our 2019 scarring assessment indicate a total of 44 entanglement events, nine of which were serious entanglements. The proportion of whales with serious entanglements, 2.5%

of all sighted individuals, was not the highest proportion in the past 10 years but is still more than double the average rate documented in the Knowlton et al. (2012) paper of 1.2% (1980-2009) and remains concerning. The sublethal effects for those whales that do survive a serious entanglement are challenging to quantify. However, whales with severe injuries acquired when young, or whales whose mother was entangled when they were nursing are "stunted", i.e. growing to shorter lengths at adulthood than unimpacted whales (Stewart et al. 2021). In addition, a paper in review by Knowlton et al. shows that whales with severe injuries are eight times more likely to die than those with minor injuries and that the small number of reproductive females with severe injuries that survived had greatly reduced fecundity. Furthermore, moderate and severe injuries may also delay the onset of reproduction for those younger females that survive the trauma. Looking at the injury severity of the 44 entanglement events, the proportion that resulted in moderate or severe injuries remained high at 27% in 2019 with the proportion of severe injuries documented at 18%.

In 2019, of the nine whales with a serious entanglement, i.e. attached gear and/or severe injury, eight are male and one is female. This female was 10 years old when severely injured from entanglement just as she was entering her reproductive years. She has not yet had a calf as of 2021. Of continued concern is the steady decline in the proportion of juveniles in this population. This trend continued in 2019 with a drop to 15% juveniles in the population from a peak of 35% in 2010 for this past decade. We continue to speculate that this decline in juveniles in the population is a combination of lower calving rates in recent years and higher levels of undocumented juvenile mortality as juveniles can drown in the gear and not be detected.

Our ability to monitor entanglement timeframes continues to improve with 90% of the 2019 entanglements documented within a one-year timeframe. Despite this improvement in monitoring entanglement occurrence on shorter timeframes, when we looked at cases that occurred within a 6-month timeframe or had attached gear that could be linked to a country of origin, we were only able to determine likely country of origin in 39% or 17 of 44 events – 10 in Canadian waters, seven in U.S. waters.

Although the number of known and potential mortalities went down to two whales from a peak of 15 dead/potentially dead whales in 2018, this is partly due to disentanglement efforts which appear to have saved two entangled whales (#4423 and #4440) as they were both seen in early 2020, subsequent to the disentanglement efforts. Pace et al. (2021) indicated that there may be close to three times more whales dying per year than are detected, so even though this number is lower from previous recent years, it is not indicative of a problem being solved. As long as we observe right whales with attached gear, especially if they are resulting in complex entanglement configurations, and moderate to severe injuries, we are no closer to adequately addressing this existential threat to this species.

On a positive note, there was a detected improvement in both the crude and annual entanglement rates in 2019 when compared to the previous nine years and bringing those rates even below the averages in the 1980-2009 timeframe. While this provides some preliminary good news, we will be reanalyzing the entire dataset to bring the historical years of data up-to- date for comparative analyses over a 40-year timeframe. The reasons for this detected improvement may be partly due to the efforts of Canada to close snow crab fishing areas when right whales are known to be present although dynamic management is by no means a perfect solution to this chronic entanglement issue facing right whales.

The data from 2020 and 2021 are not the purview of this report, but as a point of information there were three whales entangled with attached gear in each year who died or will likely die. Also, a preliminary assessment of injuries with no gear indicate three whales with moderate to severe injuries in 2020 and two in 2021. Therefore, these data indicate the problem remains all too present despite efforts at mitigation in both the US and Canada. Considering we still do not know in which country or region most of these entanglements are occurring, we maintain that a broad implementation strategy of ropeless or on-demand gear and weak ropes throughout the right whale's range will be critical for reversing the species decline.

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Figure 1. *Severe injuries caused by entanglement (no attached gear) documented in 2019 (listed in order of catalog #). Note: BIWSC = Brier Island Whale and Seabird Cruises, DFO = Department of Fisheries and Oceans Canada, NEA/CWI = New England Aquarium/Canadian Whale Institute, NEAq = New England Aquarium, N. Hawkins = Nick Hawkins. Photos not taken by the initial observer are noted with observer and date.*

Catalog # Name	Sex	Birth year	Date of entanglement detection (date seen prior)	Age at entanglement detection	Location when detected/Observer
3301	Male	2003	29 Sep 2019 (26 Aug 2019)	16 years old	Bay of Fundy/BIWSC

Description:
This 16-year-old male was seen with raw scarring across head and dorsal peduncle although photos were poor. The injuries were still not fully healed at subsequent sightings in January 2020 but his condition was uncertain. #3301 has experienced two previous entanglements and a vessel strike.

Scar across head – 29 Sep 2019 (BIWSC)

Dorsal right peduncle scarring – 29 Sep 2019 (BIWSC)

Catalog #	Sex	Birth year	Date of entanglement detection (date seen prior)	Age at entanglement detection	Location when detected/Observer
3380 Lemur	Male	Unknown	11 Jul 2019 (15 Jun 2019)	16+ years old	Gulf of St Lawrence/NEAq

Description:
This 16+-year-old male, name Lemur, was seen with moderate to severe, raw entanglement injuries around the peduncle and insertions in July. Some of these injuries were still raw in August 2019 although healing was evident. Lemur was sighted in March and December 2020 and his condition did not show evidence of decline from these injuries. Lemur has experienced six previous entanglements since 2003 and also suffered from deep propeller cuts on his left fluke in 2005.

Left fluke insertion – August 15, 2019 (DFO)

Right fluke insertion – August 15, 2019 (DFO)

Catalog # Name	Sex	Birth year	Date of entanglement detection (date seen prior)	Age at entanglement detection	Location when detected/Observer
3510	Male	2005	7 Jun 2019 (11 Apr 2019)	14 years old	Gulf of St Lawrence/NEFSC

Description:
This 14-year-old male was seen with severe, raw entanglement injuries around the front of his head, peduncle and insertions. Baleen was observed sticking out of front of rostrum indicating damage. The injuries were still not fully healed at subsequent sightings through March 2020 but he has shown no obvious evidence of decline. #3510 has experienced two previous entanglements.

Dorsal fluke – July 5, 2019 (NEA/CWI)

Head with severe wounds and damaged baleen – July 4, 2019 (N. Hawkins)

Catalog # Name	Sex	Birth year	Date of entanglement detection (date seen prior)	Age at entanglement detection	Location when detected/Observer
3908	Female	2009	26 Aug 2019 (27 Dec 2018)	10 years old	Bay of Fundy/NEAq

Description:
This 10-year-old female was seen with severe, raw entanglement injuries around peduncle and insertions. The injuries were still not fully healed at subsequent sightings through March 2020 but she has shown no obvious evidence of decline. #3908 has experienced one previous entanglement.

Dorsal peduncle and right insertion – 6 Sep 2019 (NEAq)

Left insertion – 26 August 2019 (NEAq)

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

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

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

Entanglement injury severity

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

LOW SEVERITY

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

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MEDIUM SEVERITY

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

New England Aquarium

HIGH SEVERITY

- Injuries that were greater than ~8 cm in depth and/or are known to extend into bone or muscle.
- This also includes cases of significant deformity or discoloration of fluke or flipper, for example a twisted fluke caused by torqueing 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

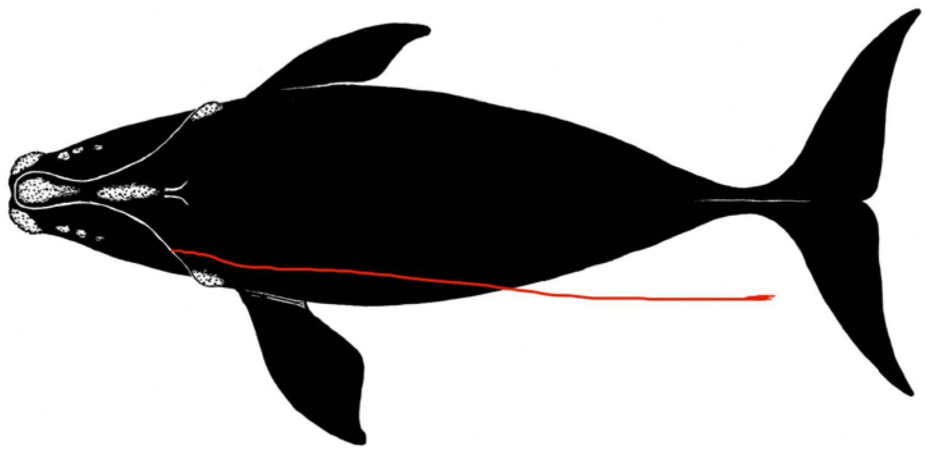
This assessment describes the layout of gear on a whale and does not take into account associated wounds. The configuration of gear on whale is generally used to assess the need for intervention, indicates how the whale may have become entangled, and may be used to make predictions about the fate of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

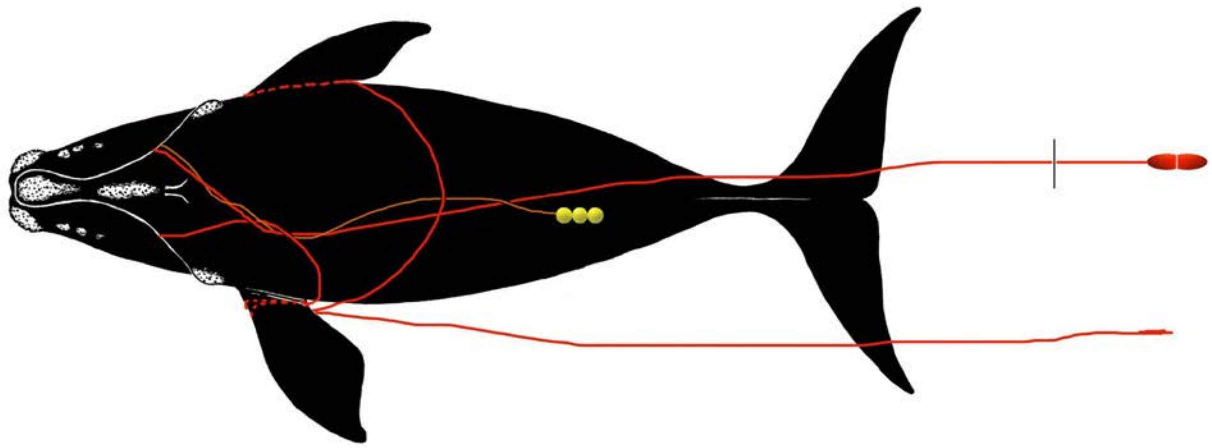
Low risk cases were those involving no tight wraps, only one attachment point, gear trailing less than one body length, and no heavy gear attached. In these cases, gear was often shed.

