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

Prepared by:
Philip K. Hamilton, Amy R. Knowlton, Kelsey R. Howe, Marilyn K. Marx,
Kate D. McPherson, Heather M. Pettis, Amy M. Warren, Shelby L. Vance, and Monica A. Zani
Anderson Cabot Center for Ocean Life
New England Aquarium
Central Wharf
Boston, MA 02110

Submitted to:
Henry Milliken and Sean Hayes
NOAA/NMFS/NEFSC
166 Water Street
Woods Hole, MA 02543

Contract No. 1305M2-18-P-NFFM-0108

Submitted October 31, 2022
Amended December 5, 2022 (executive summary and Task 7)

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 2021 using data as of August 30, 2022. The entanglement scar coding (Task 2) reports on data for 2020 and compares 2020 findings to previous years. Anthropogenic case study reports (Task 3) describe cases first documented in 2020. The near-real-time matching (Task 4) reports on matching efforts from September 1, 2021 to August 31, 2022. Finally, the visual health coding (Task 5) reports on data through 2020, with some newly added data prior to 2020 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. In addition to these ongoing tasks, this year we report on two other tasks added to this contract in 2021: conduct a vessel-strike forensic study (Task 6) and the migration of the WhaleMap infrastructure and data curation from Dalhousie to the New England Aquarium (NEAq) (Task 7).

One factor that affects our ability to perform each of these tasks is the impact the changes in right whale distribution have had on the type of surveys conducted. While the research community has adapted somewhat to the new distribution, the amount of shipboard surveys remains relatively low compared to what it had been previously. This change, along with a small portion of the population that is seen less frequently now, has made photographically identifying and cataloging calves from recent years, and collecting genetic samples from them later as juveniles, difficult. It also makes the assessment of entanglement rates and visual health more challenging. Shipboard surveys need to be expanded to better assess human impact rates, evaluate visual health, and collect biological samples for a variety of research efforts which all inform the status of this population. The need for improved resolution in the health and scarring data is essential in light of anticipated regulatory changes aimed at reversing the downward trajectory of this species.

It is particularly important that the genetic sampling work on the calving ground continue in order to support efforts to link calves to post-calf sightings and thus maintain data on age, parentage and juvenile survival. Calves that have not yet been cataloged due to limited photographic information in their calf year may be cataloged years later using genetics or more recent photographs. Using genetics collected from young calves, Hamilton et al. (2022) discovered four calves, that were thought to have died, had actually survived- two of those apparently weaned by 7.7 to 8.0 months. 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) confirm that those samples are correctly linked to the Catalog database, and 3) help confirm and disseminate genetic identifications.

We faced several challenges in the last year that impacted data processing. Due to updates in third party software that is used in our DIGITS software, we were unable to annotate images for over four months. This issue is described in detail in section III under Catalog Database, but the consequence of this issue was that the processing of a number of data sets were delayed during that time. There were also several large data sets submitted well over a year after they were collected which delayed their processing. Finally, the large number of video sightings submitted to the Catalog continue to be cumbersome. 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 still discussing a transition of the DIGITS software from a server-based system to a fully web-based system and incorporating video in such a way as to streamline the process substantially.

Since the last catalog report, there have been 3,852 sightings added to the Catalog, 2,142 identifications confirmed, and 10 new whales added. Two dead whales were identified, 20 others became presumed dead (i.e. not seen in six years), and one was resurrected (i.e. seen after a sighting gap of six or more years). There have been consistently high numbers of presumed deaths since 2017 indicating that 2011 was the beginning of a substantial increase in undocumented mortalities. There are currently 781 cataloged whales, 431 of which are presumed to be alive- a decrease of 11 from last year's report. There were two dead whales documented in 2021; the second year of relatively low numbers of *documented* mortality.

With the change in right whale distribution, there have been increasing numbers of sightings reported opportunistically: more than 50% of the contributors to the Catalog over the last two years were individuals, not organizations, many of whom do not normally collect and submit right whale images. These individuals provided over 350 sightings. Tracking down the data and images from many of these sources is challenging and time consuming- especially those only found on social media. Also, the quality of the imagery is often poor which increases the time needed to make an identification.

We accomplished several Catalog-related projects in the last year. We purchased a new server that is large enough to accommodate three to five years of growth in the database. This server is virtualized into many servers which not only house the database, but also run the public website and provide our web-based access to the DIGITS software via Citrix. We also completed a number of modifications to the software and database including adding: 1) a field to indicate accuracy of the location data, 2) telemetry tag as an option for platform, 3) UTC time as a separate field, 4) the ability to search for count of mandibular islands, and 5) pulling location data from image metadata when it is available.

Scarring data for 2020 indicate a second year of lower scarring rates compared to recent prior years in the level of entanglement of right whales in fixed fishing gear with a crude entanglement rate (newly discovered entanglement scars as a proportion of whales seen) of 12.4% and an annual entanglement rate (proportion of adequately photographed whales with new scars) of 22.4%. 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 86.4%, a decline of 0.4% from 2019. In 2020, there were 38 entanglement events, including seven serious entanglements, a continued high proportion of moderate and severe injuries (39%), and a continuing decline in the juvenile population (down to 13%). At 2.3% of all sightings, the seven serious injuries represent a decline from the peak of 3.9% documented in 2018 but still remains a concern as it is nearly double the average rate of 1.2% documented from 1980-2009.

Anthropogenic case studies were developed for four new vessel strike cases and three new entanglement cases documented in 2020. These case studies include photographs and life history data, and, for the entanglement cases, rope polymer and diameter information where available. The vessel strike cases each have a drawing depicting the location of the wounds.

Under the near-real time matching task, we were able to support the teams 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 47 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. Our identification of yearling whales is particularly important as these are the most challenging to identify and some require a biopsy to link to past calves. Finally, we rapidly identified five reportedly entangled whales, no dead whales, and one whale with new vessel strike injuries.

The visual health coding for 2,216 sightings of 339 right whales was completed since the last report, bringing the Visual Health Assessment Database up to date through 2020. Analyses of health scoring over time indicate that the predominate use of aerial survey platforms over shipboard, as well as the distribution shift of right whales since 2010, continues to impact our ability to effectively monitor the health of this species, particularly for body condition. To that end, the proportion of batches scored for body condition in 2020 fell to 29.9%, the lowest over the study period. The COVID-19 pandemic, which led to a reduction in both overall survey effort and shipboard surveys, further challenged assessments in 2020 and likely contributed to this decline. The annual proportion of estimated living whales scored for both skin and body condition declined in 2020. While the proportion of sighted right whales scored for skin condition annually remained high, that of body condition continues to fluctuate and dropped below 50% for the first time since 2015. Lastly, the proportion of whales with compromised body condition, while still high relative to that of skin, declined by 13% in 2020. The prevalence of compromised skin condition has been stable since 2017, though at a higher percentage than had been seen over the four prior years. This new information on health condition is available to researchers and managers for various efforts, including long term and real time assessments of right whale health. 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. High quality shipboard photographs provide the best level of detail for visual health assessments and remain integral to effective monitoring of the overall condition of the species. Discussions and strategies to modify the scoring criteria for both body and skin condition parameters to better capture changes in condition are underway. 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: 1) it to be integrated with other databases, 2) population health to be examined by researchers and managers, 3) the impact(s) of injuries on health to be examined, and 4) comparisons of individual and population health trends over time.

The efforts to conduct a vessel-strike forensic study are underway. Determining the appropriate consultant to do this work was challenging and took a substantial amount of time. Because the contract for this task does not require a progress report and the work is not complete, we do not provide an update in this report. Next year, we will report on the results of five objectives related to right whale cases with external evidence of a vessel strike: 1) refine and develop best practices for evaluating large whale strike events and improve our understanding of propeller dimensions and the size of vessels involved in strikes; 2) assess orientation of whale relative to vessel when strike occurred; 3) evaluate the frequency and impacts of vessel strikes on reproduction and survival; 4) determine where strike may have occurred; and 5) develop forensic assessments of recent vessel strike events.

Finally, NEAq staff coordinated efforts between IT departments at NEAq and Dalhousie University to migrate the online, real-time right whale sighting and detection platform, WhaleMap, to a cloud based server under NEAq purview. The migration was completed on May 23, 2022 and is now available at www.whalemap.org. Also in coordination with Dalhousie researchers, NEAq staff engaged in training meetings and a two day workshop to gain an understanding of WhaleMap as a resource and to learn the backend coding structure and routines that drive the platform. Training continues and on December 8, 2022 intensive coding training is planned, with the ultimate goal of NEAq researchers assuming long term data curatorial and coordinator roles for WhaleMap. Lastly, NEAq researchers engaged in multiple meetings with coordinators for Whale Insight, a mapping display of right whale sightings and detections in eastern Canadian waters that is modeled after WhaleMap. There are shared data streams between the two platforms and as such, we anticipate continued coordination meetings going forward. WhaleMap continues to be an incredibly important resource to research and management communities in both the U.S. and Canada and the migration and training accomplished under this funding stream ensure its long-term curation and utility.

Task 1: Maintenance of the North Atlantic Right Whale Catalog: 01 January - 31 December 2021

Prepared by:
Philip K. Hamilton, Kelsey R. Howe, Amy R. Knowlton, Marilyn K. Marx, Kate McPherson, Heather M. Pettis, Shelby L. Vance, Amy M. Warren, and Monica A. Zani
Anderson Cabot Center for Ocean Life
New England Aquarium
Central Wharf
Boston, MA 02110

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 2021 time period and all data reported on are as of September 1, 2022. The database, as of this date, including all data prior to 2022, was exported and queried for this report. The data exported for this report can be found at this FTP link: https://personal.filesanywhere.com/fs/v.aspx?v=8e6d678961636e78b0.

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 2021)

The Catalog 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, a "sighting" 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 as a sighting. In January 2014, records of satellite tagged whales (e.g. implanted or surface tags, or telemetry buoys attached to entangled whales) were entered into the Catalog. Each of these records represents a single, high-quality location for each day a cataloged, tagged whale transmitted a position.

Because NEAq is primarily responsible for photographic identifications, our Catalog reports only describe the status of photographic sightings. As of September 1, 2022, there were a total of 89,492 records from 1935 through 2021: 88,668 associated with photographs where the identification was made primarily through the photographs (even if genetic data were also available), 770 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. As of the writing of this report, we are still awaiting eight data sets from 2020 (n=1) and 2021 (n=7).

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 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 2002 to 2021 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 calves is more challenging if the calf is not sighted with their mother 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 that started in 2011 has resulted in fewer juveniles photographed during this period. Combined, these factors have led to a delay in calves being cataloged. It may take years, using a combination of photo-identification and genetic data, to link post-calf sightings back to a calf and then catalog that whale. Currently, an average of 68% of the calves born between 2011 and 2021 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 92% of the matching for the calendar year 2020 data and 13% for 2021 data (Appendix I). 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 2021, so although the percentage of sightings matched and confirmed for the 2021 right whale year is low, 324 unique individuals have been identified so far. This number may increase as more data are processed. The details of the 2021 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 improve data accuracy and matching efficiency. We modified the software to pull and store any GPS data from the image metadata when available. Comparing these location data with the submitted sightings data provides a good double check for the location information that is entered into the database. We added a field for UTC time to allow data collected from different time zones to be standardized and compared to look at swim speeds, etc. We also added a location accuracy assessment field. While most of the data submitted to the catalog have accurate location data associated, some sightings have estimated locations based on physical landmarks or buoys. The location accuracy categories are: 1) known or presumed to be accurate, 2) estimated- accurate within a couple of miles, 3) estimated- unable to assess accuracy, 4) known to be inaccurate. The latter category is used when a sighting maps on land or is too far from a previous sighting to be possible, and we do not have any additional information with which to correct the submitted location. Anyone using the Catalog data for spatial analysis can make their own determination of which data to use.

The anthropogenic data web interface that was developed last year with external funds, and described in detail in last year's report, has proven extremely useful. Briefly, the Right Whale Injury and Monitoring Portal is used to view data entered in DIGITS and input additional data to those existing cases as well as to enter anthropogenic monitoring cases before data are submitted. Eventually, we will have all data relating to anthropogenic injuries available in this one place. This will include such things as entanglement and vessel strike case studies and necropsy reports. The next step will be to develop an external website to provide data outputs for the public and additional query options to approved users with passwords.

Since the last Catalog report, we executed 18 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.

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). Importantly, 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 to maintain the high level of detail that manual coding and inspections provide for the Catalog data. That level of detail 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, 2021)

a. Summary of sightings

(n= 84,816)

Assessment Complete (93%)		Assessment Incomplete (7%)	
Matched: Confirmed	79,124	Matched: Unconfirmed	456
Not Matchable	3,213	Intermatched	695
		Not Yet Matched	5,180

Since the last catalog report, there have been 3,852 sightings added to the Catalog and 2,142 identifications confirmed.

b. Summary of cataloged whales

(n=781)

All Whales	Male	Female	Unknown	**Total**
Gender	373 (47.8%)	328 (42.0%)	80 (10.2%)	781

Presumed Living in 2021

	Male	Female	Unknown	**Total**
Gender	241 (55.9%)	164 (38.1%)	26 (6.0%)	431
	Adult	Juvenile	Unknown	**Total**
Age Class in 2021	372 (86.3%)	55 (12.8%)	4 (0.9%)	431

Known Dead (cataloged whales only)

	Male	Female	Unknown	**Total**
Gender	31 (41.9%)	43 (58.1%)	0	74
	Adult	Juvenile	Unknown	**Total**
Age Class at Death	45 (60.8%)	26 (35.1%)	3 (4.1%)	74

Two cataloged whales died in 2021 and are included in the age row in "All Whales" above. The remaining 72 dead whales are not included in that tally.

Presumed Dead as of 2021

	Male	Female	Unknown	**Total**
Gender	101 (36.6%)	121 (43.8%)	54 (19.6%)	276
	Adult	Juvenile	Unknown	**Total**
Age Class Last Seen	152 (55.1%)	87 (31.5%)	37 (13.4%)	276

Catalog data- 2021 only (this is for the "right whale year", which includes data from December 1, 2020 through November 30, 2021)

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 2021 data have been received and/or entered, so the numbers below will change in the future.

a. Summary of sightings- 2021

(n= 3,487)

Assessment Complete (16.4%)		Assessment Incomplete (83.6%)	
Matched: Confirmed	569	Matched: Unconfirmed	434
Not Matchable	3	Intermatched	355
		Not Yet Matched	2,126

b. Distribution of sightings

Five Main Right Whale Areas

BOF	CCB	FL/GA	GSC
6	896	412	110

Other SEUS and Mid-Atlantic Areas

DBAY	MD	NC	NJ	NY	SC	VA
1	1	26	9	4	37	7

Other Northeast Areas

GB	MB	SNE
71	296	373

Other Areas North and East

EAST	ESS	GSL	NRTH
1	1	1,235	1

c. Summary of identified whales

With 16.4% of all 2021 sightings for the right whale year matched and confirmed, 324 individual right whales have been identified (note: the 16.4% matched reported here differs from the 13.0% matched reported in Appendix I because the latter is for the 2021 *calendar* year). The numbers in section d below are low for many areas as the data have not been fully processed. 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. None of the 2021 calves are included in the counts below as none have been cataloged; they are only provisionally identified by their association with their mothers. Another 21 whales have been partially identified (i.e. we have been able to intermatch multiple sightings of the same individual, but either cannot yet confidently match to 1) an existing cataloged whale, 2) a past calf, or 3) confidently confirm it does not match any cataloged whale and thus be entered as a new whale to the catalog); All 21 are tentatively matched to calves from various years.

Age and sex for individuals seen in right whale year

	Male	Female	Unknown	**Total**
Gender	181 (55.9%)	124 (38.3%)	19 (5.8%)	324
	Adult	Juvenile	Unknown	**Total**
Age Class in 2021	272 (84.0%)	50 (15.4%)	2 (0.6%)	324

d. Distribution of identified whales

Five Main Right Whale Areas

BOF	CCB	FL/GA	GSC
1	139	37	20

Other SEUS and Mid-Atlantic Areas

DBAY	MD	NC	NJ	NY	SC	VA
1	1	18	2	1	2	3

Other Northeast Areas			
GB	**MB**	**SNE**	
34	18	112	
Other Areas North and East			
EAST	**ESS**	**GSL**	**NRTH**
0	0	24	0

Summary of deaths, resurrections, and new whales cataloged in 2021
(Details provided in Sections V, VI, and VII)

a.) Whales Presumed Dead	20
b.) Whales Resurrected	1
c.) Whales Added to Catalog	
i. In 2021 (Sep-Dec)	0
ii. In 2022 (Jan-Aug)	10
d.) Confirmed Deaths	
i. Cataloged whales	2
ii. Carcasses not ID'd to Catalog	0

III. Computerized Database Status

Sighting effort data
All of the NEAq survey data from December 1, 2020 to November 30, 2021 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 on July 25, 2022. Dr. Kenney returned the data with questions or issues on August 26, 2022. Mr. Hamilton reviewed the 64 potential errors that needed to be investigated on that same day: 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 a day of data that had been entered twice and the majority of the remainder were related to incorrect time due to daylight savings time related to two survey days with incorrect data exports. Mr. Hamilton uploaded the updated fields from the sightings database into the Catalog on October 17, 2022.

Catalog database

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 over 2 terabytes in size. Additional server space is required for the Citrix interface and to host the public Catalog website.

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. This year, we developed a composite template that has a black whale and drew the callosity and scars as white. This is more representative of how the whales actually look and shows the many scars on their bodies more clearly. A total of 10 new composites were created and 24 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. This past year, we installed a new, larger server with the capacity to accommodate three to five years of growth. That server is backed up to another server in the Boston area, but it is also backed up on a Barracuda device. That device uploads everything (database as well as web and Citrix servers) to the cloud where they could be accessed quickly if a regional disaster took out the main and backup servers. That Barracuda device will be replaced with a larger capacity Datto device in late fall of 2022. As for the DIGITS software itself, the basic maintenance is provided as a donation from Parallax Consulting, LLC. In addition to basic maintenance, we've hired Parallax to make some improvements to the DIGITS software over the last several years. The first round of those improvements was completed in September 2021 with additional modifications completed throughout the remainder of 2021 and 2022. These modifications are described in the Catalog Overview section above. Besides these improvements, several bugs were also addressed. The most challenging and impactful of which was a bug in the third-party Lead Tools software that blocked us from annotating images with arrows. The annotation of images is necessary to distinguish between whales when there is more than one whale in an image. For example, if you have an image that shows whale "A" belly up under whale "B", you need to draw an arrow pointing to "A" in the copy of the image assigned to that whale so matchers will know if they should focus on the belly-up whale, not the whale on the surface. We created a case with the software vendor, but it took them nearly six months to understand the problem and then develop a software patch. Because of this, the processing of any data set that had sightings with more than one whale in a frame was delayed.

Since the last Catalog report, the Citrix license was renewed. In the past, this was affordable and only happened every three years. Now it costs $2,000 and occurs every year. As a reminder, Citrix allows DIGITS users to access the system from any device (PC or Mac), 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 expensive renewal is in addition to the already expensive cost of server maintenance and backup. 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 103 tables, 24 of which were added in the last year, in a MS SQL Server; 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 (18 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 all documented scars and anthropogenic injury events (7 tables). The recently added tables relate to the new Anthropogenic Injury Database and include tables to describe entanglement gear (12 tables), injury type and severity (3 tables), and real-time monitoring of anthropogenic injuries (often before data are officially submitted- 4 tables). There are also 14 programmed views of the data to facilitate more complicated queries.

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 Hamilton et al. 2022).

Since the last Catalog report, there have been 10 new whales added to the Catalog: none in September through December of 2021 and ten through August 2022. All but one of them were calves from past years born in: 2019 (n=3), 2020 (n=5), and 2021 (1). The maternity and birth year of the 10th will likely be determined by genetics in the near future.

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 2022

Catalog No.	Sex	Birth Year	Mother	Father
4810*	Female			
4917	Female	2019	3317	
4970	Unknown	2019	3270	
4980*	Female	2019	4180	
5001	Unknown	2020	3101	
5012	Unknown	2020	1612	
5042*	Female	2020	2642	
5046	Male	2020	3546	
5070*	Unknown	2020	1970	
5130*+	Male	2021	3230	

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

#4810 (3+ y.o. female) - This whale was first seen as a young whale February 15, 2018 off the coast of Georgia. She was seen twice that day and has not been seen since. Even with so few sightings, we determined that we had sufficient photographic data to both re-identify her in the future and confirm that she does not match any other cataloged whale. Luckily, one of her two sightings was from a boat and a genetic sample was collected. We may well know more about this individual once the genetics have been processed.

#4980 (2 y.o. female) - This whale was first seen with her mother #4180 on February 5, 2019 off the coast of Florida. Before that sighting, the sex of her mother was unknown. The pair were seen around Cape Cod in March and April and then in the Gulf of St. Lawrence in June through August. They were seen together once more on November 19th that year- 40 miles southeast of Nantucket. A genetic sample has been obtained from this whale.

#5042 (1 y.o. female) - This whale was first seen with her mother Echo (#2642) on February 3, 2020 off the coast of Florida. The pair were seen repeatedly in the Gulf of St. Lawrence in June and July that year. She was limpet tagged in March 2021 off Virginia and the tag produced a track that goes along the east coast to Cape Cod Bay. A genetic sample has been obtained from this whale.

#5070 (1 y.o. unknown sex) - This whale was first seen with its mother Palmetto (#1970) on February 10, 2020 off the coast of North Carolina. Interestingly, all but one of Palmetto's five calves were first seen off the Carolinas. Palmetto and #5070 traveled south to Georgia later that month and were last seen together in April in Cape Cod Bay. This whale returned to the southeast in 2021 in January and February. A genetic sample has been obtained from this whale.