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

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

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

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

Task 3: Anthropogenic Injury Case Studies

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Introduction

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

The main avenues of communication that presently exist are:

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

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

Objectives and methods

The case study approach was initially developed in tandem with a study looking at rope strengths during which it was noted that there was no easy way to show fishermen and others the nature and impacts of entanglements (Knowlton et al. 2016). The goal of the case studies is to provide a consolidated two-page summary report for each individual whale providing a clear visual depiction of the entangling gear configuration or vessel strike injuries using a drawing, details about the life history of each individual including sex, age when detected with the human impact, reproductive status, and, for entanglements, the minimum and maximum durations when gear was known or estimated to be attached. These durations use data through 2019 and reflect the minimum number of days observed with gear attached and the maximum number of days that the gear could have been attached (calculated as time from date seen prior to either date with line gone if it exists or last date seen with gear attached). In addition, the status of the individual at the present time and any other pertinent information about the human impact, such as rope parameters or vessel size estimates, is provided on the first page of each case study. Under the status category, we have noted whether the whale is considered Alive, Presumed Dead, Likely Dead or Dead. We have used the term "Likely Dead" to refer to cases with no subsequent sightings (but not yet deemed "Presumed Dead") with either a life threatening gear configuration risk or severe injuries that seemed more likely to lead to compromised health and likely death. The second page includes a suite of photographs showing the entanglement or vessel strike injuries.

Initially, 30 case studies were developed for the Knowlton et al. (2016) paper for entangled right whales with retrieved and analyzed fishing gear collected from 1994-2009 (and one case in 2010). With the funding provided by NMFS/NEFSC under this Task, we have continued the development of entanglement case studies for all right whales seen with attached gear independent of whether gear was collected or not. These case studies, from 1981 to the present are now posted at www.bycatch.org under the Research Programs tab and are updated each year. With the addition of the 2019 events, there are now 135 case studies posted.

For 2019, we have created five entanglement case studies. Drawings of four of these five cases are in progress; drawings were not able to be done for the other case as photographs of the entanglement were inadequate to fully understand the configuration. We also reviewed four 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 2019 timeframe. This one case was of a carcass, #1281. One five meter long wound aligned longitudinally on the body was documented and considered to be likely the result of a large ship propeller.

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

Future steps

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

References

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

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

EGNO	Age	Sex	Retrieved Gear?	Country of origin/gear type	Date/area first observed entangled	Date/area observed prior without injuries
1226	41+	Male	No	Canada/unknown	6 Aug 2019 - GSL	(21 Jul 2019) GSL
3125	18	Male	Yes	Canada/snow crab (likely)	4 Jul 2019 -GSL	(11 Apr 2019) CCB
3466	15	Male	No	Unknown	21 Dec 2019 - SNE	(29 Apr 2019) CCB
4423	5	Male	No	Unknown	25 Apr 2019 - GSC	(28 Aug 2018) GSL
4440	5	Male	No	Unknown	29 Jun 2019 - GSL	(14 Apr 2019) MB

Appendix Ib. List of one newly completed case study for right whale vessel strikes

EGNO	**Age**	**Sex**	**Country of origin**	**Estimated general vessel size**	**Date/area first observed with injuries**	**Date/area observed prior without injuries**
1281	38+	Female	Canada	Large ship	20 Jun 2019	(6 Jun 2019)

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

Species	Right Whale	Whale ID	1226

Date first observed entangled (date seen prior without gear)	6 Aug 2019 (21 Jul 2019)		
Sex	Male	Birth year	Unk
Age at entanglement	40+		

Case study ID	CCS	NMFS	GEAR ID
	WR-2019-21	E22-19	
Gear sample collected?	No	Gear type	Canadian, unknown

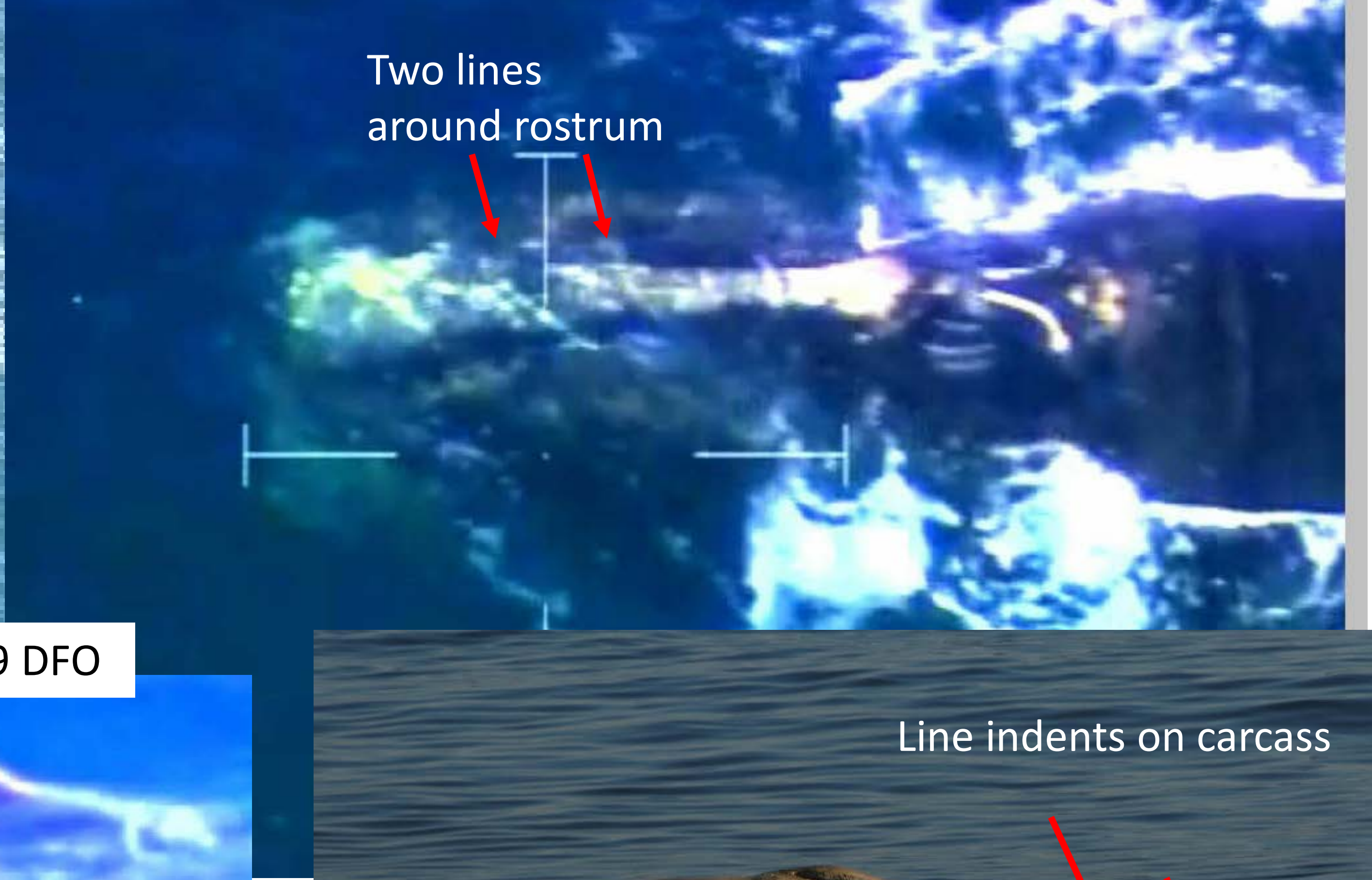
Photographs inadequate to determine complete entanglement configuration - no drawing available

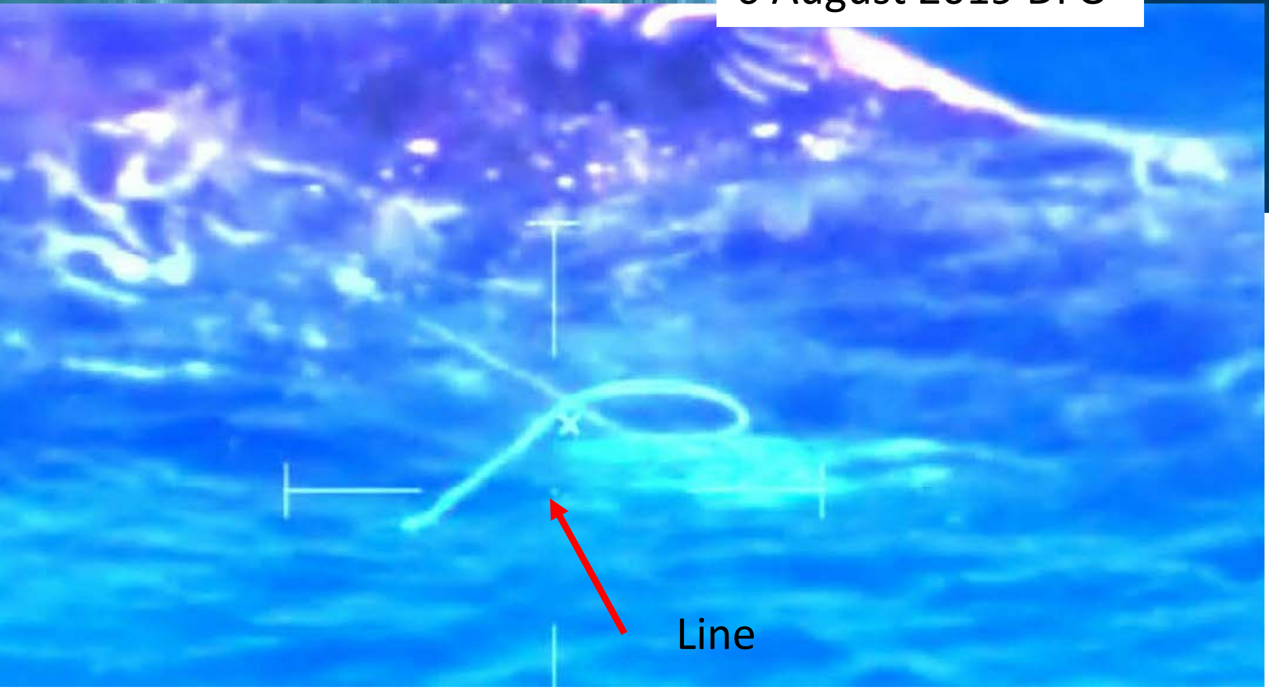
Reproductive prior to/after entanglement detection					
Entanglement injury severity	Severe				
Entanglement configuration risk	High				
Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	High	High	High	Unknown	High
Duration of time carrying gear	Minimum 1 day, maximum 55 days				
Disentangled?	No				
Status	Dead, 16 Sep 2019				
Number of prior entanglements	3				