#5130 (male calf of the year) - This whale was first seen with his mother Infinity (#3230) on January 17, 2021 off the coast of Florida. Both he and his mother were hit by a 54' sport fishing vessel near the St Augustine inlet. He was killed and the mother sustained serious, possibly fatal, injuries. A genetic sample was collected from the carcass of 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 noted above that were 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 34 calves that remain in limbo (some going back as far as 2001), 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 2021, there have been a total of 48 sighting gaps longer than six 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 48 resurrections represent 17% of the 281 presumed deaths during that time period. Many of the older resurrections occurred when gaps in sighting effort in Great South Channel and Roseway Basin in the 1990's were filled in the mid 2000's. There have been no significant effort gaps in identified high-use habitats since then and, as a result, the more recent presumed deaths are likely not effort related. For this reason, there were only four resurrections between 2005 and 2015. In the six years since, there have been seven resurrections, which may be, in part, because whales shifted their habitats beginning in 2010. Presumed deaths have been consistently high since 2015 (98 presumed deaths from 2016 to 2021, compared to 38 for the previous six years). Given the large number of *known* mortalities in the last six years, the increasing frequency of individuals with severe entanglement injuries (Task 2), and the Pace et al. (2017) model results in recent years, this increase in presumed mortality almost certainly reflects true, undetected mortalities (Pace et al. 2021).

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 2021 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 2021, 20 animals were classified as presumed dead (five of them calving females) and one whale was resurrected. This is the second highest number of presumed deaths in a given year on record; the top five highest number have all happened since 2017. This is the result of the distribution shift that began around 2011 and led to an increase in known and cryptic mortality (Pace et al. 2021). Details of the presumed dead and resurrected animals' sighting history are provided below, as well as their sex and what their age was *at their last sighting*. For all sections below, a "+" after the age means the actual age is not known and the number is a minimum age *at the time of their last sighting*, based on both their calving history (whale assumed to be at least five years old if their first sighting was with a calf) and sighting history. It should be noted that the database was searched to determine whether there were sightings of any of these whales awaiting confirmation that would be resurrected once those matches were confirmed. Any such matches were confirmed before the writing of this report and those data would be included below.

Presumed dead in 2021 (last sighted in 2015)

Catalog No.	Name	Sex	First Sighted	Birth Year	Age in 2015	Mother	Father	First Calving Year
1146	VAN HALEN	Male	1977		A			
1167	HOUDINI	Male	1981		A			
1203	SENATOR	Male	1982		A			
1946		Female	1989	1989	26	1246	1037	1997
2645	INSIGNIA	Female	1996	1996	19	1245	1170	2005
2709	TETRIS	Male	1997	1997	18	1509		

2790	TUSK	Female	1997		A			2005
3140	LOU	Male	2001	2001	14	1140		
3160	WHITE CLOUD	Male	2001	2001	14	1160		
3240	ORION	Female	2002	2002	13	1240		2011
3346	KINGFISHER	Male	2003	2003	12	1946		
3513	CANAVERAL	Female	2005	2005	10	2413		2013
3670	CHEROKEE	Female	2006	2006	9	2320		
3803	PHANTOM	Female	2008	2008	7	1703		
4005		Male	2010	2010	5	2605		
4290		Female	2012	2012	3	3390		
4315		Female	2012	2013	2	1315	2910	
4346		Female	2012	2013	2	1946	2608	
4370		Unknown	2013		U			
4530		Unknown	2015		U			

#1146 (38+ y.o. male) - This whale, named Van Halen, was first seen in Massachusetts Bay in October 1977. Over the years, he was seen in all of the major right whale habitats. He was often seen in consecutive years, but also had 3 three-year sighting gaps over his 38-year sighting history. His last sighting was in March 2015 in Cape Cod Bay; there were no outward indications of ill health at the time. There is no genetic sample on file for this whale. Because of the absence of a genetic sample, it is unknown whether he sired any calves.

#1167 (34+ y.o. male) - This whale, named Houdini, was first seen in August of 1981 in the Bay of Fundy. He was seen in all major habitats with only a few missed years- mostly in the 1980's. Prior to his disappearance, his longest sighting gap was three years. He looked thin in his second to last sighting on August 16, 2015 on the edge of the continental shelf over 140 miles southeast of Halifax, N.S. He was still thin at his last sighting on September 6, 2015 on Jeffreys Ledge. He sired no calves as far as we know. A genetic sample is on file for this whale.

#1203 (33+ y.o. male) - This whale, named Senator, was first seen in May 1982 in Great South Channel. He had only five sighting gaps over his 33-year sighting history and all were just a single year. He was seen in all major habitats, though he wasn't seen in Cape Cod Bay until 2011. He had an unhealed, open, entanglement wound on his left leading fluke edge for most of 2014. His last sighting was May 6, 2015 in the Gulf of Maine. He was in fair condition at the time and it was unclear if the open wound had healed. He has sired no calves as far as we know. A genetic sample is on file for this whale.

#1946 (26 y.o. female) - This whale was first seen with her mother Loligo (#1246) in February 1989 off the coast of Georgia. She was seen in the Bay of Fundy frequently over the years, as well as most of the other habitats. She gave birth to her first calf at the age of eight in 1997 and went on to birth four more. She had only 2 one-year gaps during her 26-year sighting history. Her last sighting was May 27, 2015 in Great South Channel;

there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#2645 (19 y.o. female) - This whale, named Insignia, was first seen in January 1996 off the coast of Florida with her mother Slalom (#1245). She was seen almost solely in the southeast U.S., Cape Cod Bay, and the Bay of Fundy. She had only a single, one-year sighting gap in her 19-year history. She had four calves, her first born when she was nine years old. Her last sighting was November 9, 2015 in Massachusetts Bay; there were no outward indications of ill health at the time (although only the head was photographed). A genetic sample is on file for this whale.

#2709 (18 y.o. male) - This whale, named Tetris, was first seen in January 1997 off the coast of Florida with his mother Rat (#1509). He was seen every year except one through 2015 and in all habitats. He was seen repeatedly on Jeffreys Ledge over the years. Prior to his disappearance, his longest sighting gap was one year. His last sighting was May 11, 2015 in Cape Cod Bay; there were no outward indications of ill health at the time. He has sired no calves as far as we know. A genetic sample is on file for this whale.

#2790 (18+ y.o. male) - This whale, named Tusk, was first seen in August 1997 in the Bay of Fundy as an apparent juvenile. He was seen there every year through 2001 and then primarily off the southeast U.S. for the next five years. He has been seen in every habitat except the Gulf of St. Lawrence. Prior to his disappearance, his longest sighting gap was one year. His last sighting was September 13, 2015 in Roseway Basin; there were no outward indications of ill health at the time. He has sired no calves as far as we know. A genetic sample is on file for this whale.

#3140 (14 y.o. male) - This whale, named Lou, was first seen as a calf in February 2001 off South Carolina with his mother Wart, #1140. He was seen frequently in the Bay of Fundy, but also in all the other habitats including the Gulf of St. Lawrence towards the end of his sighting history. He sired no calves as far as we know. He was observed with a deep gash in his peduncle in 2010 that never fully healed. He then sustained severe entanglement wounds between August 2015 in the Gulf of St. Lawrence and his last sighting on November 29, 2015 in Great South Channel. He was in very poor condition at his last sighting- covered with orange cyamids and a deep wound over his back and on his peduncle. A genetic sample is on file for this whale.

#3160 (14 y.o. male) - This whale, named White Cloud, was first seen as a calf in January 2001 off the Georgia coast with his mother Bolo, #1160. With the exception of 2013, he was seen many times every year through 2015. He was seen in all habitats, although relatively rarely in Cape Cod Bay. His only sighting in the Gulf of St. Lawrence was his last sighting on July 18, 2015. He was entangled in crab gear and anchored at the time. He was disentangled, and the response team believed he was fully disentangled, but he has not been seen since. It is unknown whether he has sired any calves; while there is a record of a genetic sample being collected, none exists at St Mary's University. This whale, if ever seen again, needs to be darted.

#3240 (13 y.o. female) - This whale, named Orion, was first seen in January 2002 off the Georgia coast as a calf with her mother Baldy, #1240. She was seen every year from 2002 through 2015 except 2004- frequently in the Bay of Fundy, southeast U.S., or Cape Cod Bay. She had one calf in 2011. In 2013, she developed swath lesions on her head, described by Hamilton and Marx (2005) as the most concerning type of lesion. Those lesions were still present at her last sighting April 12, 2015 in Massachusetts Bay. A genetic sample is on file for this whale.

#3346 (12 y.o. male) - This whale, named Kingfisher, was first seen in January 2003 off the coast of Georgia as a calf with his mother #1946. He was seen every year afterward until his disappearance after 2015. He was entangled in January of 2004 as a one-year-old, and although some of the line was removed, multiple wraps of line were bound around his right flipper with a large tangle of rope and buoy remnants also attached. The ropes eventually cut deep into the flipper creating a raw, open wound that persisted through his last sighting. Although he must have been physically compromised, Kingfisher rarely showed any external evidence of ill health. The gear was still wrapped around his flipper when he was last seen April 26, 2015 south of Cape Cod. He sired no calves as far as we know. There is no genetic sample on file for this whale.

#3513 (10 y.o. female) - This whale, named Canaveral, was first seen in January 2005 off the coast of Florida with her mother Nauset, #2413. She was seen every year after through 2015, frequently in the Bay of Fundy and off the southeast U.S. She gave birth to her first and only calf in December 2012. Her last sighting was February 12, 2015 in Cape Cod Bay; there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#3670 (9 y.o. female) - This whale, named Cherokee, was first seen in January 2006 off the coast of Florida with her mother Piper, #2320. She was seen every year through 2015 except 2013. She was seriously injured from an entanglement sometime between March and December 2014 when she was photographed with extensive wounds including the aft portion of her right lower lip missing. Her last sighting was December 12, 2015 off the Georgia coast; she appeared in very poor condition at the time. She never calved as far as we know. A genetic sample is on file for this whale.

#3803 (7 y.o. female) - This whale, named Phantom, was first seen in February 2008 off the Georgia coast as a calf with her mother Wolf, #1703. She was seen mostly around Cape Cod and Jeffreys Ledge over the years. In 2015, she was seen in the Gulf of St. Lawrence for the first time. She was hit be a vessel sometime between September 2008 and February 2010 with several propeller cuts across both blowholes. Somewhat surprisingly, those cuts appeared to heal. Her last sighting was September 1, 2015 in the Gulf of St. Lawrence; there were no outward indications of ill health at the time. She has never calved as far as we know. A genetic sample is on file for this whale.

#4005 (5 y.o. male) - This whale was first seen in March 2010 off the coast of Georgia with his mother Smoke, #2605. He was mostly seen around Cape Cod during his short life. He was last sighted July 3, 2015 in the Bay of Fundy; although his skin was in moderately poor condition, there were no other indications of ill health at the time. A genetic sample is on file for this whale.

#4290 (3 y.o. female) - This whale was first seen in January 2012 off the coast of Florida as a calf with her mother #3390. The pair were seen repeatedly in the Bay of Fundy that year and then #4290 was seen alone in Great South Channel that October. Like many other whales, she was not seen in 2013, but returned to the Bay in 2014. Her last sighting was April 13, 2015 in Massachusetts Bay; there were no outward indications of ill health at the time. She never calved. A genetic sample is on file for this whale.

#4315 (2 y.o. female) - This whale was first seen in December 2012 off the Georgia coast with her mother Foster, #1315. The pair were seen repeatedly in Massachusetts and Cape Cod Bays that spring and #4315 returned there the following year. Her last sighting was January 11, 2015 in Cape Cod Bay in a surface active group; there were no outward indications of ill health at the time. She never calved. A genetic sample is on file for this whale.

#4346 (2 y.o. female) - This whale was first seen in November 2012 off the coast of South Carolina as a calf with her mother #1946. The pair were seen off Florida and Georgia through the end of January and just once up north- in the Bay of Fundy in July. Whale #4346 was only seen three times after that: in Roseway Basin in June 2014, on George's Bank in January 2015, and finally on May 15, 2015 over 80 miles east of Portsmouth, N.H. near Cashes Ledge. Both her mother and brother Kingfisher also disappeared after 2015. In fact, all but one of #1946's five calves have likely died. There were no outward indications of ill health at the time of #4346's last sighting. She never calved. A genetic sample is on file for this whale.

#4370 (2+ y.o. unknown sex) - This whale was first seen in April 2013 in Cape Cod Bay. It was only seen four other times- always in April in or around Cape Cod Bay. Nothing is known of its age or parentage. Its last sighting was April 6, 2015 in Cape Cod Bay. It had an odd, deep wound on its fluke that looked as if it would cause the flukes to drop off. The cause of the wound is unknown. No genetic sample is on file for this whale.

#4530 (1+ y.o. unknown sex) - This whale was first seen in April 2015 approximately 15 miles south of Newport, R.I. Its only other sightings were in the Gulf of St. Lawrence that year in July and August. Nothing is known of its parentage or age, although it looked young in 2015. It had fresh entanglement wounds on its back and flukes in July and those wounds were covered with red/orange cyamids by August. Its last sighting was August 10, 2015 in the Gulf of St. Lawrence. No genetic sample is on file for this whale.

Resurrected in 2021

#3596 (16+ y.o., unknown sex) - This whale, named Loki, was first seen January 30, 2005 over 90 miles southeast of Portland, Maine. It has had just three other sightings over the ensuing 16 years: two also far from shore in the Gulf of Maine in December 2007 and January 2012. Its next and most recent sighting was nine years later on April 19, 2021 in Massachusetts Bay. No genetic sample is on file for this whale.

VI. Mortalities, Entanglements, and Significant Injuries

Overview

There were two mortalities discovered in 2021 and a summary of those cases is presented below. Three right whales were confirmed first seen entangled in 2021. One whale that had been entangled in previous years was seen still entangled in 2021 and one whale was first seen gear-free in 2021. There were two cases of significant, non-lethal injuries caused by propellers or entanglements in 2021. 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 et al. 2012). They include entanglement injuries, propeller cuts, and any other dramatic or noteworthy wounds, as determined by a subjective assessment.

Mortalities

#5130 (calf, male) - The carcass of this whale, the 2021 calf of Infinity (#3230), which is referenced as EgNEFL2103, was found dead on February 13, 2021 on the beach in Anastasia Island State Park near St. Augustine, FL. This whale had been seen alive at 1555 local time on February 12th and a sportfishing vessel reported striking a whale in the St. Augustine channel less than three hours later. The calf was found dead on the beach the next day with multiple deep propeller cuts to his head and body. A necropsy, led by Megan Stolen of Hubbs-SeaWorld Research Institute, was performed that day. This calf's mother Infinity was seen three days later on February 16th with deep propeller cuts on her left flank. She has not been seen since and her survival is uncertain.

#3920 (12 y.o., male) **–** The carcass of this whale, named Cottontail (referenced as WAM743-EG3920), was discovered floating off Myrtle Beach, S.C. on February 27, 2021. He had been entangled since at least October 19, 2020 (entanglement case reference WR-2020-18). He had line embedded in the forward part of his upper jaw with additional line trailing. On February 28, Bill McLellan from UNC Wilmington visited the carcass at sea and collected tissue samples. The carcass was seen again on two subsequent days, March 4 and 10, but the carcass was not recovered. No necropsy was performed on this individual.

Entanglements

First Reported in 2021

January 11, 2021: #1803 (33 y.o. male) - This whale was first seen entangled January 11, 2021 about 10 miles east of Amelia Island, FL. The event was assigned a CCS case number of WR-2021-02. He had multiple wraps of blue line around the peduncle and both fluke blades. A trap/pot trailed just aft of the flukes and at least one length of the blue line trailed 50-60 feet aft of the flukes. A response was mounted that day, but the team from Georgia Department of Natural Resources was not able to successfully attach a telemetry buoy. Another attempt the following day was also unsuccessful. The whale has not been seen since January 14, 2021. He had been last seen gear-free on April 7, 2019 in Cape Cod Bay.

March 3, 2021: #3560 (16 y.o. female) - This whale, named Snow Cone, was first seen entangled on March 10, 2021 about eight miles outside of Plymouth Harbor in Cape Cod Bay. She had two lengths of line exiting the left side of her mouth, trailing aft. One length of line terminated about 60 feet aft of the flukes, while the other trailed over 160 feet aft before sinking down into the water column. Line wrapping over the rostrum appeared to be deeply embedded. It was given a CCS case number of WR-2021-04. A response was mounted that day and nearly 300 feet of line removed. She was seen a couple more times in the Bay through March 12th when a second disentanglement attempt was made successfully removing some additional length of rope. She was next seen in the Gulf of St. Lawrence starting on May 10th and another disentanglement attempt was made the following day by the Campobello Whale Rescue Team (CWRT). Some more rope was removed leaving only about 20 feet of rope trailing behind the flukes. She was seen repeatedly in the Gulf that summer and another response was made on July 8 when another 20 feet of rope was removed by CWRT. She was last seen in the Gulf on August 4 and next seen south of Nantucket on October 24 and November 6. She was next seen off the southeast U.S. on December 2 with a calf by her side. The pair were seen multiple times in the southeast U.S. and then Cape Cod Bay. Snow Cone was seen alone in the Gulf of St. Lawrence in July 2022 and alone again at her most recent sighting on September 21, 2022. At her last sighting, she was entangled in a second set of gear and her condition had deteriorated significantly with cyamids covering her head.

July 13, 2021: #4615 (5 y.o. male)- This whale was first seen entangled on July 13, 2021 approximately 25 nm east of Miscou, N.B. Canada. It was given a CCS case number WR-2021-13. The line exiting the left side of the mouth traveled over the head just in front of the blowholes and twisted with the line exiting the right mouth, forming a bridle at the right mouth. One of the lines appeared to be attached to something weighted at the bottom. Members from the Campobello Whale Rescue Team were on a nearby research vessel and were able to attach a telemetry buoy to the trailing gear. That buoy took a beating as the whale thrashed. The whale was resighted the next day still entangled. The telemetry buoy only broadcasted for a short period of time and the whale has not been seen since. It was a very fresh entanglement; #4615 had been documented gear free just hours earlier that day.

Reported Prior to 2021 and Still Entangled by the End of 2021

February 18, 2021: #3920 (12 y.o., male) **–** This whale, named Cottontail, was first seen entangled October 19, 2020 and died in 2021 while still entangled. A description of this case is provided under the Mortality section above.

First Seen Free of Gear in 2021

April 7, 2021: #3466 (17 y.o. male)- This whale had first been seen entangled on December 21, 2019 south of Nantucket. He had at least three yellow lines going through the mouth and trailing far behind him. He was seen again January 22 and 31, 2020 south of Nantucket, MA with the entanglement largely unchanged. No disentanglement effort was made for any of these sightings. On April 7, 2021, he was photographed southeast of Montauk, N.Y. near Block Canyon completely free of gear and, remarkably, with little to no scarring.

Significant injuries

#3230 (19 y.o., female) – This whale, named Infinity, was first seen injured on February 16, 2021 of the coast of Florida. She had at least three propeller cuts on her left side. She was likely hit in the same incident that killed her calf (#5130)- described in mortality section above. She had last been seen uninjured four days earlier in the same area. She has not been seen since.

#3510 (16 y.o male) – This whale, named Twister, was first seen with multiple new entanglement wounds on his peduncle on August 8, 2021 in the Gulf of St. Lawrence. Although many others were seen with new entanglement wounds in 2021, he is listed here because these new wounds were on top of existing wounds that had not healed. He had last been seen without the injuries on June 21, 2021 in the Gulf.

VII. Photographic Contributions

Photos submitted from 42 different organizations or individuals who collected photographs between December 1, 2020 and November 30, 2021 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 42 organizations/individuals whose photographs were collected between December 1, 2020 and November 30, 2021.

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**
ALAR*										
MIDA	1	3	100%	0%	0%	0%	0%	1	0	1
AMTU*										
BOF	2	55	50%	0%	0%	50%	0%	1	1	2
AS										
SEUS	64	1,013	20%	33%	0%	47%	0%	5	4	9
ASP										
SEUS	1	4	100%	0%	0%	0%	0%	1	0	1
BAZO*										
SEUS	2	26	50%	0%	0%	50%	0%	1	1	2
BIAX*										
SEUS	2	7	50%	0%	0%	50%	0%	1	1	2
BWRI										
SEUS	1	42	100%	0%	0%	0%	0%	1	0	1
CCG										
NRTH	40	0	0%	0%	0%	5%	95%	0	2	2
CCS										
GSC	75	789	9%	1%	0%	8%	81%	7	4	11
NE	1,105	8,805	15%	22%	0%	9%	54%	148	19	167
CHLE*										
SEUS	2	2	0%	50%	0%	50%	0%	0	1	1
CHMU*										
SEUS	2	25	50%	0%	0%	50%	0%	1	1	2
CHPA*										
MIDA	2	10	0%	50%	0%	50%	0%	0	1	1
CMARI										
MIDA	52	336	38%	0%	0%	19%	42%	16	7	23
SEUS	79	1,242	62%	3%	0%	33%	3%	24	12	36
CMWWRC										
MIDA	2	33	50%	0%	0%	50%	0%	1	1	2
DFO										
BOF	1	4	0%	0%	0%	0%	100%	0	0	0
NRTH	566	450	1%	0%	0%	6%	93%	7	9	16
FTR										
BOF	1	18	0%	0%	0%	0%	100%	0	0	0
FWRI										
SEUS	194	2,073	19%	41%	0%	35%	5%	21	14	35
GAKI*										
SEUS	2	20	0%	50%	0%	50%	0%	0	1	1
GDNR										
MIDA	3	51	0%	33%	0%	67%	0%	0	2	2
SEUS	48	632	19%	27%	0%	29%	25%	8	8	16
GEOQM										
MIDA	3	6	33%	0%	67%	0%	0%	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
GUBA*										
EAST	1	10	0%	0%	0%	0%	100%	0	0	0
HDR										
GSC	2	0	100%	0%	0%	0%	0%	1	0	1
MIDA	17	0	100%	0%	0%	0%	0%	2	0	2
NE	1	0	100%	0%	0%	0%	0%	1	0	1
HUBBS										
SEUS	2	18	100%	0%	0%	0%	0%	1	0	1
JGRE*										
SEUS	2	11	50%	0%	0%	50%	0%	1	1	2
JOAN*										
SEUS	1	44	100%	0%	0%	0%	0%	1	0	1
JOST*										
BOF	1	11	0%	0%	0%	0%	100%	0	0	0
MAGA*										
NE	2	8	50%	50%	0%	0%	0%	1	0	1
MRC										
SEUS	3	7	67%	0%	0%	33%	0%	1	1	2
NEA										
GOM	23	303	83%	13%	0%	0%	4%	19	0	19
GSC	13	179	77%	23%	0%	0%	0%	10	0	10
MIDA	112	1,455	70%	27%	0%	1%	3%	69	1	70
NE	15	360	53%	27%	0%	13%	7%	7	2	9
NEA/CWI										
NRTH	386	406	4%	0%	0%	8%	88%	17	12	29
NEFSC										
GOM	45	240	36%	0%	0%	4%	60%	16	2	18
GSC	20	370	10%	15%	0%	10%	65%	2	2	4
MIDA	260	1,221	24%	7%	0%	3%	65%	55	7	62
NE	68	8	1%	0%	0%	3%	96%	1	2	3
NRTH	41	6	5%	0%	0%	5%	90%	2	2	4
NEFSC/AMPS										
GOM	3	32	67%	33%	0%	0%	0%	2	0	2
OSF										
MIDA	2	21	50%	0%	0%	50%	0%	1	1	2
QLM										
BOF	1	15	0%	0%	0%	0%	100%	0	0	0
STBE*										
SEUS	3	22	67%	0%	0%	33%	0%	1	1	2
SUDI*										
MIDA	3	12	33%	67%	0%	0%	0%	1	0	1
TC										
EAST	1	0	0%	0%	0%	0%	100%	0	0	0
NRTH	202	12	0%	0%	0%	4%	96%	0	6	6
TOHA*										
SEUS	2	14	0%	50%	0%	50%	0%	0	1	1
UNCW										
MIDA	1	2	100%	0%	0%	0%	0%	1	0	1
UNK										
NRTH	1	8	0%	0%	0%	0%	100%	0	0	0
WDC										
NE	1	16	100%	0%	0%	0%	0%	1	0	1
ZAMC*										
SEUS	2	35	50%	0%	0%	50%	0%	1	1	2
Report	3,487	20,492								

VIII. Catalog Related Publications and Reports

Since the last Catalog report on October 31, 2021, the following reports and publications that utilized data from the Catalog have been either published or submitted:

Bishop AL, Crowe LM, Hamilton PK, Meyer-Gutbrod EL 2022. Maternal lineage and habitat use patterns explain variation in the fecundity of a critically endangered baleen whale. Front. Mar. Sci. 9: 880910. doi: 10.3389/fmars.2022.880910

Crowe LM, Brown MW, Corkeron, PJ, Hamilton PK, Ramp C, Ratelle S, Vanderlaan ASM, Cole TVN. 2021. In plane sight: a mark-recapture analysis of North Atlantic right whales in the Gulf of St. Lawrence. Endangered Species Research. 46:227–251. https://doi.org/10.3354/esr01156

Franklin KJ, Taggart CT, Cole TVN, Cholewiak DM, Duley P, Crowe L, Hamilton PK, Knowlton AR, and Johnson HD. In press. Using sonobuoys and visual surveys to characterize North Atlantic right whale (Eubalaena glacialis) acoustic ecology in the Gulf of St. Lawrence. Endangered Species Research

Hamilton PK, Frasier BA, Conger LA, George RC, Jackson KA, Frasier TR. 2022. Case studies of North Atlantic right whale (Eubalaena glacialis) calves: genetic identifications challenge our assumptions of physical development and mother-calf associations and separation times. Mammalian Biology. 1-20. https://doi.org/10.1007/s42991-021-00177-4

Hamilton PK and Knowlton AR. 2021. The power of knowing the individual- the North Atlantic Right Whale Catalogs. In Right Whales at Risk. Special issue of Whalewatcher. Corkeron. P. ed. 18-23. https://acs.memberclicks.net/assets/Whalewatchers/Whalewatcher-2021-final.pdf

Howe, K.R., Zani, M.A., Knowlton, A.R., Hamilton, P.K. 2022. Research, Monitoring and Conservation of the North Atlantic Right Whale (Eubalaena glacialis) in the southern Gulf of St. Lawrence and the Bay of Fundy - 2021. Permit report to Fisheries and Oceans, Canada.

Khan C, Blount D, Parham J, Holmberg J, Hamilton P, Charlton C, Christiansen F, Johnston D, Rayment W, Dawson S, Vermeulen E, Rowntree V, Groch K, Levenson J, Bogucki R. 2022. Artificial Intelligence for Right Whale Photo Identification: From Data Science Competition to Worldwide Collaboration. Mammalian Biology. 1-18. https://doi.org/10.1007/s42991-022-00253-3

Knowlton AR, Clark JS, Hamilton PK, Kraus SD, Pettis HM, Rolland RM, Schick RS. 2022. Fishing gear entanglement threatens recovery of critically endangered North Atlantic right whales. Conservation Science and Practice, 4(8), e12736. https://doi.org/10.1111/csp2.12736

Lonati G.L, D.P. Zitterbart, C.A. Miller, P. Corkeron, C.T. Murphy, and M.J.Moore. 2022. Investigating the thermal physiology of critically endangered North Atlantic right whales Eubalaena glacialis via aerial infrared thermography. Endangered Species Research 48:139-154

O'Brien, O., D.E. Pendleton, L.C. Ganley, L.C., K.P. McKenna, R.D. Kenney, E. Quintana Rizzo, C.A. Mayo, S.D. Kraus, and J.V. Redfern. Repatriation of a historical North Atlantic right whale habitat during an era of rapid climate change. 2022. Scientific Reports 12, article 12407

Pettis, H.M., Pace, R.M. III, Hamilton, P.K. 2022. North Atlantic Right Whale Consortium 2021 Annual Report Card. Report to the North Atlantic Right Whale Consortium

Stewart JD, Durban JW, Europe H, Fearnbach H, Hamilton PK, Knowlton AR, Lynn MS, Miller CA, Perryman WL, Tao BWH, Moore MJ. 2022. Larger females have more calves: the influence of maternal body length on fecundity in North Atlantic right whales. Marine Ecology Progress Series. 689: 179–189. https://doi.org/10.3354/meps14040

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. 2022. Genetic identifications challenge our assumptions of physical development and mother-calf associations and separation times: A case study of the North Atlantic right whale (Eubalaena glacialis). Mammalian Biology. 1-20.

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.

Hamilton, P.K. and Marx, M.K. 2005. Skin Lesions on North Atlantic Right Whales: Categories, Prevalence and Change in Occurrence in the 1990s. Disease of Aquatic Organisms 68(1): 71-82.

Knowlton, A.R., Hamilton, P.K., Marx, M.K., Pettis, H.M, and Kraus, S.D. 2012. Monitoring North Atlantic right whale *Eubalaena glacialis* entanglement rates: a 30 year retrospective. Marine Ecology Progress Series 466:293-302.

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.

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

Appendix I. Matching status for the past 20 years through December 31, 2021 as of September 1, 2022.

A detailed breakdown of the matching status of all sightings for the *calendar* years 2002 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 2021 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
2002	119		2452	154	2725	95.6%	95.6%
2003	55		2120	231	2406	97.7%	97.7%
2004	19		1708	114	1841	99.0%	99.0%
2005	7		3261	140	3408	99.8%	99.8%
2006	23		2682	101	2806	99.2%	99.2%
2007	36		3610	125	3771	99.1%	99.1%
2008	13		4033	118	4164	99.7%	99.7%
2009	36		4545	117	4698	99.2%	99.2%
2010	25		3143	68	3236	99.2%	99.2%
2011	44		3327	108	3479	98.7%	98.7%
2012	48		2020	59	2127	97.7%	97.7%
2013	55		1784	65	1904	97.1%	97.1%
2014	100		2217	87	2404	95.8%	95.8%
2015	62		1636	76	1774	96.5%	96.5%
2016	19		2162	30	2211	99.1%	99.1%
2017	50	3	2915	158	3126	98.3%	98.3%
2018	51		3666	116	3833	98.7%	98.7%
2019	89	3	4623	204	4919	98.1%	98.1%
2020	175	17	2045	85	2322	91.7%	91.7%
2021	2573	433	451	0	3457	13.0%	13.0%

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

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

Appendix III. Abbreviations for 42 data contributors from December 1, 2020 through November 30, 2021.

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

Abbreviation	Primary Contact	Organization Name (if applicable)
ALAR*	Adrian Larrea	
AMTU*	Amy Tudor	
AS	Jim Hain	Associated Scientist
ASP		Anastasia State Park
BAZO*	Barb Zoodsma	NOAA- SERO
BIAX*	Bianca Axenfeld	
BWRI	Jamison Smith	Blue World Research Institute
CCG		Canadian Coast Guard
CCS	Brigid McKenna	Center for Coastal Studies
CHLE*	Charlene Lewis	
CHMU*	Chad Murch	Volusia County
CHPA*	Chris Paparo	
CMARI	Melanie White	Clearwater Marine Aquarium Research Institute
CMWWRC	Melissa Laurino	Cape May Whale Watch Research Center
DFO	Stephanie Ratelle	Department of Fisheries and Oceans Canada
FTR		Fundy Tide Runners
FWRI	Jen Jakush	Florida Wildlife Research Institute
GAKI*	Garret King	
GDNR	Clay George	Georgia Dept. of Natural Resources
GEOQM		Geoquip Marine Group
GUBA*	Gunter Baumgartel	
HDR	Dan Engelhaupt	HDR Environmental
HUBBS	Megan Stolen	SeaWorld Hubbs Research Institute
JGRE*	Jeff Greene	
JOAN*	Joey Antonelli	
JOST*	Joni Stryde	
MAGA*	Mark Garfinkel	
MRC	Julie Albert	Marine Resources Council
NEA	Orla O'Brien	New England Aquarium (aerial)

Appendix III. (cont.)

Abbreviation	Primary Contact	Organization Name (if applicable)
NEA/CWI	Monica Zani	New England Aquarium (vessel)
NEFSC	Allison Henry	Northeast Fisheries Science Center
NEFSC/AMPS	Debi Palka	Northeast Fisheries Science Center
OSF	Chip Michalove	Outcast Sport Fishing
QLM	Danielle Dion	Quoddy Link Marine
STBE*	Stacey Bell	
SUDI*	Susan Dixon	
TC	Stephanie Ratelle	Transport Canada
TOHA*	Tommy Hazouri	
UNCW	Bill McLellan	University of North Carolina- Wilmington
UNK		Observer Code - Unknown
WDC	Regina Asmutis-Silvia	Whale & Dolphin Conservation
ZAMC*	Zach Mckenns	

Task 2: Final Report on 2020 Right Whale Entanglement Scar Coding Efforts

Prepared by
Amy R. Knowlton, Marilyn K. Marx, Shelby L. Vance,
Philip K. Hamilton, and Heather M. Pettis
Anderson Cabot Center for Ocean Life
New England Aquarium
Central Wharf
Boston, MA 02110

Overview

This report summarizes right whale entanglement scarring analyses for 2020 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 2020 to those of 2010-2019 (data provided in previous reports and summarized here) as well as to the prior 30 years of data (1980-2009), as reported by Knowlton et al. (2012). As part of this annual review effort, we have categorized each new entanglement event in terms of injury severity levels of minor, moderate, and severe as defined in Knowlton et al. (2016; see Appendix 1) and compared frequency at these levels to prior years. Additionally, two-page case studies for all whales with attached gear and a one-page case study for all whales with severe injuries and no attached gear were developed.

These annual reports are useful in monitoring all entanglement events that occur in both the United States and Canada to see if and how management efforts influence the frequency, rate and severity of entanglement events (beyond those cases of actively entangled or severely injured whales that are reported in near real-time). We are presently working on two papers. First, we will update the last 11 years of scarring data to complement the Knowlton et al. (2012) paper which assessed 30 years of entanglement data. Second, we have developed an approach for allocating potential entanglement regions/countries based on sightings before and at entanglement injury detection that occur within a 180-day timeframe. This approach was presented to the Atlantic Large Whale Take Reduction Team in February of 2022 (see https://www.fisheries.noaa.gov/event/atlantic-large-whale-take-reduction-february-24-2022-team-meeting) and at the annual North Atlantic Right Whale Consortium meeting in October 2022. Our goal is to write and submit these papers for publication in 2023. In addition, we have worked closely with NOAA Fisheries as they developed an approach for including morbidity cases into the on-going Unusual Mortality Event (see https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2022-north-atlantic-right-whale-unusual-mortality-event) and we provided images and information of individual whales with injuries of concern for experts with veterinary knowledge to review.

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 2020 and any new, pre-2020 sightings added to the catalog since the 2021 report describing 2019 scarring events. Scar coding was also carried out for any new whales added to the catalog with sightings up to and including 2020. 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 2020 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., 2019/2020) 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 (180 days), 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 2020 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 - NOAA, 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-1980-2020 (only 7 events pre-1980) and those that were documented in 2020 only are provided below:

- Total number of animals reviewed in all years: **781**

- # of batches analyzed (one batch equals all sightings of an individual grouped within each area/season in a given year) – all years: **21,570**
    - 2020 batches analyzed: **689**
- Number of separate entanglement events detected - all years pre-1980-2020: **1,755**
    - 2020 events: **38**
        - Female – 18
        - Male – 18
        - Unknown sex - 2
- Percentage of population entangled at least once: 675/781 **86.4%**
    - # of females in the population through 2020: **328**
    - % of females entangled at least once: 292/328 **89.0%**
    - # of males in the population through 2020: **373**
    - % of males entangled at least once: 349/373 **93.6%**
    - # of unknown sex in the population through 2020: **80**
    - % of unknown sex entangled at least once: 34/80 **42.5%**

An additional six events were added from previous years – one in 2010, one in 2018, and four in 2019. 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 2020; 2) recent identifications of older sightings; 3) recently added better quality images of animals which provided evidence that a certain scar visible prior to 2020 was from entanglement – these events were back-coded to the appropriate year.

The annual tally of entanglements according to severity and gear presence/absence is provided in Figure 1. A total of 28 right whale carcasses that have died due to entanglement have been documented (24 with attached gear and 4 with severe injuries). Details of these cases can be found in Sharp et al. (2019) and Moore et al. (2004).

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) of sighted individuals with an average of 15.5%, SD +/- 5.5% (Knowlton et al. 2012). The 2010-2019 period ranged from 11.1% to 24.7% with an annual rate average of 17.6%, SD +/- 4.0%, slightly above the 30-year average. For 2020, this rate was 12.4% indicating a detectable drop in crude entanglement rate from the average over the 2010-2019 time period (Table 1).

Table 1. *Crude entanglement rate.*

Year	# of individuals sighted	# of newly detected entanglements	Percentage
2010	432	68	15.7%
2011*	444	96	21.6%
2012*	384	60	15.6%
2013	296	33	11.1%
2014*	379	67	17.7%
2015*	270	44	16.3%
2016	328	81	24.7%

2017	380	76	20.0%
2018	363	70	19.3%
2019	360	49	13.6%
2020	**306**	**38**	**12.4%**

* The tallies of newly detected entanglements 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. The number of all sighted individuals was not changed to include these whales.

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).

Table 2 is updated for all years shown. The annual entanglement rate ranges from 20.4% to 40.0% with an average of 31.5%. SD = +/-6.8%. The rate in 2019/2020 at 22.4% falls well below the average for the past decade (as does the 2018/2019 rate at 20.4%) and is similar to the historical average of 25.0%. All previous years will be updated as we work on the manuscript updating the Knowlton et al. 2012 paper.

Table 2. *Annual entanglement rate*

Year	Adequately photographed	Entangled by year 2	Entanglement rate
2009/2010	200	52	26.0%
2010/2011	192	76	39.6%
2011/2012	140	47	33.6%
2012/2013	57	20	35.1%
2013/2014	90	36	40.0%
2014/2015	97	29	29.9%
2015/2016	111	43	38.7%
2016/2017	166	46	27.7
2017/2018	178	54	33.3%
2018/2019	221	45	20.4
2019/2020	**156**	**35**	**22.4%**

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. In the 1980's, only around one-third of entanglements were detected within a two-year timeframe. By 2000-2009, over 60% of the cases were detected within a one-year timeframe (Knowlton et al. 2012). For 2010 to 2012, 68% to 76% of the entanglement detections were determined within a one-year timeframe. However, in 2013-2017, this percentage dropped with under 60% of events detected within a one-year timeframe in each year. This pattern improved in 2018-2020 with 77%, 91%, and 84% of cases detected within one year respectively. 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. The percentage is completely dependent on surveys, and particularly vessel-based surveys.

Table 3. *Total number and percentage of detections within given timeframes.*

	# of events	<6 mo	> 6 mo to < 1 yr	>1 yr to < 2 yrs	>2 yrs to < 3 yrs	>3 yrs	Unknown timeframe
2010	68	25 (37%)	21 (31%)	13 (19%)	7 (10%)	1 (>1%)	1 (>1%)
2011*	97	35 (36%)	36 (38%)	12 (12%)	7 (7%)	4 (4%)	3 (3%)
2012*	61	30 (49%)	17 (28%)	6 (10%)	4 (6%)	3 (5%)	1 (2%)
2013	33	8 (24%)	10 (31%)	6 (18%)	5 (15%)	4 (12%)	
2014*	69	17 (24%)	18 (26%)	13 (19%)	11 (16%)	9 (13%)	1 (2%)
2015*	46	14 (30%)	13 (28%)	8 (17%)	3 (6%)	7 (15%)	1 (2%)
2016	81	22 (28%)	19 (23%)	19 (23%)	7 (9%)	14 (17%)	
2017	76	27 (36%)	16 (21%)	10 (13%)	14 (18%)	8 (11%)	1 (1%)
2018	70	22 (31%)	32 (46%)	11 (16%)	1 (>1%)	3 (4%)	1 (>1%)
2019	49	31 (63%)	14 (29%)	3 (6%)		1 (2%)	
2020	**38**	**21 (55%)**	**11 (29%)**	**5 (13%)**	**1 (3%)**		

* The tallies in 2011 and 2012 include one unidentified entangled carcass in each year, in 2014, two unidentified entangled carcasses, and in 2015, two live unidentified entangled whales. They were included in the tally of cases that occurred within a 6-month timeframe.

Age at entanglement detection

Data from historical analyses have shown that calves and juveniles are entangled at a higher rate than adults (Knowlton et al. 2012). In 2010-2012, this pattern continued with 53% to 65% of all the entanglement detections involving calves and juveniles. In the 2013-2017 data, this pattern shifted with only 34% to 41% of entanglement events involving calves or juveniles (Table 4). In 2018-2020, this dropped further with 22% to 24% of events involving juveniles. Of concern is the steady decline of the proportion of calves and juveniles in the presumed living population (i.e. seen alive in the given year or the previous five years) from 2010 through 2020. 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). Further assessment of the percentage of adults and juveniles known to be alive in each given year that experience an entanglement will be conducted for the manuscript that will update the Knowlton et al. (2012) paper.

Table 4. *Entanglement events by age group.*

	Calf	Juvenile (1-8 years old)	Adult (>8 years old)	Unknown age	% of 0-8 yo in population

					presumed alive*
2010 n = 68	3 (4%)	33 (49%)	30 (44%)	2 (3%)	34% 174/507
2011+ n = 97	7 (7%)	51 (53%)	33 (35%)	5 (5%)	35% 182/514
2012+ n = 61	2 (3%)	37 (62%)	18 (30%)	3 (5%)	32% 164/509
2013 n = 33	3 (9%)	10 (30%)	20 (61%)	0 (0%)	31% 159/521
2014+ n = 69	2 (3%)	21 (31%)	44 (66%)	0 (0%)	29% 150/523
2015+ n = 46	4 (9%)	14 (32%)	24 (55%)	2 (4%)	27% 143/529
2016 n = 81	7 (9%)	22 (27%)	51 (63%)	1 (1%)	26% 136/527
2017 n = 76	1 (1%)	29 (38%)	42 (56%)	4 (5%)	23% 116/512
2018 n = 70	0 (0%)	16 (23%)	49 (71%)	4 (6%)	18% 86/486
2019 n = 49	2 (>4%)	8 (18%)	33 (73%)	2 (>4%)	15% 73/479
2020 n = 38	**3 (8%)**	**6 (16%)**	**29 (76%)**	**0 (0%)**	**13% 63/478**

* Presumed alive = all individual whales seen in given year or previous 5 years.

+ 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. They were included in the tally of unknown age except for the carcass in 2012 which was an adult female based on her measured length.

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 2010-2020, all years have been above this average rate with a range from 1.4% to 3.9%. The highest rate of 3.9% occurred in 2018 and has dropped since then to 2.5% in 2019 and 2.3% in 2020. Despite this recent decline, these percentages remain nearly double the rate from 1980-2009 (Table 5).

Case studies for the gear-carrying whales can be found under Task 3. Figure 2 provides case studies for the whales with severe injuries and no gear attached. Below is a summary of these events for 2020.

In 2020, there were seven whales with newly detected serious entanglements: three carrying gear and four with severe injuries and no attached gear.

- **Catalog #3920 (Cottontail)**, an 11-year-old male, was first seen entangled on October 19, 2020 off southern New England. The CCS disentanglement team was able to remove 100 feet of trailing gear and attach a telemetry buoy which later stopped transmitting on October 30 in the northern Gulf of Maine. Catalog #3920 was seen in Florida on February 18, 2021 in extremely poor condition. He was later found dead off South Carolina on March 1, 2021. The gear retrieved from #3920 was determined by NOAA to be consistent with Canadian snow crab gear from the Gulf of St. Lawrence.
- **Catalog #3180 (Dragon)**, a reproductive female who had given birth to three calves, was sighted on February 24, 2020 on Georges Bank with a small buoy wedged in her mouth forcing it to remain open. She was in very poor condition and has not been observed since and is likely dead.
- **Catalog #4680**, a 4-year-old male (2016 calf of #3180, described above), was seen off New Jersey on October 11, 2020 with rope tightly bound around his upper jaw and a gaping wound at his left shoulder. He has not been observed since and is likely dead.