Entanglement configuration	Two wraps around rostrum with trailing bitter end. Extensive damage at tail. May be anchored
Anchoring points	Mouth
Gear configuration confidence	Low
Remaining questions	Unsure if anchored; more rope may be involved
Comments	Found dead off Fire Island, NY. Decomposed, no gear remaining

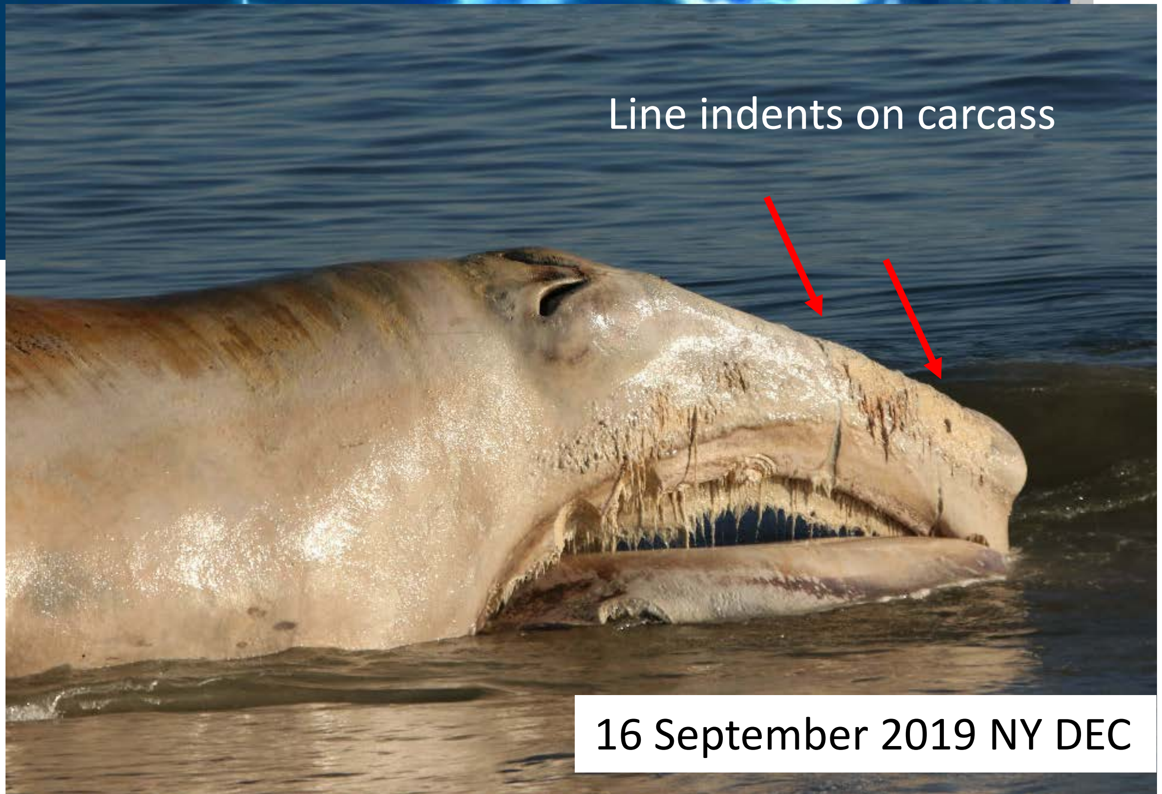
Polymer type		
Gear component	Unknown	
Rope diameter (inches)		
Breaking strength (lbs)	Tested	
	New	

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





6 August 2019 DFO



16 September 2019 NY DEC

Species	Right Whale	Whale ID	3125

Date first observed entangled (date seen prior without gear)	4 Jul 2019 (11 Apr 2019)		
Sex	Male	Birth year	2001
Age at entanglement	18		

Case study ID	CCS	NMFS	GEAR ID
	WR-2019-10	E10-19	
Gear sample collected?	Yes	Gear type	Canadian snow crab?

Drawing in progress

Reproductive prior to/after entanglement detection					
Entanglement injury severity	Severe				
Entanglement configuration risk	High				
Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	High	High	High	Medium	High
Duration of time carrying gear	Minimum 29 days, maximum 112 days				
Disentangled?	Yes, partial - 24/25 July and 2 Aug 2019				
Status	Likely dead - last seen in very poor condition				
Number of prior entanglements	1				

Entanglement configuration	Line through the mouth with multiple wraps around rostrum and entire head, around both flippers, and trailing
Anchoring points	Mouth, flippers
Gear configuration confidence	High
Remaining questions	
Comments	Damaged baleen, rope embedded, orange cyamids

Polymer type		
Gear component	Endline	
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.

19 July 2019 NEFSC

2 August 2019 CCS

2 August 2019 CCS

Species	Right Whale	Whale ID	3466

Date first observed entangled (date seen prior without gear)	21 Dec 2019 (29 Apr 2019)				
Sex	Male	Birth year	1994	Age at entanglement	15

Case study ID	CCS	NMFS		GEAR ID
	WR-2019-33	E35-19		
Gear sample collected?	No	Gear type	Unknown	

Drawing in progress

Reproductive prior to/after entanglement detection					
Entanglement injury severity	Minor				
Entanglement configuration risk	High				
Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	Unknown	None	Unknown	None	Low
Duration of time carrying gear	Minimum 41 days, maximum 707 days				
Disentangled?	No				
Status	Alive, last seen in 2021				
Number of prior entanglements	3				

Entanglement configuration	Multiple yellow lines through mouth and trailing with a jumble of rope at one bitter end
Anchoring points	Mouth
Gear configuration confidence	High
Remaining questions	None
Comments	Observed gear free in April 2021

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

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

21 December 2019   NEFSC

Species	Right Whale	Whale ID	4423

Date first observed entangled (date seen prior without gear)	25 Apr 2019 (20 Aug 2018)				
Sex	Male	Birth year	2014	Age at entanglement	5

Case study ID	CCS	NMFS		GEAR ID
	WR-2019-03	E04-19		
Gear sample collected?	No	Gear type	Unknown	

Drawing in progress

Reproductive prior to/after entanglement detection					
Entanglement injury severity	Severe				
Entanglement configuration risk	High				
Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	Low	Low	Medium	None	High
Duration of time carrying gear	Minimum 113 days, maximum 432 days				
Disentangled?	Yes, partial - 11 Jul 2019				
Status	Alive, seen 28 Oct 2019 gear free				
Number of prior entanglements	2				

Entanglement configuration	Line through mouth, forming bridle, and trailing to buoy and weighted line behind buoy
Anchoring points	Mouth
Gear configuration confidence	High
Remaining questions	
Comments	Rope wrapping around baleen plates

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

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25 April 2019 NEFSC

Species	Right Whale	Whale ID	4440

Date first observed entangled (date seen prior without gear)	29 Jun 2019 (14 Apr 2019)		
Sex	Male	Birth year	2014
Age at entanglement	5		

Case study ID	CCS	NMFS	GEAR ID
	WR-2019-09	E09-19	
Gear sample collected?	No	Gear type	Unknown

Drawing in progress

Reproductive prior to/after entanglement detection					
Entanglement injury severity	Severe				
Entanglement configuration risk	High				
Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	Medium	Low	Unknown	Low	High
Duration of time carrying gear	Minimum 20 days, maximum 120 days				
Disentangled?	Yes, partial - 16 Jul 2019				
Status	Alive, last seen in 2020				
Number of prior entanglements	1				

Entanglement configuration	Single line through mouth and wrapped tightly multiple times around tailstock with buoy under tail
Anchoring points	Mouth, tail
Gear configuration confidence	High
Remaining questions	
Comments	Whale hogtied. Gear shed by 14 Aug 2019 after line cut along body