Of the four whales with severe injuries only (Figure 2), three of them were adults between the ages of 10 and 35 years old – one male **(Catalog #1507, Manta)**, one 10-year-old female **(Catalog #4091, Quill)**, and a known reproductive female **(Catalog #1701, Aphrodite)**. The fourth whale was a 4-year-old male **(Catalog #4615, Hercules)**. All of them have been seen in 2021 and their condition is being monitored.

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

	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% (6/432)	3 (2/1)
2011*	11	3	3.2% (14/444)	5 (1/4)
2012*	5	6	2.9% (11/384)	6 (2/4)
2013	3	1	1.4% (4/296)	3 (1/2)
2014*	7	7	3.7% (14/379)	9 (2/7)
2015*	4	3	2.6% (7/270)	2 (0/2)
2016	7	5	3.7% (12/328)	10 (2/8)
2017	9	5	3.7% (14/380)	14 (2/12)
2018	6	8	3.9% (14/363)	6 (3/3)
2019	5	4	2.5% (9/360)	2 (1/1)
2020	**3**	**4**	**2.3% (7/306)**	**3 (1/2)**

* 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. The number of all sighted individuals was not changed to include these whales as we could not determine if they were unique individuals within the given year.

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 onward 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 31% (range 27-37%). 2020 was slightly below the average with 29% moderate and severe injuries combined (Table 6). And the proportion of 2020 cases resulting in severe injuries remained at a relatively high level at 18% (2010-2020 range: 7-23%; Table 6).

Table 6. *Entanglement events according to injury severity by year of detection. The number in parentheses is the subset that was seen carrying gear.*

Year (# of events)	Minor	Moderate	Severe
2010 (n = 68)	45 (0); 66%	16 (0); 24%	7 (5); 10%
2011 (n = 97)*	67 (2); 69%	23 (5); 24%	7 (4); 7%
2012 (n = 61)*	47 (1); 77%	5(1); 8%	9 (3); 15%
2013 (n = 33)	22 (0); 67%	8 (1); 24%	3 (2); 9%
2014 (n = 69)*	46 (0); 67%	9 (0); 13%	14 (7); 20%
2015 (n = 46)+	31 (0); 68%	8 (0); 17%	7 (4); 15%
2016 (n = 81)	51 (0); 63%	17 (1); 21%	13 (6); 16%
2017 (n = 76)	48 (1); 63%	16 (3); 21%	12 (5); 16%
2018 (n = 70)	47 (1); 67%	7 (0); 10%	16 (5); 23%
2019 (n = 49)	37 (1); 76%	4 (0); 8%	8 (4); 16%
2020 (n = 38)	**27 (0); 71%**	**4 (0); 11%**	**7 (3); 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 three cases with attached gear, one (#3920) was consistent with Canadian snow crab gear. The other two (#3180 and #4680) were unknown country of origin (David Morin, pers comm).

For cases involving entanglement scars only and no gear, 20 cases occurred within a six-month period as shown in Table 7. Four of these occurred in US waters; country of origin could not be determined for the remaining 16 cases.

With all gear and scarring-only cases combined, 13% or 5 of 38 cases could be attributed to likely country of origin - one occurred in Canadian waters, four occurred in U.S. waters, and the remaining 33 cases could not be attributed to country of origin.

Table 7. *Entanglement scarring* <u>*only*</u> *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, GB = Georges Bank, GSL = Gulf of St. Lawrence, MB = Massachusetts Bay, SNE = southern New England.*

Catalog No	Age at Injury	Minimum Age	Gender	Severity	Injury Time Frame (days)	Pre Injury Date	Pre Injury Area	Detection Date	Detection Area	Likely Country of Origin
5001	0		X	Minor	12	2020-01-14	GA	2020-01-26	FL	US
5042	0		F	Minor	19	2020-02-05	GA	2020-02-24	FL	US
4904	1		F	Minor	24	2020-01-16	FL	2020-02-09	MB	US
5001	0		X	Minor	42	2020-04-25	CCB	2020-06-06	GSL	Unknown
4091	10		F	Severe	73	2019-11-19	GB	2020-01-31	SNE	US
1507	35		M	Severe	87	2020-03-06	CCB	2020-06-01	GSL	Unknown
3510	15		M	Minor	102	2020-03-06	MB	2020-06-16	GSL	Unknown
3579	15		M	Moderate	103	2020-03-11	GB	2020-06-22	GSL	Unknown
1017		40	M	Moderate	120	2019-10-29	GSL	2020-02-26	CCB	Unknown
4042	10		M	Minor	122	2019-09-22	GSL	2020-01-22	SNE	Unknown
3617	14		M	Minor	127	2020-02-04	GA	2020-06-10	GSL	Unknown
4615	4		M	Severe	129	2020-03-16	CCB	2020-07-23	GSL	Unknown
3194	23		F	Minor	132	2020-03-06	MB	2020-07-16	GSL	Unknown
4991	1		F	Minor	145	2019-09-26	GSL	2020-02-18	FL	Unknown
1701	33		F	Severe	149	2019-09-13	GSL	2020-02-09	CCB	Unknown
3946	11		F	Minor	150	2019-08-21	GSL	2020-01-18	CCB	Unknown
3790	13		F	Minor	151	2019-08-26	BOF	2020-01-24	CCB	Unknown
4917	1		F	Minor	153	2019-08-24	GSL	2020-01-24	CCB	Unknown
2743	23		M	Minor	156	2020-01-22	SNE	2020-06-26	GSL	Unknown
3150	19		M	Minor	174	2019-09-20	BOF	2020-03-12	CCB	Unknown

<u>Discussion</u>

A total of 38 events were first documented in 2020, seven of which were classified as serious entanglements according to the New England Aquarium criteria (i.e. seen with attached gear or severe injuries). The crude and annual entanglement rates dropped from the averages documented for the previous 10 years which is somewhat encouraging. It suggests that management measures may be having some benefit at reducing the frequency of events but the 2020 rates at 12.4% for crude entanglement and 22.4% for annual entanglement are just slightly below the averages calculated for the data from 1980-2009 at 15.5% and 25.0%. The proportion of whales with serious entanglements, 2.3% of all sighted individuals, is slightly lower than the rate over the previous six years but is still nearly double the average rate documented in the Knowlton et al. (2012) paper of 1.2% (1980-2009) and remains concerning. One of the three whales with attached gear was later found dead and the other two were in poor condition (Pettis et al. 2004) and are likely dead. An additional sad twist is these latter two cases represented a reproductive female and her four-year-old male offspring. For the four cases with severe injuries and no attached gear, thus far the impacts on their body condition appear to be minimal. Although sublethal impacts are difficult to detect, recent scientific publications are shedding light on the role they play in this species. Knowlton et al. (2022) have shown that whales with severe injuries are eight times more likely to die than those with minor injuries, and the sublethal health effects of entanglements are more pronounced in reproductive females, resulting in reduced fecundity. An assessment of body lengths in right whales determined that whales who experience a severe entanglement when less than 10 years old, or whose mothers experienced a severe entanglement when they were nursing, are "stunted", i.e. growing to shorter lengths at adulthood than unimpacted whales (Stewart et al. 2021). In turn, females that grow to shorter lengths have fewer calves than larger females as a result of diminished energy reserves (Stewart et al. 2022). Lastly, Reed et al. (2022) have documented a dramatic decline in the abundance of reproductive females beginning in 2014 as a result of both increased mortality and a failure of pre-breeders to transition to breeding. Based on this suite of recent publications alongside the continued high rate of entanglement, it is clear that entanglement caused mortality and sublethal impacts have been hindering the ability of this species to recover for decades and is certainly playing a major role in their recent decline.

In 2020, of the seven whales with a serious entanglement, i.e. attached gear and/or severe injury, four are male and three are female. Two of these three females are reproductively active but #3180, who had attached gear, has likely died. Catalog #1701, who has severe injuries, last had a calf in 2015 and her condition is compromised. The third female, #4091, acquired severe injuries at 10 years old, just as she was entering her reproductive years. Although her condition did not appear to be impacted, she has not yet had a calf as of 2022.

Of continued concern is the steady decline in the proportion of juveniles in this population. This trend continued in 2020 with a drop to 13% juveniles in the population from a peak of 34% in 2010 for this past decade. We 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. To explore this idea further, we queried the data and determined that 25 0-8-year olds have been determined to be dead (n = 8) or presumed dead (i.e. not seen in the for six years; n = 17) from 2013 to 2020. If we add those back into the tally for 2020, we would have 88/503 or 17.5% calves/juveniles in the population. This warrants further investigation for prior years but the level of cryptic mortality observed in this species (Pace et al. 2021) suggests that undocumented drownings of juveniles by entanglement may be playing a role.

Our ability to monitor entanglement timeframes remains high with 84% of the 2020 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 (180 day) 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 13% or 5 of 38 events – one in Canadian waters, four in U.S. waters. This is a lower percentage than 2019 (39% of cases) and 2018 (27% of cases) that were attributed to country of origin. The allocation approach under development at the New England Aquarium will provide a different and hopefully valuable approach for assessing where entanglements are likely occurring although its utility will be improved only if surveillance remains high.

Both the U.S. and Canada have been implementing important measures aimed at reducing entanglement risk. In Canada, snow crab closures in the Gulf of St. Lawrence have been put in place beginning in 2017 in both a dynamic, and more recently, a static approach. They have been testing ropeless gear in that fishery to provide fishers access during the closed time periods. Canada is also mandating the use of weakened ropes starting in January 2023. Although the transition to weak ropes was initially planned for January 2022, it was delayed due to COVID-19. In the U.S., a final rule was put in place in May 2022 that included additional seasonal closures, trawling up to reduce the total number of endlines, and the integration of weak rope or weak points into a portion of the endline. Despite these significant efforts on the part of both countries, entanglements persist. Unfortunately, closures in both countries are either implemented mainly when whales are detected (Canada) or based on a right whale/fishing gear co-occurrence models (U.S.). Until measures are implemented broadly that make fishing gear safer (i.e. ropeless or weak rope gear) throughout their range, these entanglement cases will continue at an unsustainable rate leading to this species' extinction.

NOAA recently included morbidity cases, i.e. those cases that have moderate or severe injuries that are not considered life-threatening but likely to have sublethal impacts, into the ongoing Unusual Mortality Event (https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2022-north-atlantic-right-whale-unusual-mortality-event). NEAq provided retrospective images for cases documented with moderate and severe injuries during scar coding that had not been deemed to be a serious injury by NOAA. An independent team of veterinarians and others reviewed these cases and provided expert opinion as to whether these cases fit the morbidity criteria. NEAq will continue to coordinate with NOAA on this effort. Inclusion of morbidity data provides a valuable avenue for providing this information to managers and the public in near real-time about what right whales are experiencing.

All of these data, including the case studies and follow up gleaned from our gear analyses are being incorporated into the recently created Anthropogenic Events Database curated by NEAq. This will allow for clear linkage of these injury events to sightings and life history information.

Our hope is that this information will provide the impetus needed for both countries to implement broadscale measures quickly and effectively.

Literature Cited

Knowlton, A.R., Clark, J.S., Hamilton, P.K., Kraus, S.D., Pettis, H.M., Rolland, R.M., and Schick, R.S. 2022. Fishing gear entanglement threatens recovery of critically endangered North Atlantic right whales. Conservation Science and Practice, 4(8), e12736. https://doi.org/10.1111/csp2.12736

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

Knowlton, A.R., Hamilton, P.K., Marx, M.K., Pettis, H.M, and Kraus, S.D. 2012. Monitoring North Atlantic right whale *Eubalaena glacialis* entanglement rates: a 30 year retrospective. Marine Ecology Progress Series 466:293-302.

Moore, M.J., Knowlton, A.R., Kraus, S.D., McLellan, W.A., Bonde, R.K. (2004) Morphometry, gross morphology and available histopathology in North Atlantic right whale *(Eubalaena glacialis)* mortalities (1970–2002). J Cetacean Res Manag 6: 199−214

Pace, R.M., Williams, R., Kraus, S.D., Knowlton, A.R., Pettis, H.M. 2021. Cryptic mortality of North Atlantic right whales. Conservation Science and Practice e346. https://doi.org/10.1111/csp2.346

Pettis HM, Rolland RM, Hamilton PK, Brault S, Knowlton AR, Kraus SD. 2004. Visual health assessment of endangered North Atlantic right whales (*Eubalaena glacialis*) using photographs. Canadian Journal of Zoology 82:8-19.

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

Sharp SM, McLellan WA, Rotstein DS, Costidis AM and others (2019) Gross and histopathologic diagnoses from North Atlantic right whale *Eubalaena glacialis* mortalities between 2003 and 2018. Dis Aquat Org 135:1-31. https://doi.org/10.3354/dao03376

Stewart, J.D., Durban, J.W., Knowlton, A.R., Lynn, M.S., Fearnbach, H., Barbaro, J., Perryman, W.L., Miller, C.A., & Moore, M.J. (2021) Decreasing body lengths in North Atlantic right whales. Current Biology, 31(14), 3174-3179.e3. https://doi.org/10.1016/j.cub.2021.04.067.

Stewart, J.D., Durban, J.W., Europe,H., Fearnbach, H., Hamilton, P.K., Knowlton, A.R., Lynn, M.S., Miller, C.A., Perryman, W.L., Tao, B.W.H., Moore, M.J. (2022) Larger females have more calves: influence of maternal body length on fecundity in North Atlantic right whales. Mar Ecol Prog Ser 689:179-189. https://doi.org/10.3354/meps14040

Figure 1. Annual tally of new entanglement events according to severity and presence/absence of attached gear.

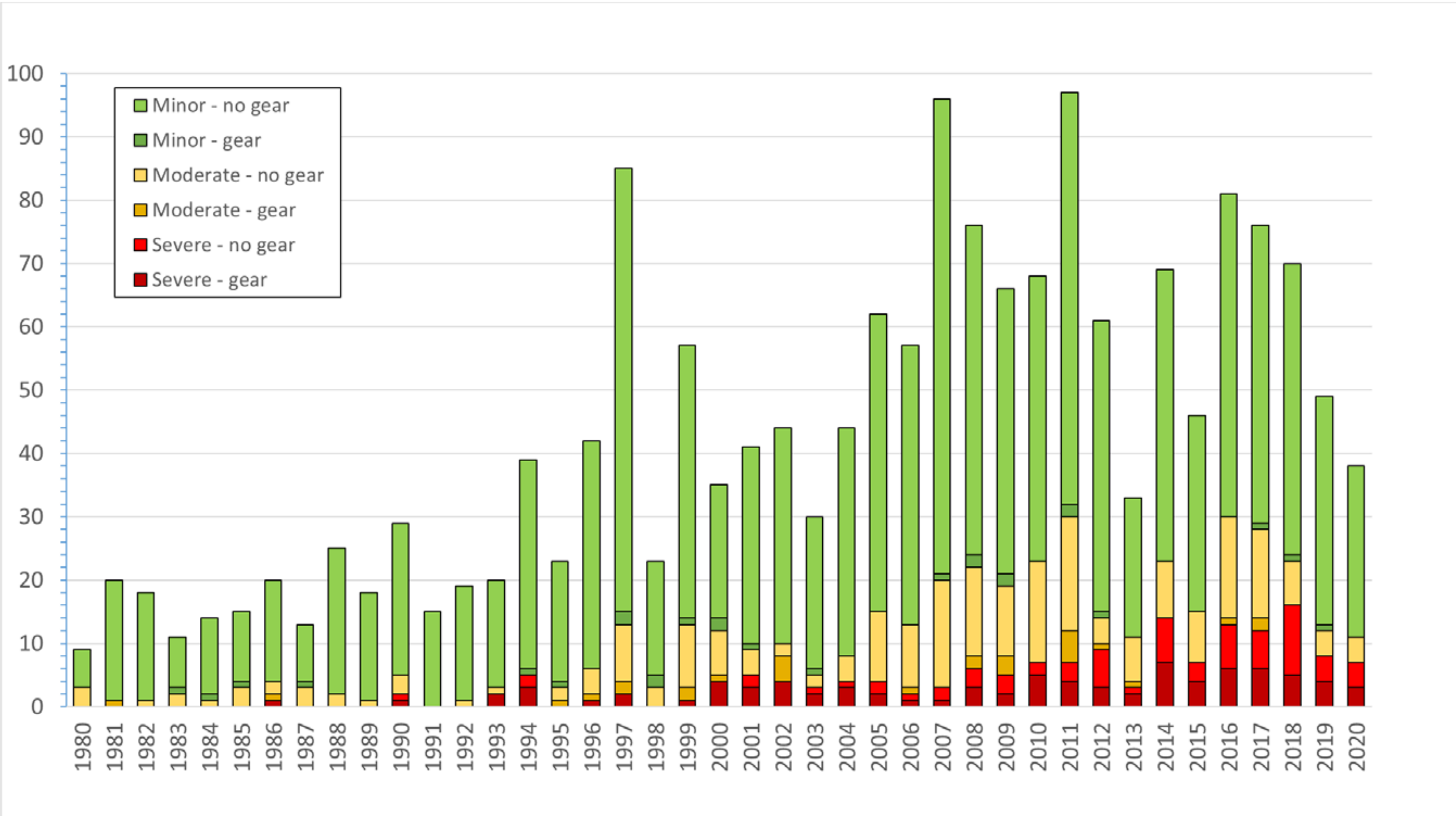


Figure 2. *Severe injuries caused by entanglement (no attached gear) documented in 2020 (listed in order of catalog #). Note: DFO = Department of Fisheries and Oceans Canada, NEA/CWI = New England Aquarium/Canadian Whale Institute, N. Hawkins = Nick Hawkins. Photos are noted with observer and date.*

Catalog # Name	**Sex**	**Birth year**	**Date of entanglement detection (date seen prior to injury)**	**Age at entanglement detection**	**Location when detected/Observer**
1507 Manta	Male	1985	01 Jun 2020 (06 Mar 2020)	35 years old	Gulf of St. Lawrence/DFO

Description:
This 35-year-old male was seen with moderate to severe raw scarring around the peduncle with additional scarring at the head. The peduncle injuries were still not fully healed at subsequent sightings in late August 2020 and his overall condition was uncertain. He has experienced eight previous minor entanglements.

Raw insertion wounds two months post detection – 23 Aug 2020 (DFO)

Injuries at head and tail – 22 Jun 2020 (DFO)

Catalog # Name	Sex	Birth year	Date of entanglement detection (date seen prior to injury)	Age at entanglement detection	Location when detected/Observer
1701 Aphrodite	Female	1987	9 Feb 2020 (13 Sep 2019)	33 years old	Cape Cod Bay/opportunistic

Description:
This 33-year-old reproductive female was seen with severe, raw entanglement injuries around the peduncle in February 2020. These injuries were still raw in July 2020 and her health condition was compromised. She was seen in 2021 and her injuries showed signs of healing but she still appears in compromised condition. Aphrodite has experienced four prior entanglements since 1988, three minor and one moderate. Her last calf was born in 2015.

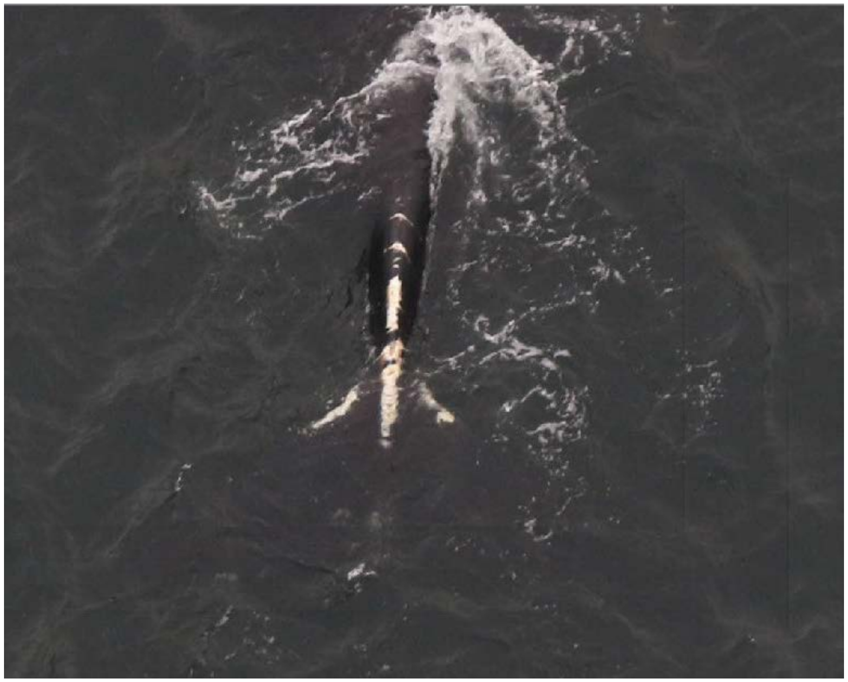
Left insertion and leading edge - 9 February 2020 (opportunistic)

Right insertion and peduncle - July 18, 2020 (N. Hawkins)

Catalog # Name	Sex	Birth year	Date of entanglement detection (date seen prior to injury)	Age at entanglement detection	Location when detected/Observer
4091 Quill	Female	2010	31 Jan 2020 (19 Nov 2019)	10 years old	Southern New England/NEFSC

Description:
This 10-year-old female was seen with severe, raw entanglement injuries on her upper jaw, peduncle and insertions. These injuries remained raw nearly two months after first detected. She was seen in 2021 and injuries appear to be healing and she has shown no obvious signs of decline. #4091 has experienced four minor entanglements and superficial propeller cuts since 2011.


Left head, open mouth -February 26, 2020 (CCS)


Dorsal peduncle – March 11, 2020 (CCS)

Catalog # Name	Sex	Birth year	Date of entanglement detection (date seen prior to injury)	Age at entanglement detection	Location when detected/Observer
4615	Male	2016	23 Jul 2020 (16 Mar 2020)	4 years old	Gulf of St. Lawrence/DFO

Description:
This 4-year-old male was seen with severe, raw entanglement injuries around peduncle and insertions. The injuries were still not fully healed at subsequent sightings through March 2021 and his condition is inconclusive. #4615 has experienced three prior entanglements, two minor and one severe (in 2018).

Dorsal peduncle and right insertion – 6 Sep 2019 (NEA/CWI)

Left insertion – 26 August 2019 (NEA/CWI)

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

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

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

Entanglement injury severity

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

LOW SEVERITY

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

New England Aquarium

MEDIUM SEVERITY

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

New England Aquarium

HIGH SEVERITY

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

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

Photo courtesy of Florida Fish and Wildlife Conservation Commission

Entanglement configuration risk

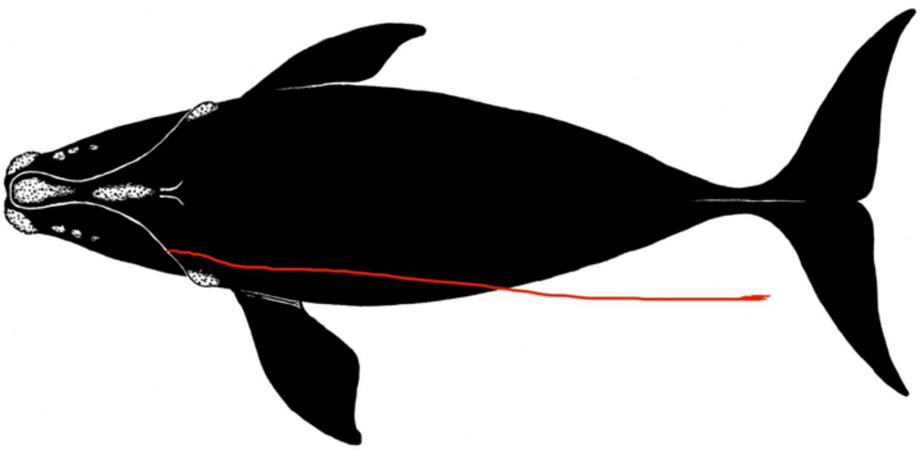
This assessment describes the layout of gear on a whale and does not take into account associated wounds. The configuration of gear on whale is generally used to assess the need for intervention, indicates how the whale may have become entangled, and may be used to make predictions about the fate of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

LOW

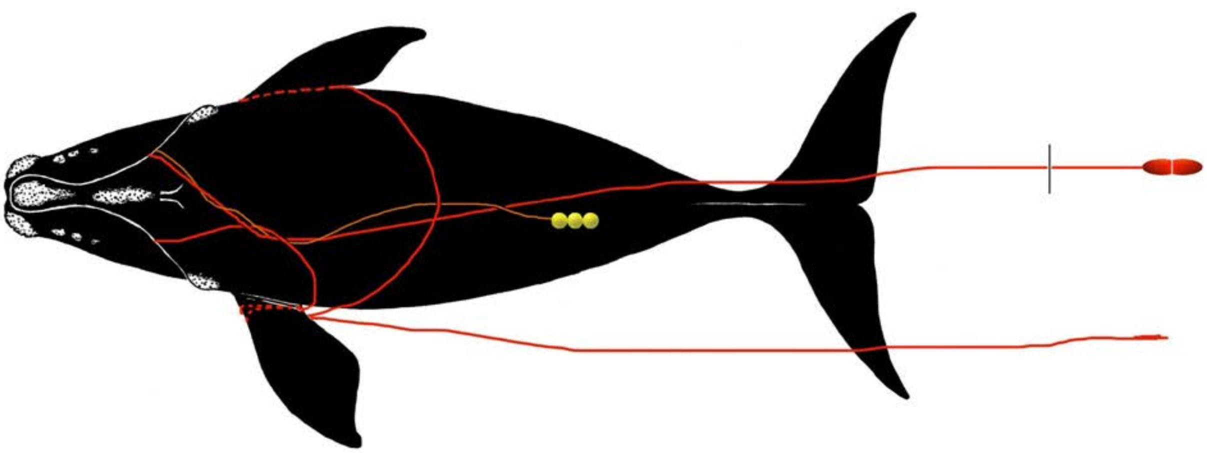
Low risk cases were those involving no tight wraps, only one attachment point, gear trailing less than one body length, and no heavy gear attached. In these cases, gear was often shed.

HIGH

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



Low risk entanglement configuration



High risk entanglement configuration

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

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

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

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

Task 3: Anthropogenic Injury Case Studies

Prepared by:
Amy R. Knowlton and Heather M. Pettis
Anderson Cabot Center for Ocean Life
New England Aquarium
Central Wharf
Boston, MA 02110

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) Right whales with concerning injuries or status – survey teams in the U.S. and Canada provide images near real-time to NEAq and the Northeast Fisheries Science Center to consider for inclusion as a serious injury case and, now, as a morbidity case (see #4 and #5 below). These cases are integrated into the recently developed Right Whale Injuries and Monitoring Portal maintained by NEAq to more easily monitor injuries of concern over time (see #4).
2) 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. These pages remain archived on their website.
3) 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.
4) Serious Injury/Human Impact Report – a report on the addition of new entangled, vessel struck, or severely injured right whales as well as the status of existing cases of severely injured individuals is compiled by NEAq and provided to NOAA Fisheries and the right whale community annually. 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
5) Unusual Mortality Event morbidity cases – in 2022, we provided NOAA Fisheries with images and sighting information of entanglement and vessel strike cases that were not considered as a serious injury under NOAA criteria. These included all right whales with moderate or severe entanglement injuries or shallow or deep propeller cuts or other whales in very poor condition due to unknown cause. A team of veterinarians and others with expertise in assessing cetacean injuries weighed in on each case and provided an opinion as to whether it should be included in a morbidity table because of concerns of sublethal impacts. NOAA Fisheries has now included this information in their UME website (https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2022-north-atlantic-right-whale-unusual-mortality-event) and we will continue to provide updates.

6) Anthropogenic Events Database -– this recently developed database is used to integrate all right whale human impact cases into a MS SQL database which allows for links between each case and information about the sex and age of the individual at injury detection, sighting locations, and timeframe of when the event occurred. These cases will also be linked to case studies, necropsy reports and other pertinent information relating to the event via the Right Whale Injury and Monitoring Portal.

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 2020 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”, i.e. not sighted for six years) 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 (https://www.bycatch.org/project/case-studies-north-atlantic-right-whale-fishing-gear-entanglements) and are updated each year. With the addition of the 2020 events, there are now 139 case studies posted.

For 2020, we have created three entanglement case studies. Drawings of these cases are in progress. 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 four case studies for the 2020 timeframe.

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 https://www.bycatch.org/project/case-studies-north-atlantic-right-whale-fishing-gear-entanglements

The vessel strike case studies will also be important in our efforts to evaluate the forensics of propeller cuts to gain further insights into vessel sizes involved. This work is underway by NEAq and a contractor familiar with vessel strike injury forensics with NOAA Fisheries support.

The evolution of the Anthropogenic Events Database continues. Case studies, necropsy cases, and all other pertinent information will continue to be integrated annually and visual outputs of this information will be developed for sharing with managers and the public.

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 three newly completed cases studies for right whale entanglements in whale number order

Right Whale Catalog #	Age	Sex	Retrieved Gear?	Country of origin/ gear type	Date/area first observed entangled	Date/area observed prior without injuries
3180	19	Female	No	Unknown	24 Feb 2020 - GB	11 Apr 2019/CCB
3920	11	Male	Yes	Canada/snow crab	19 Oct 2020 - SNE	16 Mar 2020/SNE
4680	4	Male	No	Unknown	11 Oct 2020 - NJ	7 Jul 2020/GSL

Appendix Ib. List of four newly completed case studies for right whale vessel strikes in whale number order

Right Whale Catalog #	**Age**	**Sex**	**Country of origin**	**Estimated general vessel size**	**Date/area first observed with injuries**	**Date/area observed prior without injuries**
1017	40+	Male	Unknown	Likely <40 feet	26 Feb 2020/CCB	17 Aug 2019/GSL
3860	12	Female	Unknown	Likely <40 feet	23 Dec 2020/FL	26 Jul 2020/GSL
5010	0	Unknown	US	>40 feet and potentially much larger	8 Jan 2020/GA	Unknown
5060	0	Male	US	>65 feet (series 1) >40 and <65 ft (series 2)	25 Jun 2020/NJ	6 Apr 2020/NC

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

Species	Right Whale	Whale ID	3180

Date first observed entangled (date seen prior without gear)	24 Feb 2020 (11 Apr 2019)				
Sex	Female	Birth year	2001	Age at entanglement	19

Case study ID	CCS	NMFS		GEAR ID
	WR-2020-01	E04-20		
Gear sample collected?	No	Gear type	Unknown	

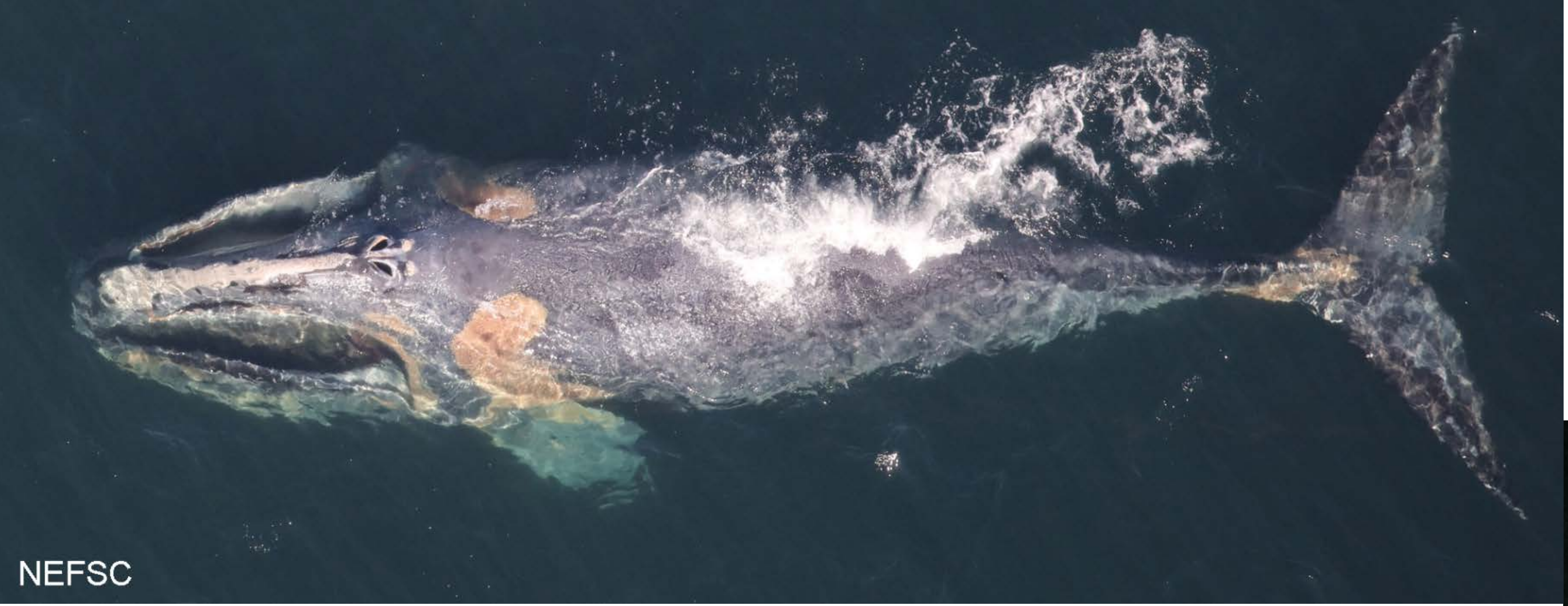
Photographs inadequate to determine complete entanglement configuration - no drawing available

Reproductive prior to/after entanglement detection					
Entanglement injury severity	Severe				
Entanglement configuration risk	High				
Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	Low	High	Unknown	Unknown	Low
Duration of time carrying gear	Minimum 1 day, maximum 318 days				
Disentangled?	No				
Status	Likely dead, no additional sightings				
Number of prior entanglements	3				

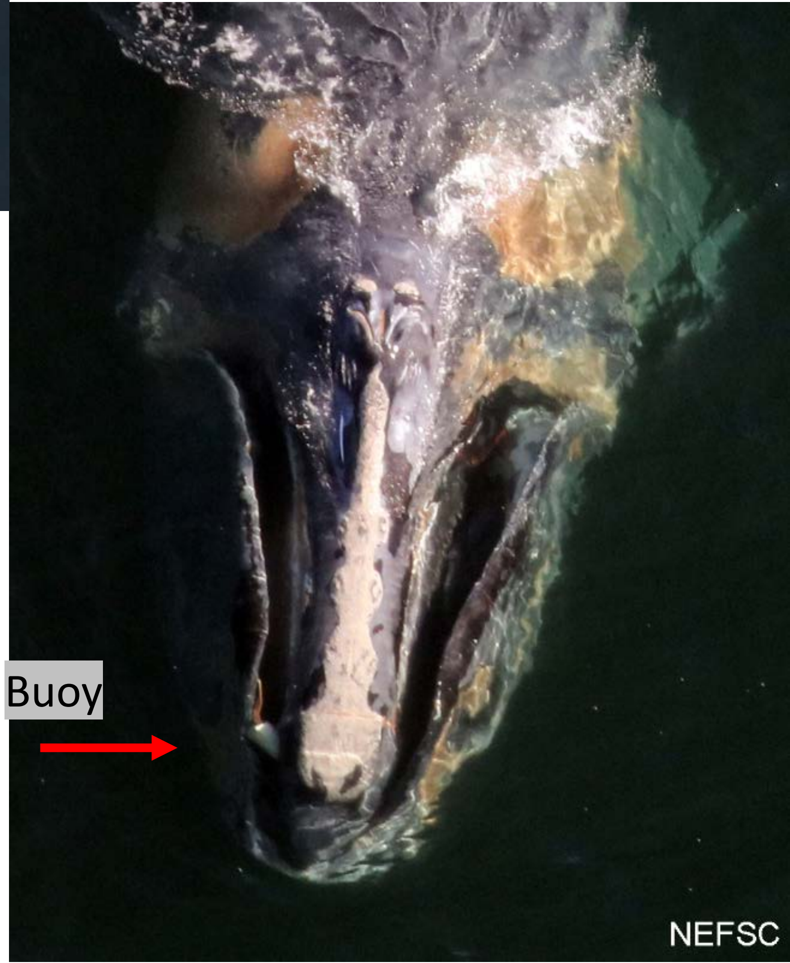
Entanglement configuration	Single tight wrap over rostrum, white bullet buoy lodged in mouth, no trailing gear evident
Anchoring points	Mouth
Gear configuration confidence	Low
Remaining questions	
Comments	Mouth wedged open, whale in very poor condition

Polymer type		
Gear component		Buoy and portion of 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.



24 Feb 2020 NEFSC



Species	Right Whale	Whale ID	3920

Date first observed entangled (date seen prior without gear)	19 Oct 2020 (16 Mar 2020)		
Sex	Male	Birth year	2009
Age at entanglement	11		

Case study ID	CCS	NMFS	GEAR ID
	WR-2020-18	E22-20	
Gear sample collected?	Yes	Gear type	Canadian snow crab

Photographs inadequate to determine complete entanglement configuration - no drawing available

Reproductive prior to/after entanglement detection					
Entanglement injury severity	Severe				
Entanglement configuration risk	High				
Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	Low	High	Unknown	None	High
Duration of time carrying gear	Minimum 122 days, maximum 338 days				
Disentangled?	No				
Status	Dead, 27 Feb 2021				
Number of prior entanglements	2				

Entanglement configuration	Embedded rope in upper jaw, trailing 4-5 body lengths
Anchoring points	Mouth
Gear configuration confidence	??
Remaining questions	
Comments	Found dead off South Carolina

Polymer type	Poly float and poly leaded	
Gear component	Endline	
Rope diameter (inches)	5/8	
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 Oct 2022 CCS

Species	Right Whale	Whale ID	4680

Date first observed entangled (date seen prior without gear)	11 Oct 2020 (7 Jul 2020)				
Sex	Male	Birth year	2016	Age at entanglement	4

Case study ID	CCS	NMFS		GEAR ID
	WR-2020-17	E21-20		
Gear sample collected?	No	Gear type	Unknown	

Photographs inadequate to determine complete entanglement configuration - no drawing available

Reproductive prior to/after entanglement detection					
Entanglement injury severity	Severe				
Entanglement configuration risk	High				
Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	Unknown	High	Unknown	High	High
Duration of time carrying gear	Minimum 1 day, maximum 95 days				
Disentangled?	No				
Status	Presumed dead - no subsequent sightings				
Number of prior entanglements	1				

Entanglement configuration	Two tight wraps of rope around rostrum
Anchoring points	Mouth
Gear configuration confidence	Low
Remaining questions	Not sure if flippers involved or if trailing gear present
Comments	Gaping wound in left shoulder, whale in poor condition

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.

11 Oct 2020

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

Species	**Right Whale**
Whale ID #	**1017**
Necropsy/Other ID #	

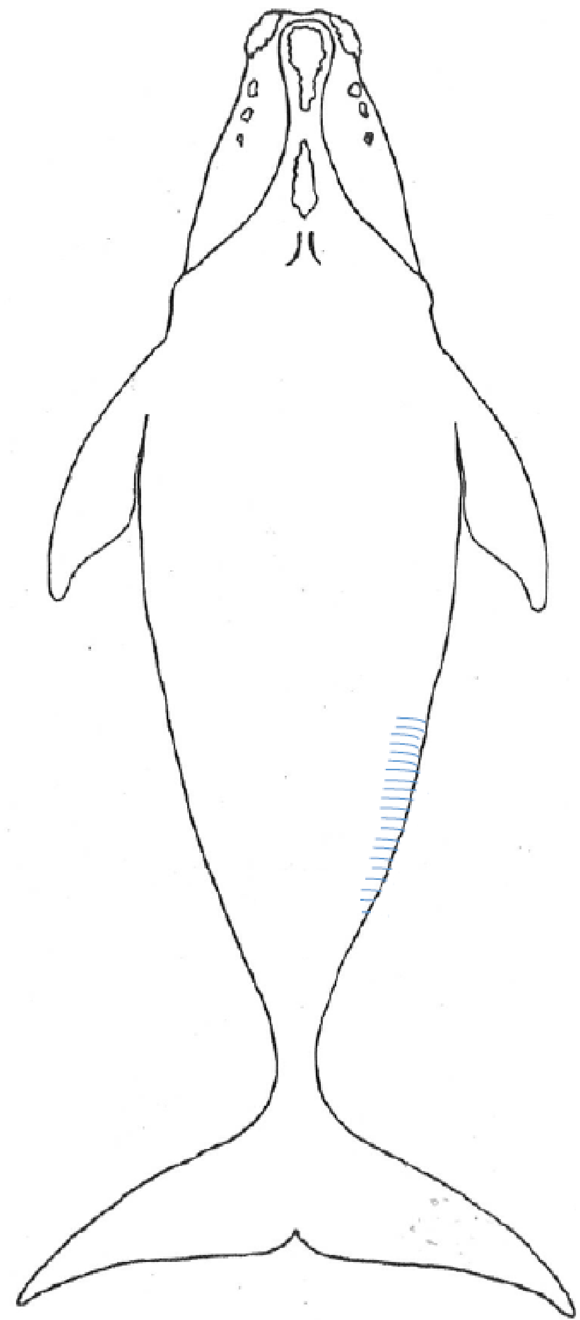
Sex	Male
Birth Year	Unknown

Age at Detection w/ Injury	40+
Date First Detected w/ Injury	26 Feb 2020
Date Seen Prior w/o Injury	(17 Aug 2019)

Reproductive Prior Injury Detection	
Reproductive After Injury Detection	

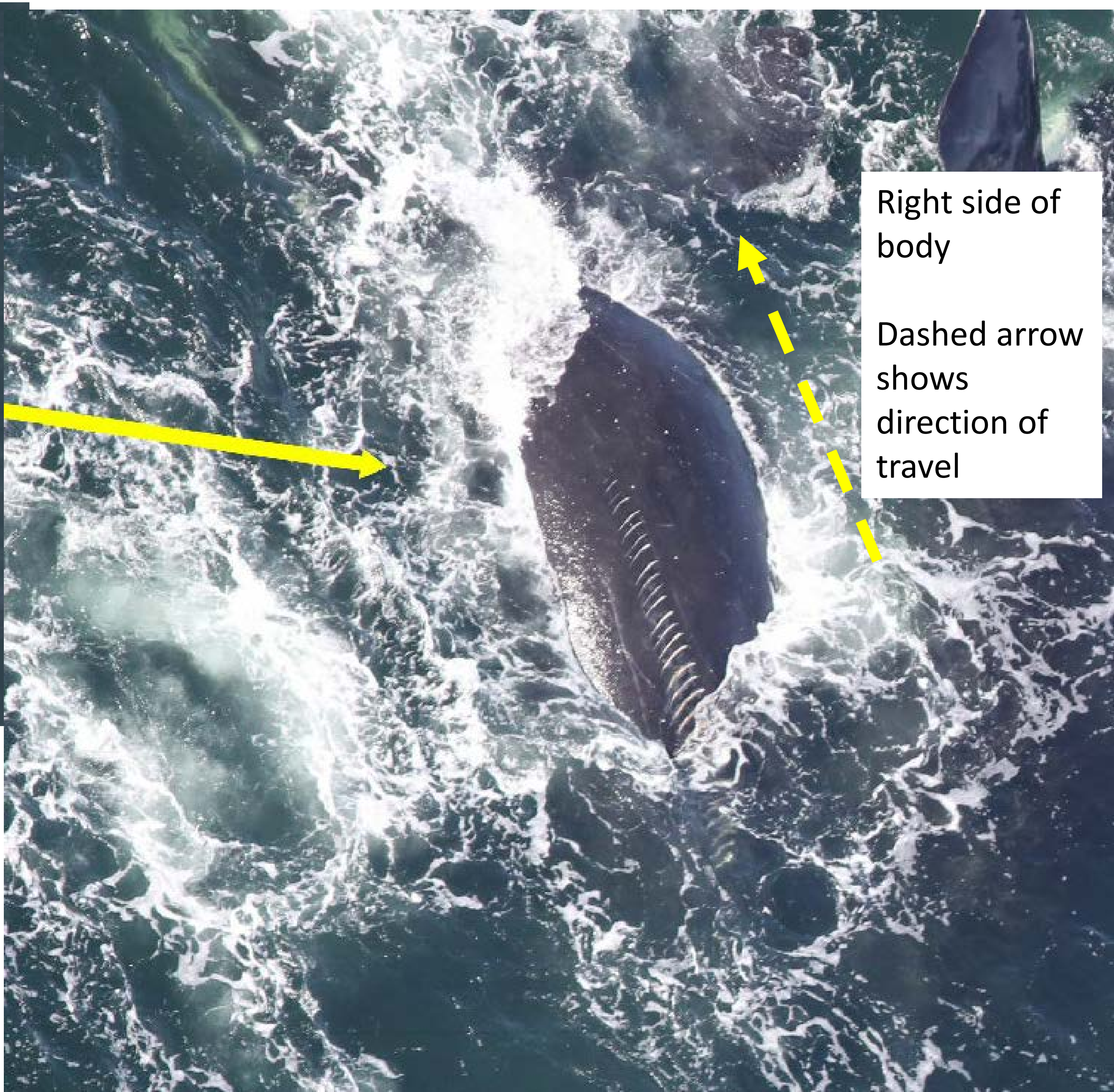
Relative Wound Depth	Superficial
Body Region(s) With Injury	Body
Description of Injury	Propeller cuts
Status/Year Last Seen	Alive/ 2021
MMPL Vessel Size Category	
Vessel Size Range	Analysis has not been done but likely <40 feet
Max Wound Length (cm)	

Vessel Related Comments	Series of at least 20 superficial propeller cuts along right flank.
Whale Related Comments	



This case study was developed at the New England Aquarium with financial support from NOAA Fisheries. Whale data were provided by the North Atlantic Right Whale Consortium (www.narwc.org).
All images are listed with appropriate credit information and taken under permit. Please contact Amy Knowlton (aknowlton@neaq.org) for potential use.