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

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5 July 2019 N. Hawkins

5 July 2019   NEA/CWI

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

Species	**Right Whale**
Whale ID #	**1281 (Punctuation)**
Necropsy/Other ID #	

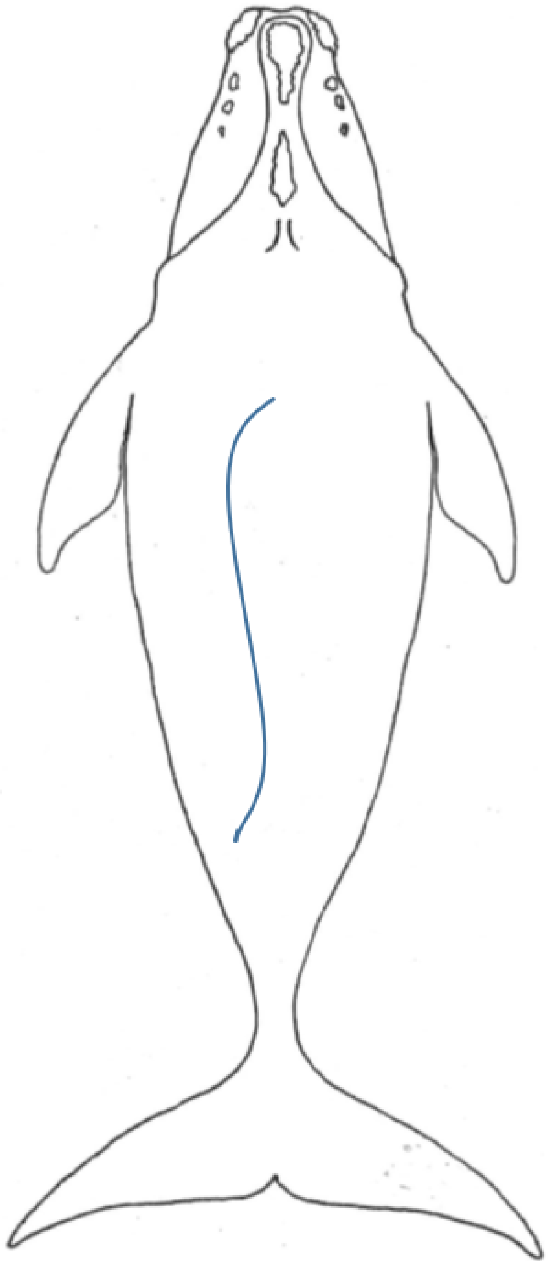
Sex	Female
Birth Year	Unknown

Age at Detection w/ Injury	38+
Date First Detected w/ Injury	20 June 2019
Date Seen Prior w/o Injury	(6 June 2019)

Reproductive Prior Injury Detection	Yes
Reproductive After Injury Detection	No

Relative Wound Depth	Deep
Body Region(s) With Injury	Body
Description of Injury	Propeller cut
Status/Year Last Seen	Dead
MMPL Vessel Size Category	Category IV (>65 feet)
Vessel Size Range	Analysis has not been done but likely large ship
Max Wound Length (cm)	5 meters

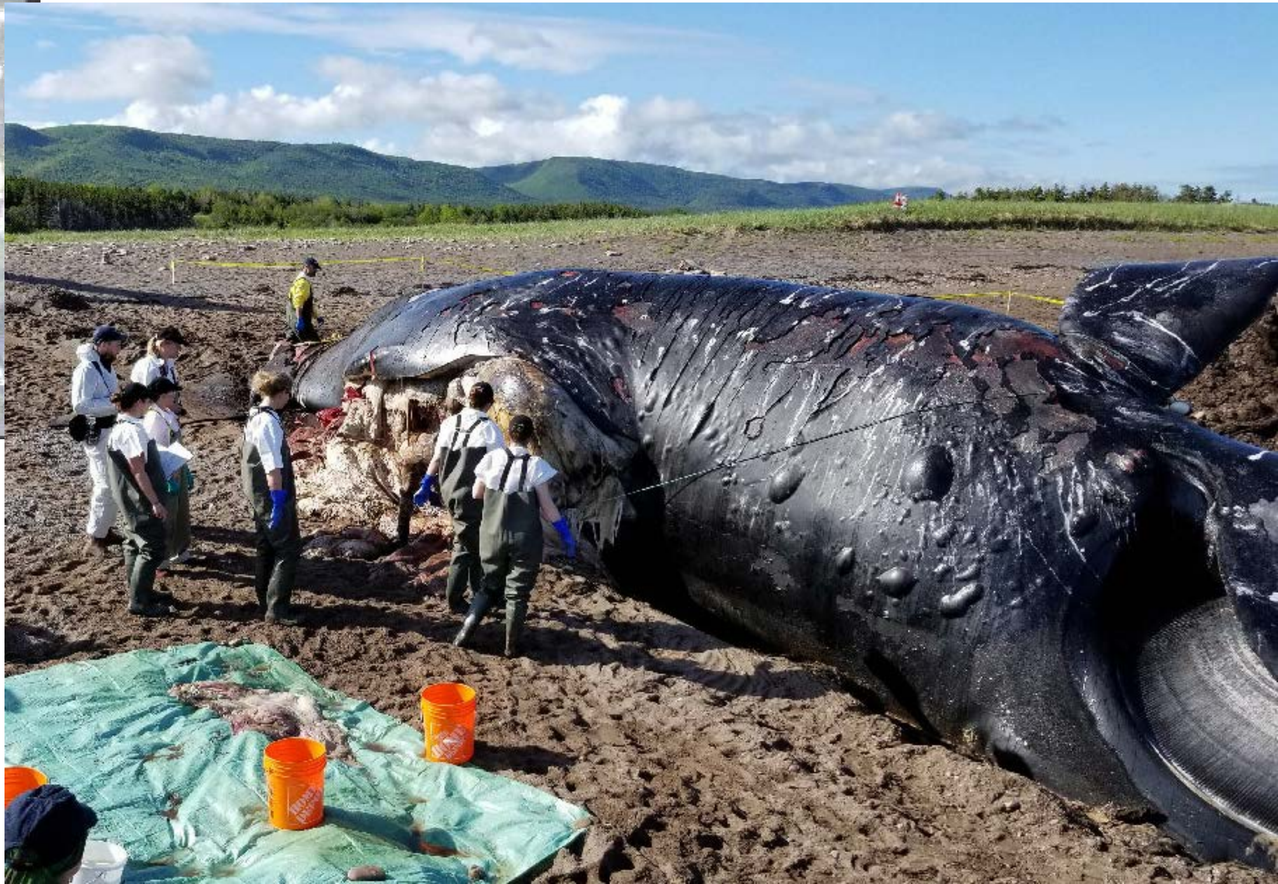
Vessel Related Comments	One deep 5 meter long cut on dorsal body determined to be premortem. Necropsy team noted that "This type of laceration would be caused by a very large category 4 vessel (cruise ships, tug boats, large shipping vessels, and mega yachts) and could be either caused by a fixed protruding structure (keel, skeg, rudder) or a massive propeller with a large pitch." Placement and shape of cut are estimated as imagery made it difficult to determine accurately.
Whale Related Comments	Necropsy showed good blubber layer but #1281 was not pregnant. #1281 had eight calves between 1986 and 2016. She died in the Gulf of St Lawrence and was found near the shipping lanes between the Magdelen Islands and Cape Breton and close to the Cabot Strait. She had experienced a previous vessel strike detected in 1986.



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. Please contact Amy Knowlton (aknowlton@neaq.org) for potential use.

20 June 2019   Transport Canada

25 June 2019   MARS



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

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Objectives

The goals of this work were to provide near real-time matching for biopsy efforts, entangled, injured, sick, or dead right whales sighted from September 1, 2020 to August 31, 2021. The biopsy portion of this task initially focused primarily on the southeast U.S., but has since expanded. 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. In 2021, Dr. Tim Frasier at St Mary's University in Halifax, NS and Mr. Philip Hamilton received a five-year genetics grant from Genome Canada which will require additional genetic sampling to investigate the epigenetic impacts of anthropogenic injuries. In addition to the usual biopsy target list, biopsy teams will now also receive a list of candidate whales for this investigation. This list will include whales that were biopsied before a severe entanglement but still need a post-entanglement sample.

The near real-time matching provides information on the last time a sick, injured or dead whale was seen alive/healthy/gear-free, potentially indicating where the harmful event took place. It also allows necropsy teams to be alerted to any individual-specific data that should be collected from dead whales. Finally, near real-time matching of entangled whales provides individual sighting histories and age, which informs the decision of whether to intervene with an entanglement, and whether genetic sampling should be undertaken if the opportunity presents itself.

In December 2020, two aerial surveys were added during the calving season. In addition to their surveys off Georgia, Clearwater Marine Aquarium Research Institute performed regular surveys off both North and South Carolina. We have grouped the real time matching for this area with that of the Southeast since the timing and whales overlap.

Results

Matching for reproduction and biopsy efforts

Southeast and mid-Atlantic
A list of females available to calve during the 2020/2021 season was sent to all survey teams on November 19, 2020, along with a list of all right whales that needed to be biopsied (i.e. need to have a skin sample collected for genetic analysis). At the same time, the newly exported E Catalog file was posted to both a Google Drive and Dropbox folder and an email sent to team leaders to download it. We used to also provide the option of receiving the E Catalog on a CD, but, as the main file has continued to increase in size, people were having increasing difficulty downloading it off the CD. There have been no issues with the direct download from a web-based file share system.

We reviewed images of 63 unique whales from the Carolinas or points south. We were able to match/confirm 56 to currently cataloged whales and six to calves from previous years which will be cataloged in the near future. One whale remains unmatched because there are only two photographs and the whale has few distinguishing features. 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. One mother and sixteen of the calves of the year were biopsied on the calving ground. One mother/calf pair was only seen off North Carolina on a single day and neither of the two were biopsied. Aside from the mother/calf pairs, three of the other 45 whales still needed to be biopsied by the end of the season. One young whale that had been biopsied last year was biopsied for second time before its identity was determined. A list of biopsied animals is included as Appendix II.

Feeding grounds

After last year's hiatus due to the pandemic, we re-initiated our rapid matching work to support darting efforts in Cape Cod Bay and the Gulf of St Lawrence. In Cape Cod Bay, the joint Northeast Fisheries Science Center/New England Aquarium (NEAq) biopsy effort went forward- though there were few trips due to poor weather and other logistical constraints. We were also able to continue our photo-identification support for the Woods Hole Oceanographic Institution photogrammetry work in Cape Cod Bay following appropriate COVID safety protocols. There were a number of changes in the Gulf of St. Lawrence. Neither Nick Hawkins nor Mingan Island Cetacean Studies (MICS) posted images for us to identify rapidly this year. The NEAq/Canadian Whale Institute/University of New Brunswick team was the only dedicated shipboard effort for photo-identification and biopsy in the Gulf of St Lawrence in 2021. Besides supplying them with the E Catalog and the usual files describing whales that needed to be biopsied, we supplied the team with a list of 41 whales to be re-darted for the epigenetics study conducted by St Mary's University. The members of our team who participated on these cruises were able to match most of the 390+ sightings, identify several biopsy candidates, and successfully obtain samples from two whales. Over 100 unique individuals were identified. We also provided matching assistance to the Department of Fisheries and Oceans Canada (DFO)- making matches or confirming their tentative matches upon request. It was through this effort that we determined that the recently discovered Lobster and her calf had entered the Gulf of St Lawrence.