29 Feb 2020 CCS



Species	**Right Whale**
Whale ID #	**3860 (Bocce)**
Necropsy/Other ID #	

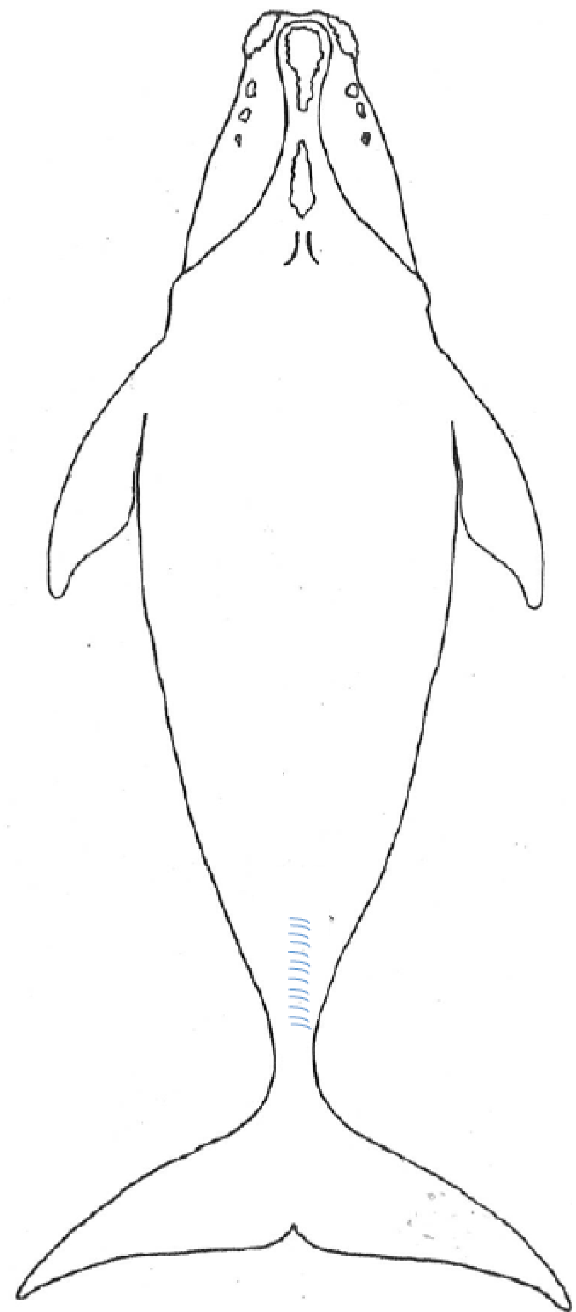
Sex	Female
Birth Year	2008

Age at Detection w/ Injury	12
Date First Detected w/ Injury	23 Dec 2020
Date Seen Prior w/o Injury	(26 Jul 2020)

Reproductive Prior Injury Detection	Yes
Reproductive After Injury Detection	Yes

Relative Wound Depth	Superficial
Body Region(s) With Injury	Peduncle
Description of Injury	Propeller cuts
Status/Year Last Seen	Alive/ 2021
MMPL Vessel Size Category	
Vessel Size Range	Analysis has not been done but likely <40 feet
Max Wound Length (cm)	

Vessel Related Comments	Series of 13 superficial propeller cuts along dorsal peduncle
Whale Related Comments	



This case study was developed at the New England Aquarium with financial support from NOAA Fisheries. Whale data were provided by the North Atlantic Right Whale Consortium (www.narwc.org).
All images are listed with appropriate credit information and taken under permit. Please contact Amy Knowlton (aknowlton@neaq.org) for potential use.

23 December 2020   GA DNR

Species	**Right Whale**
Whale ID #	**5010**
Necropsy/Other ID #	

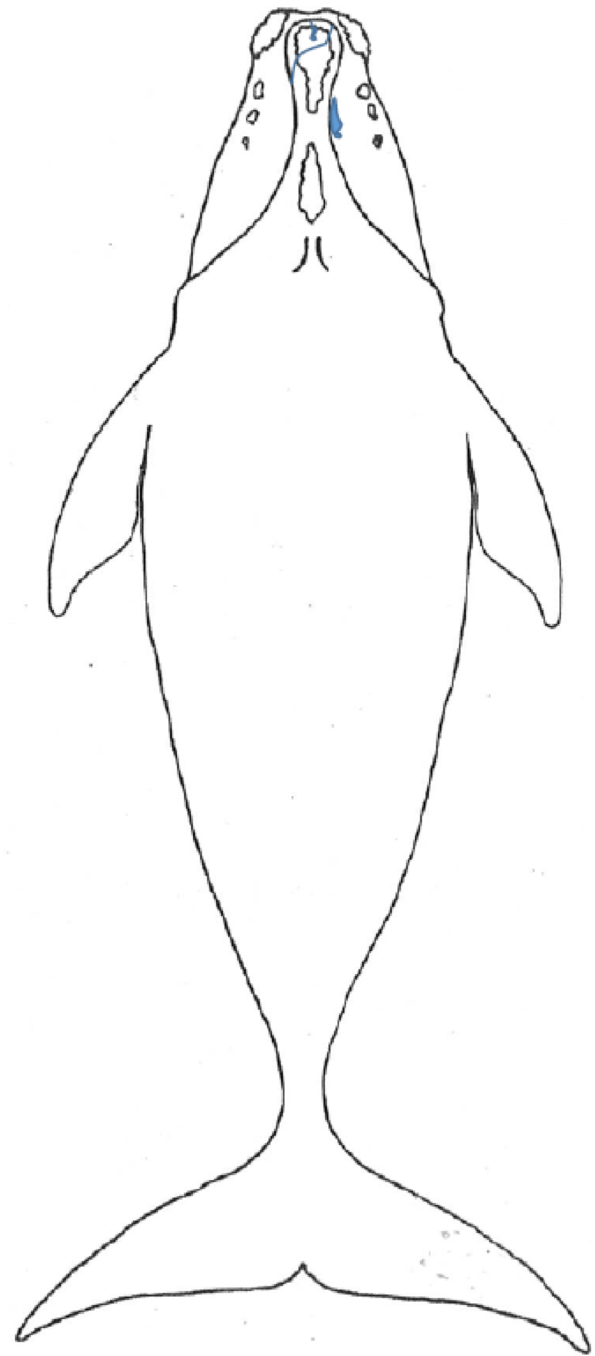
Sex	Unknown
Birth Year	2020

Age at Detection w/ Injury	0
Date First Detected w/ Injury	8 Jan 2020
Date Seen Prior w/o Injury	(unknown)

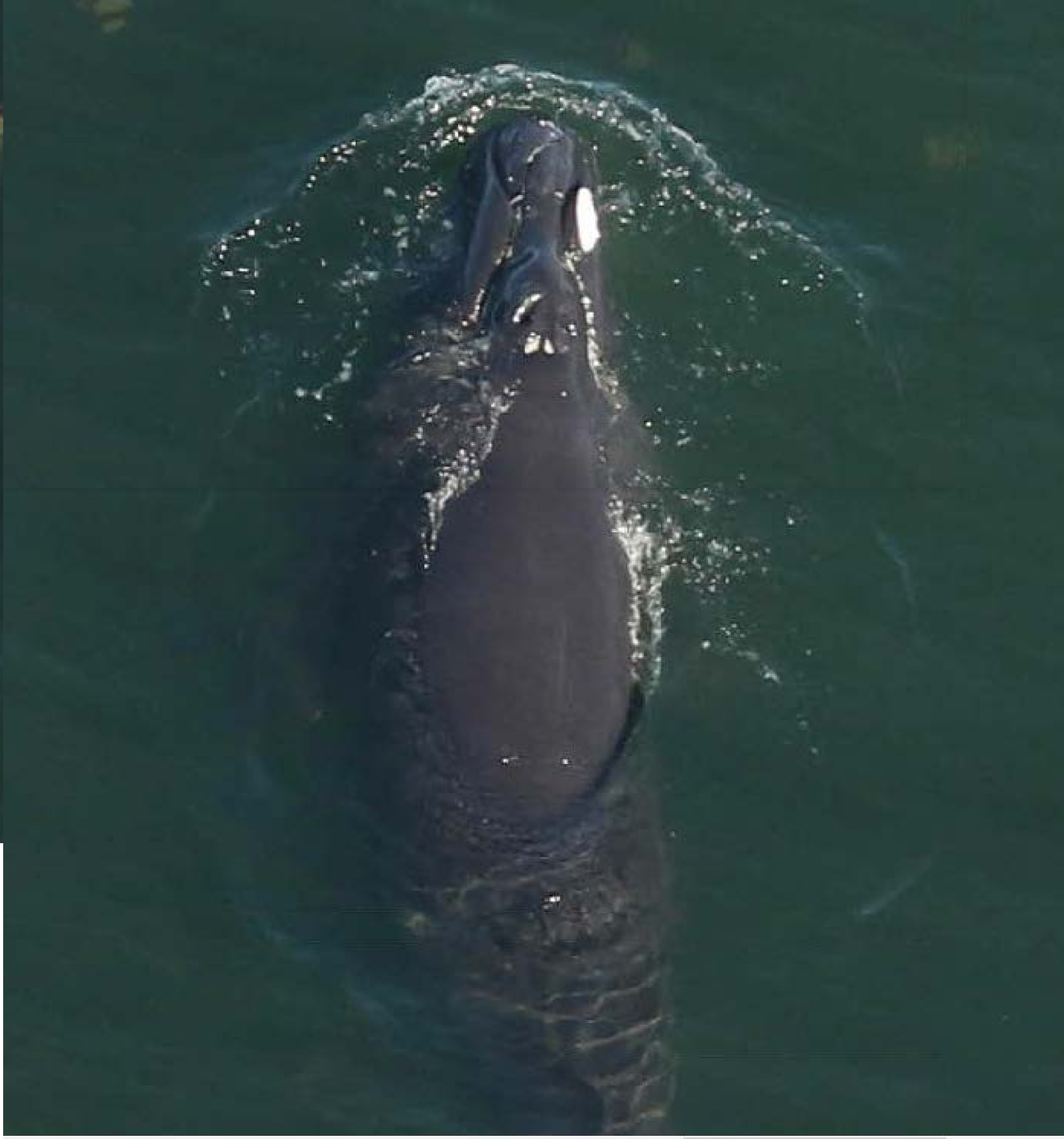
Reproductive Prior Injury Detection	
Reproductive After Injury Detection	

Relative Wound Depth	Deep
Body Region(s) With Injury	Head
Description of Injury	Propeller cuts
Status/Year Last Seen	Likely dead/2020
MMPL Vessel Size Category	
Vessel Size Range	>40 feet and potentially much larger
Max Wound Length (cm)	

Vessel Related Comments	One deep, sigmoid cut across the forward rostrum with a second cut or abrasion on right lip. Difficult to determine estimated measurements because of distortion of cuts. Strike occurred in the southeast U.S.
Whale Related Comments	Calf was observed for about one week after first detection with injuries and was actively trying to nurse but could not do so successfully because of the injury. The cut across the rostrum soon caused a flap of tissue to pull away from the head which opened up the mouth cavity. Milk could be seen in the water. The calf has not been observed since 15 Jan 2020 and likely died.



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.



23 December 2020   GA DNR

Species	**Right Whale**
Whale ID #	**5060**
Necropsy/Other ID #	**MMSC-20-104**

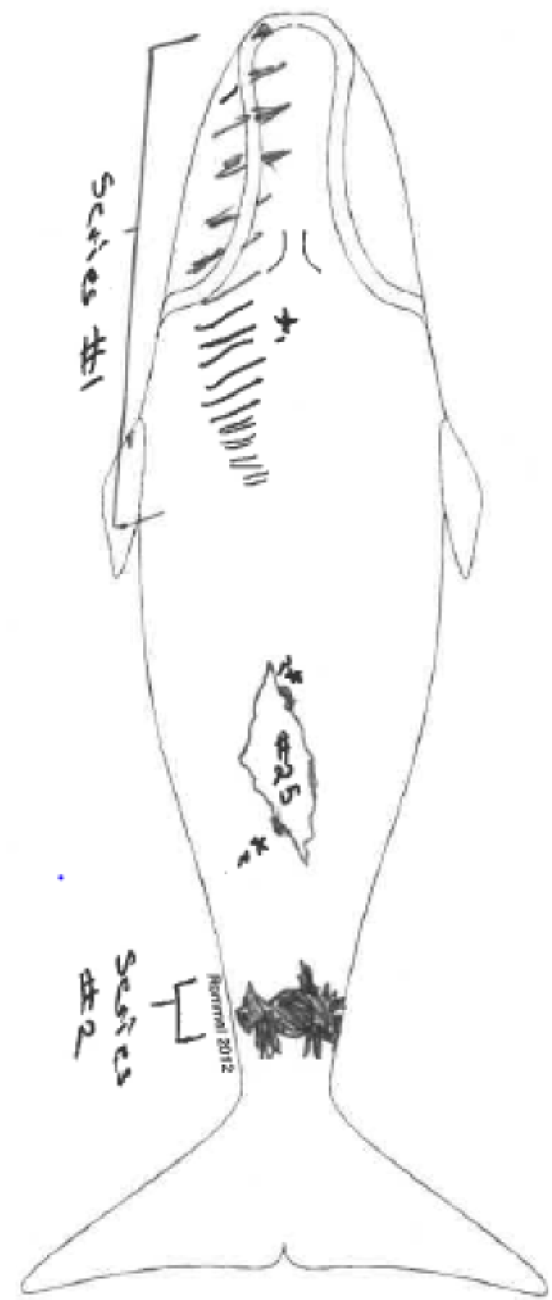
Sex	Male
Birth Year	2020

Age at Detection w/ Injury	0
Date First Detected w/ Injury	25 Jun 2020
Date Seen Prior w/o Injury	(6 Apr 2020)

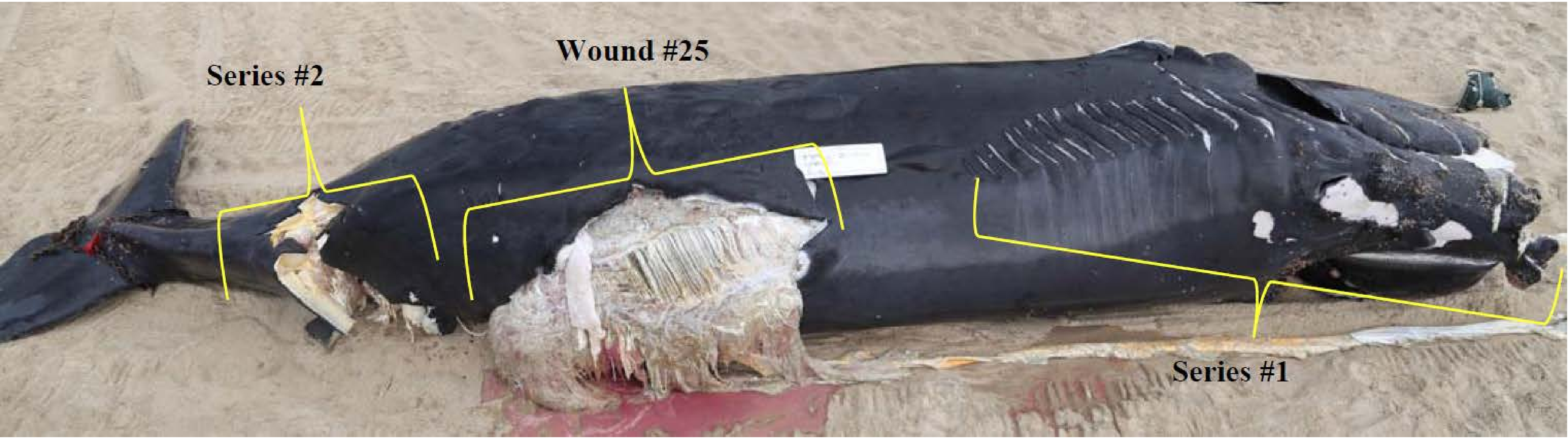
Reproductive Prior Injury Detection	
Reproductive After Injury Detection	

Relative Wound Depth	Deep
Body Region(s) With Injury	Head, body, peduncle
Description of Injury	Prop cuts (two sets from different vessels)
Status/Year Last Seen	Dead
MMPL Vessel Size Category	Ser 1: Upper Cat III or Cat IV; Ser 2: Cat III
Vessel Size Range	>65 feet (series 1); 40-65 feet (Series 2)
Max Wound Length (cm)	

Vessel Related Comments	Wound series 1: 24 propeller cuts on head and body. Wound #25 is likely related to this wound series. Wound series 2: 9 propeller cuts and skeg wounds at peduncle potentially caused by a counter rotating propeller. Information summarized from necropsy report written by Alex Costidis, Virginia Aquarium.
Whale Related Comments	This calf suffered the first series of cuts at head and body some number of weeks prior to the second fatal strike at the tail stock. The sighting prior to his death occurred in April off NC when still with his mother. The first series of wounds showed evidence of healing but the injuries would have affected ability to nurse. Wound series 2 severed the spinal cord causing hemorrhage and paralysis and occurred within 2-3 days of detection off the coast of NJ.



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



27 June 2020   Virginia Aquarium (at necropsy after carcass retrieved)

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

Prepared by:
Philip K. Hamilton, Heather M. Pettis, Monica A. Zani, and Amy M. Warren
Anderson Cabot Center for Ocean Life
New England Aquarium
Central Wharf
Boston, MA 02110

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, 2021 to August 31, 2022. 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, N.S. 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 or vessel strike but still need a post-injury sample.

The near real-time matching allows for preliminary information on the last time a sick, injured, entangled, 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 (such as investigating wounds from tag attachments). 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 2021/2022 season was sent to all survey teams on November 15, 2021, 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 47 unique whales, not counting calves of the year, from the Carolinas or points south. We were able to match/confirm 39 to currently cataloged whales and seven to calves from previous years – all of which will be cataloged in the near future. One whale remains unmatched (referred to by a season code of S082); it appears to be young, but so far, does not match any past calves for which we have adequate photographs. 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. Three mothers, 13 calves of the year, and one unknown juvenile were biopsied on the calving ground. As happened last year, one mother/calf pair was only seen off North Carolina on a single day and neither of the two were biopsied (although both were later biopsied in July in the Gulf of St. Lawrence). Only one other calf was not biopsied during the season. Aside from the mother/calf pairs, only one of the other 32 whales still needed to be biopsied by the end of the season, and that whale was only seen off North Carolina. A list of biopsied animals is included as Appendix II.

Feeding grounds

We continued 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 multiple sightings of the 2021 calf of #3720 during the winter and spring from North Carolina on December 26 to southern Long Island on January 23, to Cape Cod Bay on February 9, to Great South Channel on May 1. Our near-real-time matching allowed us, along with our collaborators, to connect sightings of this whale along the east coast and, when it was discovered entangled in the Gulf of St. Lawrence in August 2022, we were able to provide the last date seen gear free.

In the Gulf of St. Lawrence, we provided quite a few rapid identifications for the DFO tagging team led by Christian Ramp in the summer of 2022, as well as providing our assessments of which whales should not be tagged due to apparent poor health. The members of our team who were aboard the *JD Martin* in the Gulf were able to match most of their 260+ sightings, identify several biopsy candidates, and successfully obtain samples from four whales. Over 80 unique individuals were identified. Two of the genetic samples were particularly important. Our team identified #4180 and calf within minutes of sighting them, the first and only shipboard sighting of the pair in the Gulf, and were then able to get biopsy samples from both. This mother/calf pair had only been seen once off North Carolina during the winter and a genetic sample was needed from both.