Entangled or Entrapped Whales

During this contract period, there were six reports of newly entangled live right whales, and no previously entangled or entrapped right whales that needed rapid identification (Table 1). One of the reported entangled whales was in fact not entangled; This case is described in the discussion.

Table 1. List of six newly entangled or entrapped whales that were first reported between September 1, 2020 and August 31, 2021 for which matching attempts or confirmations were made quickly. One of the reports was incorrect - the whale was deeply scared but had no rope embedded in the scaring.

Date	Incident	ID	Location and comments	ID Date	Darted Previously?
10/11/2020	First entangled	4680	Off New Jersey	10/15/2020	Yes
10/19/2020	First entangled	3920	South of Nantucket, found while searching for 4680	10/19/2020	Yes
1/11/2021	First entangled	1803	Off Florida	1/11/2021	Yes
3/10/2021	First entangled	3560	Cape Cod Bay	3/10/2021	Yes
7/13/2021	First entangled	4615	Gulf of St. Lawrence, seen ~4 hours prior without gear	7/13/2021	Yes
8/12/2021	Reported as possibly entangled, was not	3510	Gulf of St. Lawrence, not entangled but new entanglement wounds on head	8/12/2021	Yes

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

Dead Whales

During this contract period, matching efforts were made on two dead right whales (Table 2). This does not include the perinatal mortality discovered in N.C. on November 20, 2020.

Table 2. List of matching efforts on two sightings of dead whales that were first reported between September 1, 2020 and August 31, 2021.

Date	Incident	ID	Location and comments	ID Date	Darted Previously?
2/13/2021	Dead on beach	2021 calf of 3230	Florida, deep propeller cuts, photos not shared, but we confirmed the ID of injured mom alone seen 3 days later	2/16/2021	Yes
2/27/2021	Dead	3920	Off South Carolina. Had been seen off FL still entangled before being found dead.	2/27/2021	Yes

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). They included one adult (vessel strike), one juvenile (entanglement), and one a calf of the year (injury cause to be determined).

Table 3. List of sick or injured whales, other than those seen entangled in fishing gear, that were reported between September 1, 2020 and August 31, 2021 and rapidly identified (or for which a significant effort was made to identify them rapidly).

Date	Incident	ID	Location and comments	ID Date	Darted Previously?
2/16/2021	Injured	3230	Off Florida. Alone w/ at least three prop cuts to left side. Calf was fatally struck by vessel on 2/13/21	2/16/2021	Yes
7/7/2021	Injured	4633	Gulf of St. Lawrence. Fresh entanglement wounds on peduncle, no gear. Found by CWRT while searching for a different entangled whale.	7/7/2021	Yes
7/11/2021	Injured	2021 calf of 3232	Gulf of St. Lawrence. Injuries on head and back. Darted July 17th	7/12/2021	No- but darted later

<u>Opportunistic Sightings</u>

Although not specifically part of our contract, we attempt to match any opportunistic sighting as soon as possible, especially mother/calf pairs or sightings from unusual locations or times of year. We received over 80 opportunistic sightings during this contract period. Some of the interesting rapid match results for these sightings include:

1) A mother and calf seen in St Mary's Bay in the Bay of Fundy. This was Lobster, #3232, and an important sighting as it was a new mother for the year. The identification was made within a day of receiving the sighting;
2) A one-year old right whale, the 2020 calf of 2642, in Cape Cod Bay on August 3, 2021. This is an unusual time of year for a right whale to be in the Bay;
3) A one-year old right whale, the 2020 calf of 2642, in the Bay of Fundy on August 10, 2021. This was just seven days after he had been seen over 270 miles to the southwest in Cape Cod Bay and one of the only sightings in the Bay of Fundy this year;
4) A calf of the year seen alone along the southern point of Tenerife Island in the Canary Islands on December 22, 2020. We cannot identify calves at this young age, but we provided information to local researchers and compared the mandible callosities on this calf to any calf first seen at a later date. This calf likely died as it is very unusual for a calf to be without its mother in December;
5) An adult female, Wolf, #1703, far up the St Lawrence River near Tadoussac, Quebec on September 25, 2020;
6) Mother #3720 and calf south of Long Island, N.Y. on March 7, 2021. This is an unusual area and also an early arrival to the northern feeding grounds for a mother and her calf;
7) Mother Binary, #3010, and calf off Cape May, N.J. on March 21, 2021. Like #3720 and calf above, this is an unusual area and an early arrival to the northern feeding grounds for a mother and her calf;

<u>Discussion</u>

Our matching support for the broader calving ground region included the match or confirmation of 62 animals (Appendix I) and 18 darting events (Appendix II). For a second year in a row, half of the calves from the previous year were seen during the calving season; five of the 10 from 2020 were photographed. These young whales always require extra effort to identify. One juvenile, the 2020 calf of 1970, was initially thought to be the calf of 2642. We requested shots of the mandibles to make a final determination and, when those images were collected two weeks later, we were able to confidently identify it as 2642's 2020 calf, not 1970's. This level of communication and coordination between the field teams and our matching team is invaluable. Although common in the 2000's, one and two-year-old whales have been infrequent visitors to the Southeast in recent years, so the increase in their presence the last two years is noteworthy.

Due to distribution shifts related to climate change, calves are now seen less frequently in the spring and summer when their callosity patterns have developed more, and juveniles are also seen less frequently throughout the whale's range- not just off the southeast U.S. The high-quality images from the Southeast of the five yearlings this year allowed for a solid identification between their calf sightings and their juvenile sightings after their callosities were more established. These links ensure that these whales will be easy to catalog and re-identify going forward.

Because of the aforementioned challenge of cataloging calves recently, we encourage teams to biopsy any young-looking whale if they can't identify it immediately. This does lead to occasional duplicate samples as was the case for the 2020 calf of 1970 this year, but those samples can still be useful. Duplicate samples have been very effective in looking for any photo-identifications errors in the Catalog in the past (Frasier et al. 2009).

Matches to two of the entangled whales in Table 1 are worth mentioning. The match to whale #4680 was challenging because the photographs showed only partial sections of the head and he was sick with a heavy cyamid load. The match allowed us to determine that he was last gear-free eight months earlier and thus could have been entangled for many months. The match to whale #3510 highlights the value of real time matching. When the NEAq team aboard the *JD Martin* in the Gulf of St. Lawrence came upon this whale, he had fresh entanglement scarring and they thought there was line embedded in the rostrum. It can be very difficult to determine if there is line when it becomes completely embedded and then covered with cyamids. The team texted us photographs of the whale and within 20 minutes we had identified it and located images on DFO's google drive of #3510 taken just four days earlier. The combined information allowed us to confirm that it was just a deep scar and there was no line embedded. The *JD Martin* was able to continue on with their research rather than stand by to support a disentanglement effort.

The identification of the new mother Lobster is also worth mentioning. It is somewhat rare to find a new mother on the feeding grounds, but it does happen so we try to review images of mothers on the feeding grounds as soon as we receive them. In the case of Lobster, although the sighting happened on May 20th, images did not make it to our team until May 31, Memorial Day. We immediately reviewed the images and made the challenging match to Lobster, a female whose one previous calf was only documented with one sighting by an observer on a dredge. A stroke of luck that a whale watch employee saw her this time and knew to take photographs. Once the match was made, we alerted the right whale community and particularly those doing surveys in the Gulf of St Lawrence since Lobster has been seen frequently in the Gulf in recent years. The communication paid off as she and her calf showed up there just weeks later and eventually the calf was biopsied- strengthening the identification link between this calf and future sightings.

It was unfortunate that we were not able to successfully establish contact with the new staff at MICS. In the past, Christian Ramp was quick to provide images of whales seen around Anticosti Island and we were quick to supply identifications. This was an important relationship as he was one of the few researchers permitted to collect biopsy samples from right whales in the Gulf and data from that area provided important information on whale movements. He was also kind enough to collect right whale fecal samples which provide a wealth of information on the species. Christian no longer works with MICS and we will continue our efforts to establish a relationship with the new team leader there.

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, Kate McPherson, and Christine Bubac (Clearwater Marine Aquarium Research Institute). As in the past, the high level of cooperative responsiveness made the near real-time matching effort possible. In other regions, many researchers responded quickly to requests for images and data. The list is too long to mention everyone, but we particularly want to mention Tim Cole, Leah Crowe, and Allison Henry (Northeast Fisheries Science Center); Brigid McKenna (Center for Coastal Studies); Orla O'Brien (New England Aquarium); Liz Thompson, Mylene Dufour, and Stephanie Ratelle (Department of Fisheries and Oceans, Canada); Nick Hawkins; Shelley Lonergan (Brier Island Whale and Seabird Cruises); Laura Howes (Boston Harbor City Cruises); Danielle Dion (Quoddy Link Marine); and Andrew Westgate (Grand Manan Whale and Seabird Research Station).

References

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

Appendix I. List of 62 whales photographed off the Carolinas or southeast U.S. during the calving season 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. An 18th mother was discovered on the feeding grounds and is described under opportunistic sightings. A sex of "C" under other whales signifies the whale has calved in past years.