Finally, we also provided matching assistance to the Department of Fisheries and Oceans Canada (DFO)- providing matches or confirming their tentative matches upon request.

Entangled or Entrapped Whales

During this contract period, there were five reports of newly entangled live right whales, and no previously entangled or entrapped 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 five newly entangled or entrapped whales that were first reported between September 1, 2021 and August 31, 2022 for which matching attempts or confirmations were

made quickly. One of the reports was incorrect - the whale was not entangled. It was simply skim feeding.

Date	Incident	ID	Location and comments	ID Date	Darted Previously?
5/19/2022	First entangled	3823	Gulf of St. Lawrence - weighted gear	5/19/2022	Yes
6/30/2022	First entangled	1403	Gulf of St. Lawrence	7/1/2022	Yes
8/20/2022	First entangled	2021 calf of 3720	Gulf of St. Lawrence	8/20/2022	Yes
8/24/2022	First entangled	4501	Gulf of St. Lawrence	8/24/2022	Yes
6/8/2022	Potential entanglement	3810	Was reported by the public as a potential entanglement. Determined to just be skim feeding.	6/8/2022	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, no dead right whales were discovered.

Injured or Sick Whales
In addition to the entangled whales above, there was one sighting of an injured whale for which rapid identification attempts were made during the reporting period (Table 2).

Table 2. List of sick or injured whales, other than those seen entangled in fishing gear, that were reported between September 1, 2021 and August 31, 2022 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?
6/13/2022	Vessel strike	5012	Seen by NEFSC offshore cruise on George's Bank on May 24, 2022- images not provided until June 13. At least four propeller cuts on the left body	6/14/2022	Yes

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

1) Mogul (#3845) seen on Stellwagen Bank by a whale watch boat on September 21, 2021 and then off Nags Head, N.C. ten days later. Mogul is the whale that swam to Iceland, France and Newfoundland in 2018 and 2019;

2) Video of two right whales skim feeding off northern Newfoundland on November 8, 2021. The two are moving very slowly in the pixilated video. We were asked by DFO to determine whether it was a mother/calf pair, which it was not. This is an unusual location and time of year. We put extra effort into matching these whales the day we received the video, but the quality was too poor to make a definitive match;
3) In a similar situation, three days later we received poor quality photos of a single right whale taken with a phone east of the previous sighting. We discovered two possible matches to these pixilated images (#3392 & #3981), but will likely never be able to confidently identify them. It may well be one of the two whales seen three days earlier to the west of this sighting;
4) The 2021 calf of Grand Teton (#1145), which will be cataloged in the near future, was videoed swimming amongst many pilot whales in Hermitage Bay off southern Newfoundland on June 17, 2022. We received images on June 21 and made the tentative match on June 22;
5) We identified the 2021 calf of Bocce (#3860), which will be cataloged in the near future, far up the St. Lawrence River near Tadoussac, Quebec on August 7, 2022;
6) We made a thorough matching attempt of a small whale seen around Cape Cod in the spring of 2022. Because we could not match it to any recent calves or other whales, we alerted teams that it should be biopsied if the situation presented itself.

<u>Discussion</u>

Our matching support for the broader calving ground region included the match or confirmation of 46 of the 47 whales seen (Appendix I) and 17 darting events (Appendix II). The one unidentified whale, referenced by season code S082, looks young but we have not yet been able to match it to a calf from previous years. Luckily, although it was only seen once, the team from NEFSC were on site and able to biopsy it. The combination of good photographs from the southeast U.S. as a juvenile, and a potential genetics identification to link it to a recent calf, will allow us to catalog this whale in the future.

For a third year in a row, a number of the calves from the previous year were seen during the calving season; seven of the 18 (39%) calves from 2021 were photographed in the southeast U.S. in the winter of 2021/2022. Because some calves are not seen in the spring and summer when they are still with their mothers after their callosity patterns have fully developed, they can be very hard to identify in subsequent years. High quality images of them as yearlings are especially helpful in cataloging these whales. Even with good photographs, these young whales require extra effort to identify. In fact, one from this past season is only a tentative identification. The 2021 calf of #3593 was only seen once in 2021- on March 11 off North Carolina. We believe the juvenile seen in 2022 off North Carolina is that calf, but given the paucity of photo-identification information from its calf year, we may never be certain. Although the calf was not darted, a genetic sample from this juvenile would determine whether it *could* be #3593's calf. The need for a biopsy was relayed to the field teams, but it was only seen that one day and in an area without a biopsy team.

The communication and coordination between the field teams and our matching team remained rapid and seamless- this type of cooperation is invaluable. The case of S082 (described above) serves as a particularly good example of this cooperation. The NEFSC team texted us pictures of this whale while they were with it and we immediately reviewed them. We relayed that we could not find a match and they immediately biopsied it. The whale was only seen that day so this ended up being the only opportunity for a biopsy. It remains unidentified.

Because of the aforementioned challenge of cataloging calves, we encourage teams to biopsy any young-looking whale if they can't identify it immediately, even if our team has not had an opportunity to see images and weigh in. This occasionally leads to duplicate samples being collected, as was the case for the 2020 calf of 1970 last year, but those samples can still be useful. Duplicate samples have been very effective in looking for any photo-identification or genotyping errors in the past (Frasier et al. 2009). The practice of darting young whales paid off for whale #4810, one of the whales newly cataloged in 2021 (see the New Whale section in Task 1). This whale was only seen on one day in February 2018. The Georgia Department of Natural Resources team was on the water, did not recognize it, and biopsied it. That was the only sighting of this whale to date. The genetics will be processed soon and, thanks to GDNR's biopsy, we may be able to link this whale to an unidentified calf in the near future.

In the Gulf of St. Lawrence, our rapid identification and assessment of potentially entangled #3810 allowed disentanglement teams to stand down. The opportunistic sighting was reported to us at 11:39 a.m. on the morning of June 8. The description was a live entangled right whale with possible weighted gear on the flukes. Our team identified it in less than an hour and relayed the identification. We received additional videos at 1:28 p.m. and responded a few minutes later that the whale was skim feeding and there was no reason to suspect it was entangled. The behavior of the head angled out of the water had confused observers. A team from DFO were just about to head out on the water to attach a telemetry tag to this whale; our prompt work avoided that unnecessary effort.

The number of opportunistic sightings, like #3810, has increased substantially in recent years. These sightings are both interesting and important as many come from unusual areas or unusual times of year (like the Newfoundland sightings). Unfortunately, many also have poor quality images or video and often scant location data which require more time to review. We always make an extra effort with these challenging, extra limital sightings- even if their poor quality makes a successful match unlikely.

It is unfortunate that we have still not been successful at establishing a relationship with the new staff at the Mingan Island Cetacean Study (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. We do receive images from MICS eventually through DFO, but not soon enough to alert the community of potential biopsy targets.

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. The calf, #4295, has been seen in subsequent years, but this was the last sighting of mother #3995; she 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 species.

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, Shelby Yahn, 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 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; 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 47 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. A sex of "C" under other whales signifies the whale has calved in past years.

Mothers with calves

Whale ID	Age	Last calf	Mom darted?	Calf darted?	Comments	Confirmed sighting	Date confirmed
1245	40	2011	Y	Y	Calf born between Nov. 2 and Nov. 24 off S.C.	2021-11-24-CMARI-SC Eg A	24-Nov-21
1301	39	2014	Y	Y	Calf born between Dec. 18 and Jan. 18	2021-12-18-FWRI-A Eg A	18-Dec-21
1515	>37	2017	Y	Y	With calf at her first sighting	2022-01-23-FWRI Eg A	24-Jan-22
1620	>36	2015	Y	Y	With calf at her first sighting	2021-12-10-CMARI-GA Eg C	11-Dec-21
1817	>34	2009	Y	Y	With calf at her first sighting	2021-12-16-FWRI Eg A	16-Dec-21
2040	32	2014	Y	Y	With calf at her first sighting	2021-12-31-OTHER	01-Jan-22
2360	>29	2020	Y	Y	Calf born between Dec. 11 and Dec. 18	2021-12-10-FWRI-A Eg A	11-Dec-21
2614	26	2017	Y	Y	With calf at her first sighting	2021-12-26-CMARI-GA Eg A	26-Dec-21
2753	25	2013	Y	Y	With calf at her first sighting off S.C.	2021-12-10-CMARI-SC Eg A	11-Dec-21
3157	21	2014	Y	Y	Calf born between Jan. 13 and Feb. 11	2022-01-13-CMARI-GA Eg A	13-Jan-22
3220	>20	2012	Y	Y	Alone of S.C. Dec. 24 and unidentified at the time, calf born between then and Jan. 6	2022-01-06-CMARI-SC Eg I	07-Jan-22
3320	>24	2009	Y	N	Calf born between Dec. 4 and Dec. 16	2021-12-02-CMARI-GA Eg C	02-Dec-21
3430	18	2011	Y	Y	With calf at her first sighting	2021-12-18-FWRI-A Eg J	18-Dec-21
3560	17	2020	Y	Y	With calf at her first sighting, mother entangled	2021-12-02-FWRI-A Eg A	02-Dec-21
4180	>11	2019	N*	N*	With calf at her first sighting off N.C.	2022-03-02-CMARI-NC Eg A	03-Mar-22

* Both were darted in July 2022, but neither had been darted prior to leaving the southeast U.S.

Appendix I (cont.)

Other whales

Whale ID	Age	Sex	Darted?	Comments	Confirmed sighting	Date confirmed
1121	>41	M	Y	Only seen off N.C.	2021-12-27-CMARI-NC Eg C	28-Dec-21
1149	>41	M	Y	Only seen off N.C.	2022-02-15-CMARI-NC Eg C	16-Feb-22
1209	>42	F	Y	Only seen off S.C.	2022-02-09-CMARI-SC Eg A	10-Feb-22
1409	38	M	Y	Only seen off S.C.	2022-01-06-CMARI-SC Eg 1	07-Jan-22
1920	33	M	Y	Only seen off S.C.	2022-02-09-CMARI-SC Eg B	10-Feb-22
1934	33	F	Y	Only Carolinas- first off N.C., 2 months later off S.C.	2021-12-27-CMARI-NC Eg A	28-Dec-21
2271	30	M	Y	Only seen off N.C.	2022-01-13-CMARI-NC Eg C	14-Jan-22
2743	25	M	Y	Only seen off S.C.	2022-02-24-CMARI-SC Eg C	25-Feb-22
2770	>26	M	Y	Only seen off S.C.	2022-01-06-CMARI-SC Eg B	07-Jan-22
2912	23	C	Y	Only seen off N.C.	2022-01-13-CMARI-NC Eg B	14-Jan-22
3245	20	M	Y	Only seen off S.C.	2022-02-24-CMARI-SC Eg B	25-Feb-22
3351	19	M	Y	Only seen off N.C.	2022-01-13-AMAPPS Eg A	14-Jan-22
3530	18	M	Y	First seen off S.C., then GA.	2022-01-06-CMARI-SC Eg A	07-Jan-22
3890	14	F	Y		2021-12-02-CMARI-GA Eg B	02-Dec-21
3908	13	F	Y	Only seen off N.C.	2022-01-13-CMARI-NC Eg D	14-Jan-22
3912	13	F	Y		2022-01-30-FWRI Eg A	31-Jan-22
3946	13	F	Y		2021-12-02-CMARI-GA Eg D	02-Dec-21
4050	12	F	Y	First seen off S.C., then GA.	2022-01-06-CMARI-SC Eg C	07-Jan-22
4190	11	F	Y		2021-12-02-CMARI-GA Eg A	02-Dec-21
4220	10	M	Y	Only seen off N.C.	2021-12-28-CMARI-NC Eg B	29-Dec-21
4510	>7	F	Y	Only seen off N.C.	2021-12-27-CMARI-NC Eg B	28-Dec-21
4523	7	M	Y	Only seen off N.C.	2021-12-28-CMARI-NC Eg A	29-Dec-21
4545	7	F	Y	Only seen off N.C.	2022-01-13-AMAPPS Eg B	14-Jan-22
4617	6	F	Y	First seen off S.C., then GA.	2022-01-06-CMARI-SC Eg D	07-Jan-22
2021CalfOf3593*	1	U	N	Only seen off N.C.	2022-01-24-CMARI-NC Eg A	24-Jan-22
2021CalfOf3010	1	M	Y		2021-12-17-FWRI Eg A	18-Dec-21
2021CalfOf3020	1	U	Y	Only seen off N.C.	2022-01-13-CMARI-NC Eg A	14-Jan-22
2021CalfOf3232	1	U	Y		2022-02-21-HDR	22-Feb-22
2021CalfOf3860	1	U	Y	Only seen off S.C.	2022-01-25-CMARI-SC Eg A	25-Jan-22
2021CalfOf3904	1	M	Y		2022-02-09-FWRI Eg A	10-Feb-22
2021CalfOf4040	1	M	Y		2022-01-06-FWRI Eg G	07-Jan-22
S082	U	F	Y		2022-01-19-NEFSC Eg C	20-Jan-22

* ID tentative due to limited photo-identification data from 2021

Appendix II. List of 17 right whales biopsied off the southeastern U.S. from December 1, 2021 to March 31, 2022.

Whale	Biopsied as:	Date Confirmed
3560	2021-12-02-GDNR Eg A	02-Dec-21
2022 calf of 3560	2021-12-02-GDNR Eg B	02-Dec-21
2022 calf of 1245	2021-12-10-GDNR Eg B	10-Dec-21
2022 calf of 3430	2021-12-24-FWRI-V Eg B	27-Dec-21
2022 calf of 2614	2021-12-26-GDNR Eg B	27-Dec-21
2022 calf of 2360	2021-12-28-GDNR Eg B	30-Dec-21
2022 calf of 1620	2021-12-28-GDNR Eg D	30-Dec-21
S082	2022-01-19-NEFSC Eg C	20-Jan-22
2022 calf of 3220	2022-01-25-FWRI-V Eg B	25-Jan-22
2022 calf of 2040	2022-01-06-GDNR Eg D	07-Jan-22
2022 calf of 1817	2022-01-13-GDNR Eg B	14-Jan-22
1817	2022-01-15-GDNR Eg A	16-Jan-22
2022 calf of 2753	2022-01-30-GDNR Eg B	31-Jan-22
1301	2022-01-31-GDNR Eg A	01-Feb-22
2022 calf of 1301	2022-01-31-GDNR Eg B	01-Feb-22
2022 calf of 1515	2022-02-01-NEFSC Eg B	01-Feb-22
2022 calf of 3157	2022-02-10-NEFSC Eg B	11-Feb-22

Summary

17 biopsied whales
13 calves of the year
3 adults
1 juvenile

Task 5: Final Report on 2020 Right Whale Visual Health Assessment

Prepared by Heather M. Pettis
Anderson Cabot Center for Ocean Life
New England Aquarium
Central Wharf
Boston, MA 02110

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 (Good)	Thin, moderately concave back Profile (Fair)	Severely concave back profile, Emaciated (Poor)
Skin Condition	Dark skin, clean skin (Good)	Significant skin lesions, severe Sloughing (Poor)	N/A
Rake Marks	Zero to Few marks (Good)	Moderate marks (Fair)	Many marks, deep bright marks (Poor)
Cyamids around Blowholes	Zero to few cyamids (Good)	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 Catalog (also known as the Identification Database (described previously under Task 1 of this report)) since the previous update in 2021. 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 available health data (including all 2020 data, pre-2020 data that were added since the last funding period, and a limited number of 2021 batches) were analyzed and the VHA Database is considered complete through 2020.

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 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; 4) the proportion of right whales estimated to be alive (based on Pace et al. 2017 methodology) that were scored for skin and body condition were calculated by year to assess how well the living population is assessed for visual health annually; 5) the proportion of whales sighted annually that were scored for body and skin condition to assess trends in parameter assessment; and 6) 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.

In previous reports we used Presumed Alive calculations rather than estimates of living whales derived via the methodology described in Pace et al. 2017. Given the known overestimation of living whales that the Presumed Alive calculation returns and the accepted use of the Pace et al. (2017) methodology in annual population estimates, we moved to utilize the latter estimate here and going forward. These estimates of living whales were available for 1990 on and so all analyses incorporating this estimate included data for 1990 onward. All other analyses included data from 1980 onward.

Results

Update of Database
A total of 733 batches consisting of 31,412 images from 2,216 sightings of 339 individual right whales were evaluated and scored for visual health parameters for this update, including 28 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). Though there were several batches of 2021 sightings assessed, scored, and entered into the VHA Database, that year is not considered complete and so VHA data from 2021 are summarized in this report but are not included in annual comparison analyses.

Database Overview
The updated VHA Database contains 21,543 batches consisting of 78,704 sightings from 1935-2021. The number of batches and associated sightings available to be assessed has varied annually (Figure 1, sample period 1980-2020 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 41% 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 2020, in fact increasing by 13% over that in 2019. The relative percentage of aerial sightings in 2020 represents the highest proportion of aerial sightings (78.8%) in this study period. Though relatively insignificant in number, sightings of right whales from land and drone are represented in the database (total of 890 and 585 of 78,704 sightings, respectively).

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
2018	3	18	3
2019	39	219	25
2020	684	1933	304
2021	7	46	7
Total	**733**	**2216**	**339***

*The total number of right whales assessed during this update was 339, including repeat samples of 28 individual whales in multiple years.

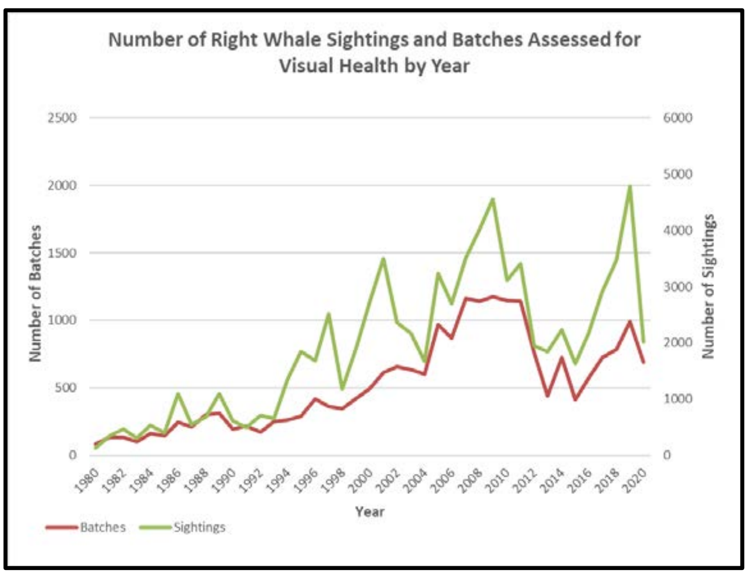


Figure 1. Count of North Atlantic right whale sightings and batches by year in the Visual Health Assessment Database 1980-2020.

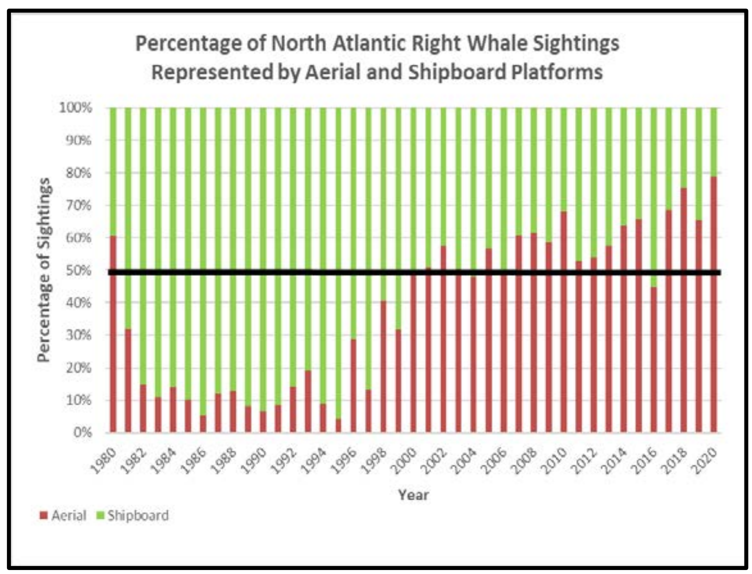


Figure 2. Percentage of North Atlantic right whale sightings scored for VHA represented by aerial and shipboard platforms between 1980- 2020. 50% line included in black. Land and drone-based sightings are excluded from this analysis as they represent a relatively insignificant number of annual sightings.

Body and Skin Condition
Batches for which at least one health parameter could be scored were parsed according to their composition, i.e. aerial sightings only (n =7897), shipboard sightings only (n =7041), or a combination of both aerial and shipboard sightings (n = 4412). Batches for which no health parameters could be scored were removed from this analysis because they are not reflective of differential scoring based on platform, rather, reflect overall image detail and quality.

While skin condition is generally assessable from both aerial and shipboard sightings, batch composition significantly impacts the ability to score body condition. For batches comprised of aerial sightings only, 98% were scored for skin condition compared to only 5.7% scored for body condition (Figure 3). The proportion of batches scored for body condition is substantially higher when the batch is comprised of shipboard sightings only or a mix of aerial and shipboard sightings (89.9% and 71.1%, respectively). The proportion of batches scored for skin condition remains high for shipboard only and mixed platform batches (89.7% and 97.5%, respectively).

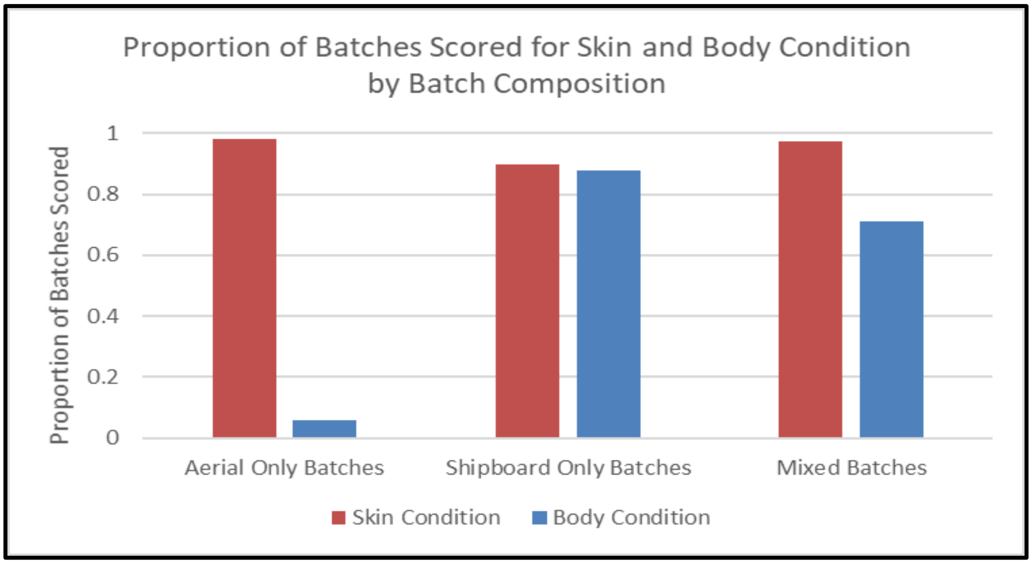


Figure 3. Proportion of right whale sighting batches scored for skin and body condition for each batch composition type, 1980-2020.

The annual proportion of right whale sighting batches that were assessable for skin and/or body condition varied by year and was consistently higher for skin condition (min/max% 62.7/95.5) than body condition (min/max% 29.9/82.4, Figure 4). While the proportion of batches scored for skin condition rose slightly in 2020, the proportion of batches scored for body condition fell to a new low of 29.9%.

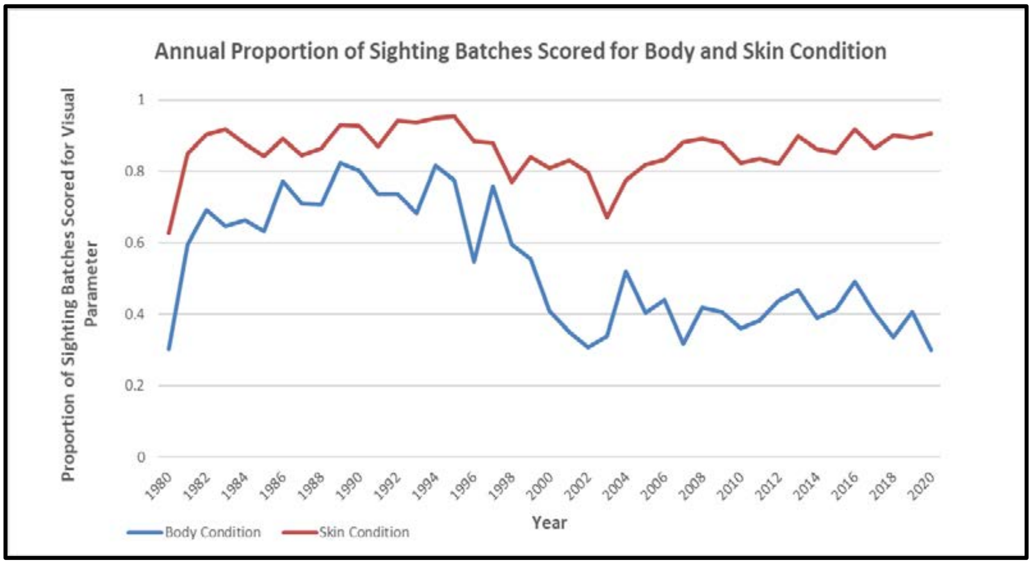


Figure 4. Annual proportion of right whale sighting batches that were scored for skin and body condition, 1980-2020.

The proportion of individual right whales estimated to be alive that were scored for skin or body condition at least once varied by year (Figure 5). Between 1990 and 2020, the annual proportion of estimated living right whales with at least one batch of scored skin condition was consistently higher (min/max% 45.9/93.3) than the proportion of estimated living whales with scored body condition (min/max% 27.4/748). The proportion of estimated living whales scored for body condition dropped below 50% in 2020.

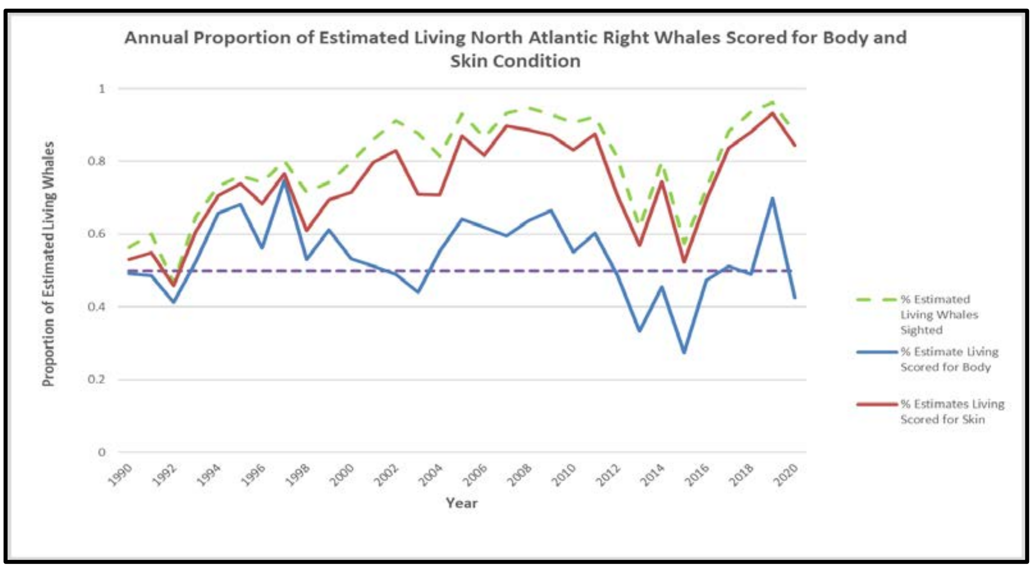


Figure 5. Annual proportion of estimated living right whales that were scored for skin and body condition by year, 1990-2020. Analyses including estimated living population encompass 1990 forward as that is the time frame of the available data. The proportion of estimated living whales sighted each year is included and the dashed purple line represents 50% estimated living population.

The proportion of whales sighted annually that were scored for body and skin condition also varied over time (Figure 6), with a higher proportion of sighted whales scored for skin condition than body condition. For the first time since 2015, fewer than 50% of sighted whales were scored for body condition in 2020.

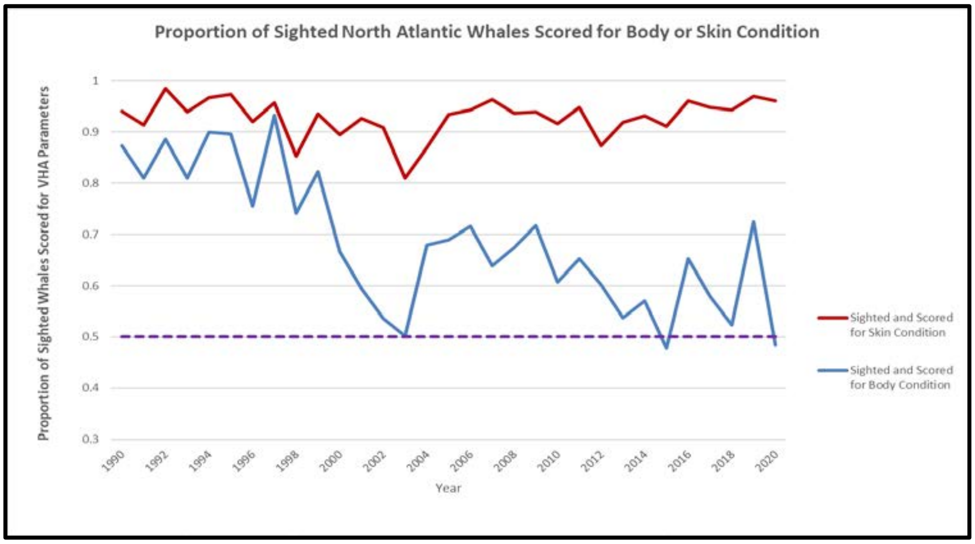


Figure 6. Annual proportion of sighted right whales that were scored for skin and body condition in one or more batches by year, 1990-2020. Analyses including estimated living population encompass 1990 forward as that is the time frame of the available data. The dashed purple line represents 50% sighted whales.

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 7). 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 declined in 2020 to 29.1% from 38.2% in 2019. The prevalence of compromised skin condition also declined slightly in 2020 (18.0%) compared to 18.9% in 2019.

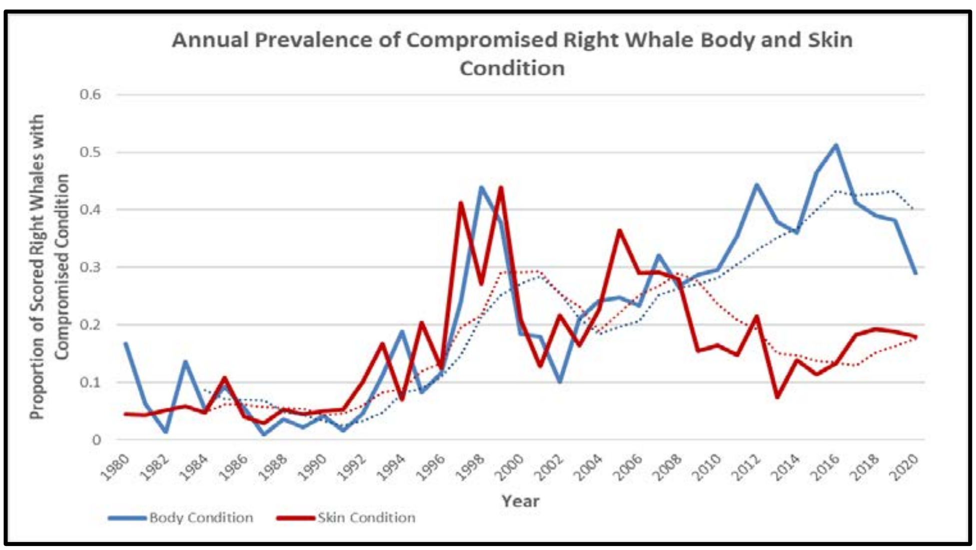


Figure 7. Annual proportion of right whales with compromised skin and body condition. Prevalence was defined as at least one sighting batch for an individual right whale scored as compromised for skin or body condition by year, 1980-2020. Reproductive females were excluded from the body condition analysis in each of their calving years. Stippled lines represent 5-year rolling average.

Discussion

Visual health data for 339 right whales across four 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 related to:

1. Conservation genomics of the endangered North Atlantic right whales
2. Vessel strike forensics
3. Estimating the population size of the North Atlantic right whale

Additionally, ongoing use of the VHA Database includes informing Bayesian model estimates of the population consequences of multiple stressors on right whales and an initial publication on that work has been submitted. Lastly, two recent publications utilizing the VHA database are available:

1. Knowlton, A.R., Clark, J.S., Hamilton, P.K., Kraus, S.D., Pettis, H.M., Rolland, R.M. and Schick, R.S., 2022. Fishing gear entanglement threatens recovery of critically endangered North Atlantic right whales. *Conservation Science and Practice*, *4*(8), p.e12736.

2. King, K., Joblon, M., McNally, K., Clayton, L., Pettis, H., Corkeron, P. and Nutter, F., 2021. Assessing North Atlantic Right Whale (*Eubalaena glacialis*) Welfare. *Journal of Zoological and Botanical Gardens*, *2*(4), pp.728-739.

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 2020. While this trend has been primarily related to an increase in aerial survey effort on the calving ground in the southeast United States and Great South Channel in the 2000s and more recently, distribution shifts into habitats primarily surveyed aerially (i.e. Cape Cod Bay, southern New England, and the Gulf of St. Lawrence), the further decline in shipboard sightings in 2020 is undoubtably related to impacts of the COVID-19 pandemic on survey efforts. The impact of predominantly aerially based sightings on our ability to asses body condition is clear; fewer than 50% of sighting batches have been scored for body condition since 2004. Further, the increase in the proportion of aerial sightings in 2020 to nearly 80% was accompanied by the lowest proportion of batches scored for body condition over the entire study period at less than 30%.

The shift in distribution after 2010 resulted not only in a change of the predominant sighting platform, but also in a decrease of the proportion of estimated living right whales assessed for visual health annually compared to the 2000s. These proportions rebounded following 2015, likely due to increased survey efforts (both aerial and shipboard) in the Gulf of St. Lawrence, but dropped again in 2020, particularly for body condition. The trend holds true for the proportion of sighted whales that are scored for skin and body condition; there was a decline in both, with a drop from over 70% to under 50% for body condition, from 2019 to 2020 coinciding with the reduction in overall sightings and the predominance of aerially based sightings in the latter year. Again, this marked decline is undoubtedly due to decreases in both total survey effort as well as shipboard effort due to the pandemic. 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 as well as those habitats for which irregularly sighted right whales are detected (e.g. southern New England).

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 assess 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, including planned comparisons during the 2023 field season.

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, whales 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. Adjusting the scoring protocols for these two parameters would create challenges for comparing scored data going forward with historical data. There are two potential solutions to this. First, we could re-score all historical data with the new scoring protocols. This would be incredibly time consuming and would require the re-examination of hundreds of thousands of archived slide and print images. Second, we could maintain the original skin and body condition parameter scoring fields and introduce a new field for each parameter with a data qualifier that would be tied to the old scoring criteria. For example, skin condition is currently scored as either a 1 (good condition) or 2 (poor condition). The new scoring criteria might be 2a (presence of lesions, moderate, not severe) and 2b (very poor condition, severe, widespread lesions). The “2” would link these new scores to the old scoring criteria, and the “a” and “b” would allow for more qualifying details to be captured. The same idea would be applied for body condition scoring. This latter option is much more realistic in terms of workload feasibility and would maintain comparative capabilities with historical data. Additionally, for the last several years of health assessment scoring, notes on whether batches would fit into a modified scoring system have been included in the database. These notes would allow us to examine these batches and add the new scoring qualifiers to some previously scored batches.

For much of the study period, the fluctuations in the prevalence of compromised skin and body condition for right whales were relatively synchronous (Figure 7). However, there was a marked divergence beginning in 2009 that remained through 2020, with a general 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). Although the annual prevalence of compromised body condition remains higher than skin condition, the prevalence in compromised body condition declined relatively sharply between 2019 and 2020 to pre-skin/body condition divergence levels. While reasons for this decline are likely complex, it is cause for cautious optimism that right whales are finding stable and adequate prey-resources in habitats in which we are able to assess body condition.

While the proportion of compromised skin condition rose over recent years, it has been relatively stable since 2017. One potential explanation for the initial rise in compromised skin condition and now the leveling out is the distribution shift to the Gulf of St. Lawrence. Anecdotally, whales utilizing this habitat appear to be prone to developing skin lesions midway through the season (July-September). This remains an observation worth pursuing in detail and would likely benefit from a refinement of the skin condition scoring as these lesions appear to be ephemeral and not severe. This refinement would allow us to distinguish between annual levels of these mild/moderate skin lesion cases and those that are more severe and are associated with other declining health parameters.

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: 1) it to be integrated with other databases, 2) population health to be examined by researchers and managers, 3) the impact(s) of injuries on health to be examined, and 4) 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 and scarring assessments) is effectively and efficiently collected.

References

North Atlantic Right Whale Consortium Data Access Protocol. March 2021. https://www.narwc.org/uploads/1/1/6/6/116623219/consortium_database_access-revisedmar2021.pdf

Pace III, R.M., Corkeron, P.J. and Kraus, S.D., 2017. State–space mark–recapture estimates reveal a recent decline in abundance of North Atlantic right whales. *Ecology and Evolution*, *7*(21), pp.8730-8741.

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

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

Rolland, R.M., Hamilton, P.K., Marx, M.K., Pettis, H.M., Angell, C.M., Moore, M.J. 2007. External perspectives on right whale health. Pages 273-309 in: Kraus, SD and Rolland, RM (eds.). *The Urban Whale: North Atlantic Right Whales at the Crossroads*. Harvard University Press, Cambridge, Massachusetts.

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

Schick R.S., Kraus S.D., Rolland R.M., Knowlton A.R., Hamilton P.K., Pettis H.M., Kenney R.D., and Clark J.S. 2013. Using Hierarchical Bayes to Understand Movement, Health, and Survival in the Endangered North Atlantic Right Whale. PloS ONE 8:e64166.

Waring G.T., Josephson E., Maze-Foley K., and Rosel, P.E. (eds) 2015. US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments - 2014. NOAA Tech Memo NMFS NE 231; 361 p. doi: 10.7289/V5TQ5ZH0.

Task 7: Final Report on the Migration of WhaleMap Infrastructure and Data Curation

Prepared by Heather M. Pettis
Anderson Cabot Center for Ocean Life
New England Aquarium
Central Wharf
Boston, MA 02110

Introduction

The software system WhaleMap is a tool that provides an efficient and effective means of collating and displaying whale survey results from the entire east coast of the US and Canada in near real-time (within ~1 day). WhaleMap has improved conservation outcomes for baleen whales, especially the endangered North Atlantic right whale, and it serves as a critical outreach and engagement tool by making the latest whale survey results available to a diverse group of stakeholders including those from industry, research, government, nongovernmental organizations, and the general public. WhaleMap's utility is dependent upon stable, long term curation and the goal of this task is to develop the infrastructure to maintain WhaleMap in perpetuity.

Activities under this task included:

1. Overseeing the migration of WhaleMap from Dalhousie University to the New England Aquarium (NEAq)
2. Training researchers at NEAq to facilitate data transfer from survey teams and serve as curators for the mapping system.
3. Coordination with the North Atlantic Right Whale Consortium (NARWC) to develop an integration plan for WhaleMap into the existing NARWC data sharing framework.

Transfer of WhaleMap to the New England Aquarium

New England Aquarium staff facilitated coordination efforts between NEAq and Dalhousie IT staff to develop a pathway forward for the migration of WhaleMap from Dalhousie University to the New England Aquarium. NEAq completed the migration on May 23, 2022 and WhaleMap is now cloud hosted (AZURE), accessed via https://www.whalemap.org, and accessible to WhaleMap data curators at multiple organizations.

Training Data Curators and Coordinators

In December 2021, the NEAq researcher who will be overseeing WhaleMap data curation met with the current curator for a general introduction to WhaleMap as well as an overview and installation of the programming needs to curate and run the software. Also in December 2021, the NEAq curator attended a two-day workshop demonstrating the application of open source coding and its utility in conservation efforts, with an emphasis on WhaleMap.

A two-day workshop was held on April 11th and April 13th, 2022 with researchers at multiple organizations who have been identified to onboard as WhaleMap data curators and contributors. Researchers from both US and Canadian organizations were represented. The agenda for the workshop was as follows:

Session 1: Coordination

April 11th, 2022

- Introduction
    - How WhaleMap works
    - Exchange of near real-time data in US/Canada
    - Future of WhaleMap
- Coordination
    - Requests
    - NARWC data
    - Conventions

- Issue tracking/feature requests
- Basic Troubleshooting
- Discussion

Session 2: Curation

April 13th, 2022

- Introduction
- Code tour
- Email notifications
- Common tasks
  - Accessing the system
  - Restarting the shiny app
  - Fixing processing errors
  - Adding new data streams
  - Extracting data
- Discussion

Post meeting notes were distributed to participants and a second workshop for data curators (i.e. those who will be responsible for overseeing data feeds and backend coding) is planned for December 8th, 2022.

Integrating WhaleMap with North Atlantic Right Whale Consortium Data Access Protocols

Over the funded performance period, multiple meetings were held with primary WhaleMap coordinators to discuss options for incorporating WhaleMap as a North Atlantic Right Whale Consortium (NARWC) accessible database. Additionally, a survey was distributed to both NARWC data contributors and users for input on data access protocols. The survey sought to understand which organizations contribute to and use WhaleMap and importantly, if/how contributors would like to see these real time data made available through a modified NARWC data access protocol. Following the survey, a meeting was convened in June 2022 for major NARWC data contributors to discuss current and proposed changes to NARWC data access protocols, including a strategy for incorporating WhaleMap into the NARWC data access stream. The general consensus coming out of that meeting was that real time sightings will be accessible primarily for management action purposes and we are currently working with organizations to determine what level of engagement they want in reviewing such requests for real time data (i.e. blanket permission or case by case review). The NARWC data access request protocols and framework are currently under review and revision and the finalized WhaleMap protocols will be included in the final products from this review.

Other

In May 2022, Fisheries and Oceans Canada (DFO) released Whale Insight (https://gisp.dfo-mpo.gc.ca/apps/WhaleInsight/eng/). This platform, modeled after WhaleMap, displays NARW detections (visual and acoustic) in eastern Canadian Waters. While the two platforms (WhaleMap and Whale Insight) are separate platforms, they do share and exchange several incoming data streams. Given the cross functionality between the two platforms, we have met periodically over the last year with curators of Whale Insight to discuss data streams, cross platform integration, data access, and display protocols for data originating from existing agreements between WhaleMap and the NARWC. We anticipate the need for such meetings will continue as both platforms evolve to ensure that any required cross functionality is maintained.

Summary

The persistent, long term support of WhaleMap offers a wide range of conservation benefits to marine mammals, including the North Atlantic right whale, that are consistent with the goals of the Marine Mammal

Protection Act and other related mandates. Incorporating WhaleMap as a NARWC data product will encourage seamless interaction between NARWC data products, and, most importantly, community oversight of WhaleMap data access requests and/or future modifications. It also offers a common source of near real-time baleen whale data for the east coast of the US and Canada. This facilitates dynamic management efforts including vessel speed restriction and re-routing as well as fisheries closures and/or gear restrictions. Lastly, WhaleMap directly benefits research activities in several ways including the planning of more efficient monitoring and research efforts.