Mothers with calves

Count	Whale ID	Age	Last calf	Mom darted?	Calf darted?	Comments	Confirmed sighting	Date confirmed
1	1145	40+	2010	Y	Y	With calf at her first sighting	2021-01-11-FWRI-A Eg C	12-Jan-21
2	1243	39	2011	Y	Y	With calf at her first sighting	2021-01-04-FWRI-A Eg C	04-Jan-21
3	2413	27	2013	Y	Y	With calf at her first sighting	2020-12-28-CMARI-GA Eg A	29-Dec-20
4	2420	27+	2011	Y	Y	With calf at her first sighting	2021-01-11-FWRI Eg C	12-Jan-21
5	2430	27+	2010	Y	Y	With calf at her first sighting	2021-01-08-FWRI Eg A	09-Jan-21
6	2460	27+	2010	Y	Y	With calf at her first sighting	2021-02-12-FWRI-A Eg C	13-Feb-21
7	3010	21+	2011	Y	Y	Calf born between Dec. 22 and Jan. 9	2020-12-22-FWRI-A Eg B & 2020-12-22 CMARI-GA Eg-A	23-Dec-20
8	3020	21+	2011	Y	Y	Seen off S.C. in December, later in the SEUS. Calf born between Jan. 25 and Mar. 4	2020-12-23-CMARI-SC Eg A	24-Dec-20
9	3130	20	2011	Y	Y	With calf at her first sighting	2021-01-13-FWRI-A Eg Q	14-Jan-21
10	3230	19	N/A	Y	Y	With calf at her first sighting	2021-01-17-FWRI Eg A	17-Jan-21
11	3520	16	2013	Y	Y	With calf at her first sighting	2020-12-06-FWRI Eg A	07-Dec-20
12	3593	>16+	N/A	N	N	With calf at her first sighting. Only seen once off N.C.	2021-03-11-CMARI-NC Eg A	12-Mar-21
13	3720	14	N/A	Y	Y	With calf at her first sighting	2021-01-19-CMARI-GA Eg D	20-Jan-21
14	3860	13	2016	Y	Y	Calf born between Dec. 23 and Jan. 13	2020-12-23-FWRI-A Eg A	24-Dec-20
15	3904	12	N/A	Y	Y	Calf born between Nov. 19 and Jan. 21	2020-11-19-BEMU Eg A	20-Nov-20
16	3942	12	N/A	Y	Y	With calf at her first sighting	2020-12-11-OTHER039 & 2021-01-04-CMARI-GA Eg A	12-Dec-20
17	4040	13	N/A	Y	Y	With calf at her first sighting	2020-12-04-CMARI-GA Eg A	05-Dec-20

Appendix I (cont.)

Other whales

Count	Whale ID	Age	Sex	Darted?	Comments	Confirmed sighting	Date confirmed
1	1112	>41	M	Y		2021-02-11-FWRI-A Eg B	12-Feb-21
2	1158	>40	C	Y		2020-12-22-FWRI-A Eg A & CM	23-Dec-20
3	1208	>40	C	Y		2020-12-12-CMARI-GA Eg D	13-Dec-20
4	1307	>47	M	Y		2020-12-27-FWRI-A Eg A	28-Dec-20
5	1607	35	M	Y	First seen off S.C.	2020-12-27-CMARI-SC Eg G	28-Dec-20
6	1803	33	M	Y	Entangled	2021-01-11-CMARI-GA Eg C &	11-Jan-21
7	1810	>33	C	Y		2020-12-12-CMARI-GA Eg C	13-Dec-20
8	1934	32	F	Y		2021-01-07-ALAR Eg A	19-Jan-21
9	2010	31	M	Y	First seen off S.C.	2020-12-23-CMARI-SC Eg B	24-Dec-20
10	2602	25	M	Y	First seen off S.C.	2020-12-28-CMARI-SC Eg G	29-Dec-20
11	2681	25	M	Y		2020-12-27-FWRI-A Eg C	28-Dec-20
12	3245	19	M	Y		2021-01-03-FWRI-A Eg C	04-Jan-21
13	3250	>19	M	Y	First seen off N.C.	2020-12-28-CMARI-NC Eg B	29-Dec-20
14	3380	>18	M	Y	First seen off N.C.	2021-03-08-CMARI-NC Eg A	09-Mar-21
15	3401	17	M	Y	First seen off N.C.	2020-12-28-CMARI-NC Eg A	29-Dec-20
16	3420	17	C	Y	First seen off N.C.	2021-01-11-CMARI-NC Eg G	12-Jan-21
17	3503	16	F	Y	First seen off S.C.	2020-12-27-CMARI-SC Eg B	28-Dec-20
18	3590	16	F	N	First seen off N.C.	2021-01-05-CMARI-NC Eg E	06-Jan-21
19	3651	15	M	Y	First seen off S.C.	2020-12-23-CMARI-SC Eg C	24-Dec-20
20	3701	14	M	Y	First seen off S.C.	2020-12-27-CMARI-SC Eg E	28-Dec-20
21	3790	14	F	Y	First seen off S.C.	2021-01-07-CMARI-SC Eg C	08-Jan-21
22	3810	13	M	Y		2021-01-17-GDNR Eg B	17-Jan-21
23	3812	13	M	Y	First seen off S.C.	2020-12-27-CMARI-SC Eg F	28-Dec-20
24	3820	13	F	Y		2021-01-19-CMARI-GA Eg A	20-Jan-21
25	3920	12	M	Y	Entangled	2021-02-18-CMARI-GA Eg A	18-Feb-21
26	3940	12	F	Y		2021-02-11-FWRI-A Eg A	12-Feb-21
27	3950	12	M	Y		2021-02-11-FWRI-A Eg C	12-Feb-21
28	3991	12	F	Y	First seen off N.C.	2021-01-11-CMARI-NC Eg F	12-Jan-21
29	3997	12	M	N	First seen off N.C.	2021-01-11-CMARI-NC Eg A	12-Jan-21
30	4041	11	F	Y		2020-12-27-FWRI-A Eg B	28-Dec-20

Appendix I (cont.)

Other whales

Count	Whale ID	Age	Sex	Darted?	Comments	Confirmed sighting	Date confirmed
31	4120	10	F	Y		2021-01-19-CMARI-GA Eg C	20-Jan-21
32	4129	10	M	Y	First seen off N.C.	2021-01-11-CMARI-NC Eg H	12-Jan-21
33	4140	10	M	Y		2021-01-19-CMARI-GA Eg B	20-Jan-21
34	4190	10	F	Y	First seen off S.C.	2020-12-27-CMARI-SC Eg D	28-Dec-20
35	4313	8	F	Y	First seen off N.C.	2021-01-05-CMARI-NC Eg D	06-Jan-21
36	4340	8	F	Y		2021-01-17-GDNR Eg A	17-Jan-21
37	4457	7	M	Y	First seen off N.C.	2021-01-11-CMARI-NC Eg C	12-Jan-21
38	4510	>6	F	Y	First seen off N.C.	2021-01-11-CMARI-NC Eg B	12-Jan-21
39	4617	5	F	Y	First seen off S.C.	2021-01-07-CMARI-SC Eg B	08-Jan-21
40	2019 calf of 3270?	2	U	N	First seen off N.C.. Needs to be biopsied again	2021-01-05-CMARI-NC Eg C	06-Jan-21
41	2020 calf of 1612	1	U	Y	First seen off S.C.	2021-01-07-CMARI-SC Eg A	08-Jan-21
42	2020 calf of 1970	1	U	Y	Darted 1/26. Initially thought to be the 2020 calf of 2642, needed mandibles to confirm, matched to 1970's calf after Feb 11 sighting showed mandibles	2021-01-26-GDNR Eg A	12-Feb-21
43	2020 calf of 2642	1	U	Y	First seen south of opportunistically south of Cape Canaveral	2021-02-15-Dredge-Stuyvesant Eg A	16-Feb-21
44	2020 calf of 3101	1	U	Y	In S.C. 10 days after opportunistic first sighting in FL.	2021-01-15-HBOI Eg A & MRC	17-Jan-21
45	2020 calf of 3546	1	U	Y		2021-03-10-FWRI-A Eg C	11-Mar-21

Appendix II. List of 18 right whales biopsied off the southeastern U.S. from December 1, 2020 to March 31, 2021.

Count	Whale	Biopsied as:	Date Confirmed
1	2413	2021-01-03-GDNR Eg A	29-Dec-20
2	2020 calf of 1970	2021-01-26-GDNR Eg A	12-Feb-21*
3	2021 calf of 1145	2021-01-11-FWRI-V Eg D	12-Jan-21
4	2021 calf of 1243	2021-01-19-FWRI-V Eg C	20-Jan-21
5	2021 calf of 2413	2020-12-28-GDNR Eg D	29-Dec-20
6	2021 calf of 2420	2021-01-11-FWRI-V Eg B	12-Jan-21
7	2021 calf of 2430	2021-01-11-FWRI-V Eg F	12-Jan-21
8	2021 calf of 2460	2021-02-12-FWRI-V	13-Feb-21
9	2021 calf of 3010	2021-01-17-FWRI-V Eg F	17-Jan-21
10	2021 calf of 3020	2021-03-11-GDNR Eg B	11-Mar-21
11	2021 calf of 3130	2021-01-21-GDNR Eg D	22-Jan-21
12	2021 calf of 3230	2021-01-17-FWRI-V Eg B	17-Jan-21
13	2021 calf of 3520	2021-01-19-FWRI-V Eg E	20-Jan-21
14	2021 calf of 3720	2021-01-19-GDNR Eg E	20-Jan-21
15	2021 calf of 3860	2021-01-17-FWRI-V Eg D	18-Jan-21
16	2021 calf of 3904	2021-01-21-GDNR Eg B	22-Jan-21
17	2021 calf of 3942	2021-01-04-GDNR Eg B	05-Jan-21
18	2021 calf of 4040	2020-12-23-FWRI-V Eg B	24-Dec-20

* See note in Appendix 1 to explain delay in identification

Task 5: Final Report on 2019 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 2020. Photographs from all sightings of an individual whale were grouped sequentially by right whale habitat (e.g. Gulf of Maine, Cape Cod Bay, Bay of Fundy) (Waring et al. 2015) and those groups of images were referred to as "sighting batches." These are the same batches used for the scarring analysis described above in Task II. All images in each batch were evaluated together and a single score was assigned for each visual parameter. If any change in a visual parameter occurred within a batch, this was noted and the score at the end of the given batch was the one assigned to the entire batch. Because the quality of the images varied from sighting to sighting, and only one side of a whale was photographed in some sightings, each visual health parameter score represents a composite of information gleaned from all the sightings in the batch. Health assessment scores and associated batch information, including date range of batch, habitat, and comments related to condition, were incorporated into the VHA Database. The database is linked to the Identification Database so that spatial, behavioral, and life history data can be coupled with health data.

Each year, there are previously assessed sighting batches for which new sightings become available or new sighting batches are added. For these cases, the health assessment scores for the existing batch were examined and new information available in the new sightings was assessed and incorporated into the existing batch. Any new batches were assessed and coded as well. Under the current year of funding for this project, all health data through 2019 (including pre-2019 data that were added since the last funding period) were analyzed and the VHA Database is considered complete through 2019.

Database Summary and Analyses

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 of body condition excluded calving females of the year to remove the known impacts of reproduction on body condition.

Results

Update of Database

A total of 937 batches consisting of 59,628 images from 4,545 sightings of 380 individual right whales were evaluated and scored for visual health parameters for this update, including 31 whales assessed and scored in multiple years (Table 2). These visual health data were entered into the VHA Database and integrated with the Identification Database. The updated visual health data are now accessible via the North Atlantic Right Whale Consortium for scientists, managers, students, or other individuals with a bona fide purpose (NARWC 2021).

Database Overview

The updated VHA Database contains 20,835 batches consisting of 76,594 sightings from 1935-2019. The number of batches and associated sightings available to be assessed has varied annually (Figure 1, sample period 1980-2019 shown).

The percentage of sightings photographed by aerial and shipboard platforms has changed over time (Figure 2), with a continued increasing trend in aerial sightings. Between 1980–1999, 83% of right whale sightings were observed via shipboard platforms. Since then, only 42% of sightings have come from shipboard platforms. This is important because higher quality and more complete health assessment data are obtained from shipboard photographs. The relative percentage of aerial sightings remained high in 2019, though slightly lower than in 2018 which represented the highest proportion of aerial sightings (76.4%) in this study period. Though relatively insignificant in number, sightings of right whales from land and drone are represented in the database (total of 779 and 431 of 76,480 sightings, respectively, from 1980-2019).

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
2009	2	21	1
2010	2	2	1
2011	2	4	1
2012	1	2	1
2014	1	8	1
2015	5	13	4
2016	7	45	7
2017	11	38	6
2018	14	45	12
2019	892	4,367	346
Total	**937**	**4,545**	**380***

*The total number of right whales assessed during this update was 380, including repeat samples of 31 individual whales in multiple years.

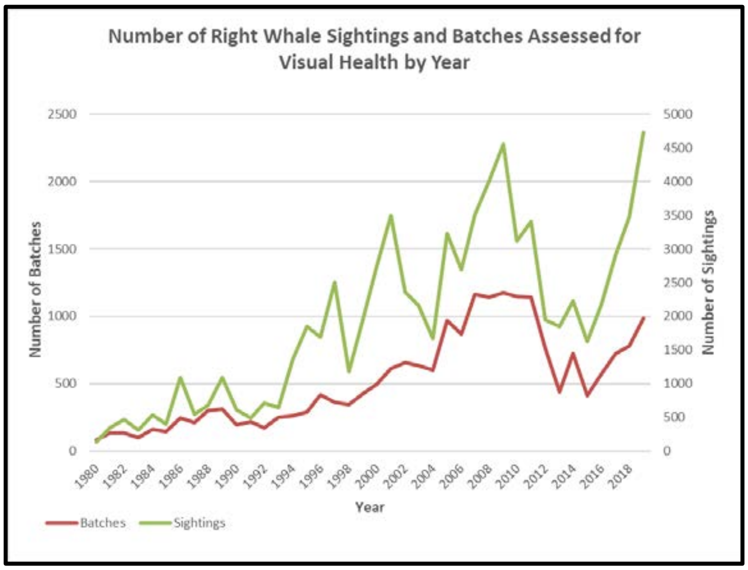

Figure 1. Count of North Atlantic right whale sightings and batches by year in the Visual Health Assessment Database 1980-2019.

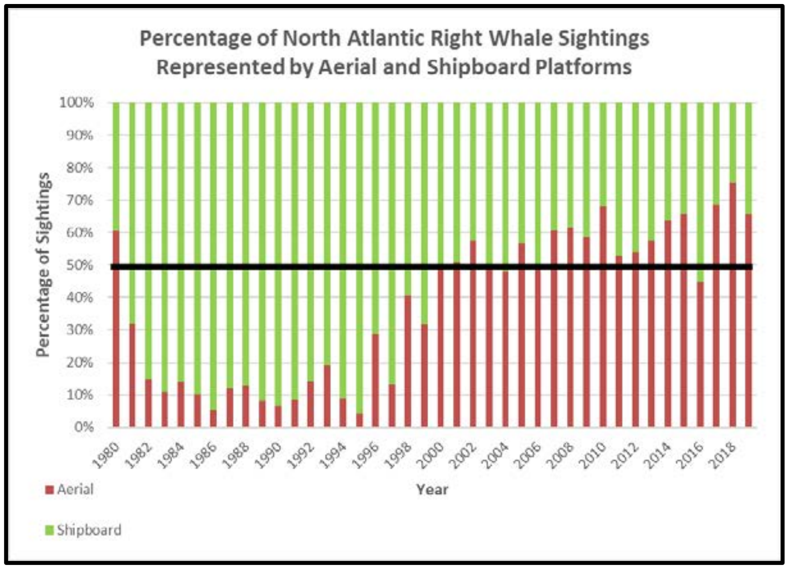

Figure 2. Percentage of North Atlantic right whale sightings scored for VHA represented by aerial and shipboard platforms between 1980- 2019. 50% line included in black. Land and drone based sightings are excluded from this analysis as they represent a relatively insignificant number of annual sightings.

Body and Skin Condition

The annual proportion of right whale sighting batches that were assessable for skin and/or body condition also varied by year and was consistently higher for skin condition (min/max% 62.7/95.5) than body condition (min/max% 30.1/82.4, Figure 3). The proportion of individual right whales presumed to be alive each year that were sighted and scored for either skin or body condition at least once varied by year (Figure 4). Between 1980 and 2019, the annual proportion of presumed alive right whales with scored skin condition was consistently higher (min/max% 37.9/82.4) than the proportion of presumed alive whales with scored body condition (min/max% 21.9/70.3).

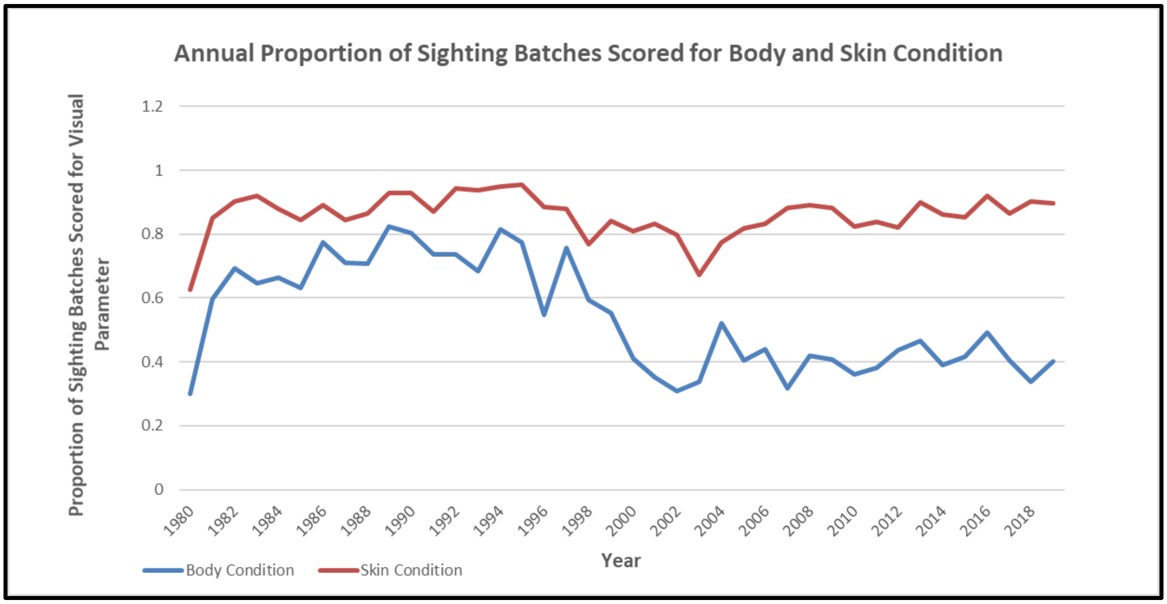

Figure 3. Annual proportion of right whale sighting batches that were scored for skin and body condition, 1980-2019.

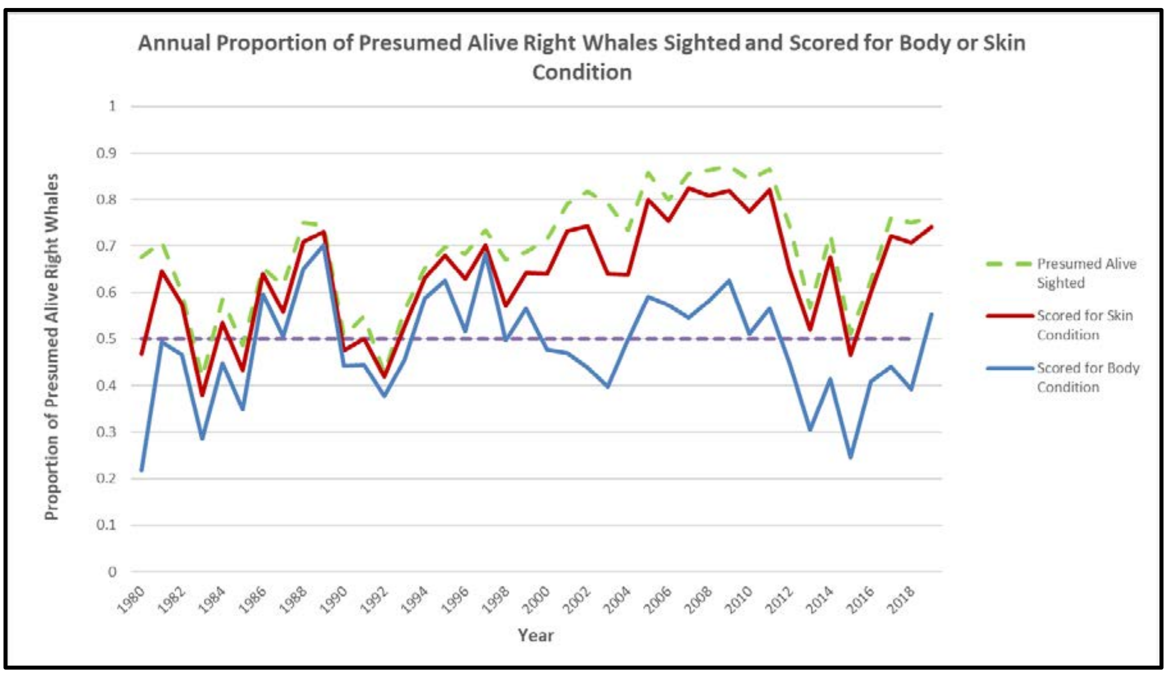

Figure 4. Annual proportion of presumed alive right whales that were seen and scored for skin and body condition by year, 1980-2019. Dashed purple line represents 50% presumed alive population.

The prevalence of compromised skin and body condition detected visually in North Atlantic right whales varied by year with peak prevalence of compromise for both parameters in the late 1990s and again in 2012 and 2016 for body condition (Figure 5). Both parameters showed similar trajectories until 2009 when a divergence occurred, with a higher proportional prevalence of compromised body condition than skin condition detected every year since 2009. The prevalence of compromised body condition rose slightly in 2019 (39.7% as compared to 38.6% in 2018) while the prevalence of compromised skin condition remained the same at 19.0%.

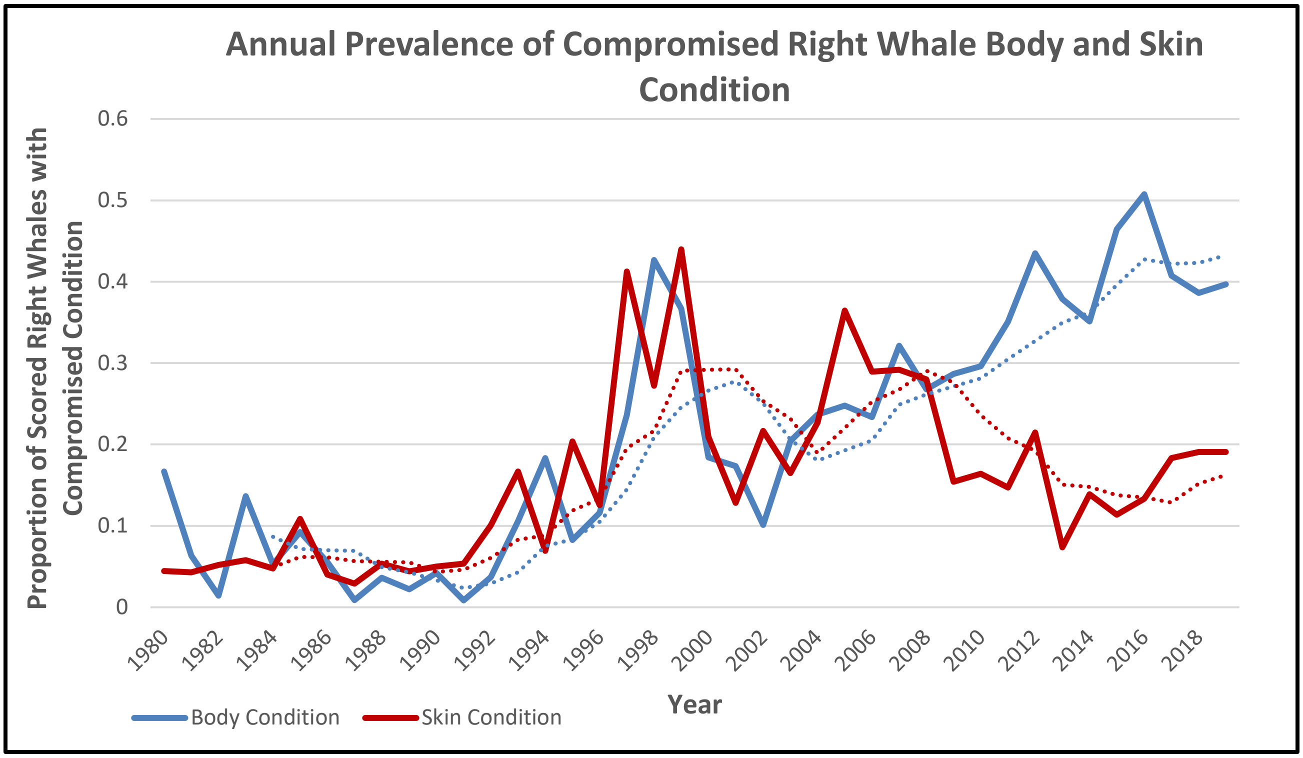

Figure 5. Annual proportion of right whales with compromised skin and body condition. Prevalence was defined as at least one sighting batch for an individual right whale scored as compromised for skin or body condition by year, 1980-2019. Reproductive females were excluded from the body condition analysis in each of their calving years. Stippled lines represent 5-year rolling average.

Discussion

Visual health data for 380 right whales across 10 years 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 injury cases (entanglement and vessel strike) for which intervention is being considered, and must be developed rapidly. Additionally, the VHA technique is an important tool in monitoring the North Atlantic right whale species on multiple fronts, including investigating the impact of entanglement events on health and assessing the impacts of health on reproduction and survival. Access to the VHA Database for research, management, education, and conservation purposes is available via the North Atlantic Right Whale Consortium and over the past year, the VHA database has received several requests for data access, including proposals to:

1. Model the impact of single and multiple stressors on right whales

2. Understand comprehensive physiological responses of North Atlantic right whales living in the Anthropocene
3. Assess options to allocate entanglement events to region/country
4. Asses impacts of fishing gear entanglements on marine species along the New Jersey coast

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

The ability to effectively monitor health is dependent on the availability of adequate photographs to score each parameter. Some visual parameters, including body condition, rake marks, and cyamids in the blowholes, are often difficult to assess using aerial images and therefore rely primarily on the availability of shipboard photographs. Since 2000, the proportion of right whale sightings photographed from aerial platforms has increased, with the lowest percentage of shipboard sightings recorded in 2018. This is related to several factors, including an increase in aerial survey effort on the calving ground in the southeast United States and Great South Channel in the 2000s. More recently, a shift in right whale distribution away from habitats traditionally surveyed by shipboard platforms (i.e. the Bay of Fundy) and into habitats primarily surveyed aerially (i.e. Cape Cod Bay and the Gulf of St. Lawrence) began in 2010. Additionally, the shift in distribution after 2010 resulted not only in a change of the predominant sighting platform, but also in a decrease the proportion of presumed living right whales seen annually compared to the 2000s. The proportions of presumed alive whales sighted and those scored for skin and body condition have increased since a low point in 2015, likely due to increased survey efforts (both aerial and shipboard) in the Gulf of St. Lawrence. Sighting whales and visually assessing their health each year are critical to not only understand changes in individual and population wide health over time, but also to adequately monitor both the impacts of anthropogenic injury (i.e. entanglements and vessel strikes) as well as emerging consequences of climate and oceanographic changes. For these reasons, it is important to continue to include vessel surveys in all high aggregation habitats.

The use of drone technologies to photograph right whales (primarily direct overhead images for photogrammetry measurements) has increased over the last several years and there is interest in investigating the potential for this platform to aid visual health assessments, particularly with regards to body condition in habitats such as Cape Cod Bay where traditional aerial platforms and skim feeding behavior make it difficult to comprehensively asses whales in that area. A preliminary comparison of shipboard images and drone images taken of whales in Cape Cod Bay from 2016-2019 suggests that drone imagery may be useful in supporting visual body condition assessments, but there will likely need to be adjustments to the angle of image capture from the standard overhead drone photogrammetry images. We will continue to work with those using drones for right whale research to determine best practices for drone imagery support of VHA assessments.

In addition to increasing the proportion of right whale sightings we are able to assess for body condition, there is interest in refining and narrowing the uncertainty around visual assessments of both body and skin condition scores. For body condition, the middle score encompasses a wide range of compromised body condition; lactating females, post-lactating females, whale on the verge of emaciation, and whales with slight concavity to their backs. We are currently assessing options, including adjusting our scoring protocol for body condition from a three-point scale to a four-point scale. This switch would allow for each score to be more narrowly defined, would align the scoring criteria with the fluctuations in body condition that we observe, and would create a scoring regime that allows for a more accurate assessment of changing condition over time. Similar discussions have focused on modifying the skin condition scoring criteria as well, for the same reasons proposed for body condition.

For much of the study period, the fluctuations in the prevalence of compromised skin and body condition for right whales were relatively synchronous (Figure 5). However, there was a marked divergence beginning in 2009 that remained through 2019, 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 there are many consequences of poor body condition including reduced reproductive capacity and reduced resiliency in response to other stressors (intrinsic or extrinsic). The prevalence in compromised body condition rose slightly in 2019, but was still below the peak in 2016. If right whales are finding habitats that remain stable in quality prey resources inter-annually, we would expect this prevalence in compromised body condition to decline. Monitoring visual body condition over time, in concert with other body condition assessments such as photogrammetry, may provide insights in right whale habitat quality. The prevalence of compromised skin condition remained stable in 2019, but still relatively high as compared to the preceding few years. Anecdotally, researchers have noted the development of skin lesions on right whales using the Gulf of St. Lawrence as the summer/fall seasons progress and this is an observation worth pursuing further.

The database remains an important tool in monitoring this endangered species, particularly given its utility in longitudinal comparisons of individual and population wide health. Maintaining and updating the database allows for: it to be integrated with other databases, population health to be examined by researchers and managers, the impact(s) of injuries on health to be examined, and comparisons of individual and population health trends over time. Recent analyses have utilized health assessment data to improve estimates of undetected mortalities in the population. The 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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