Maintenance of the North Atlantic Right Whale Catalog, Whale Scarring and Visual Health Databases, Anthropogenic Injury Case Studies, and Near Real-Time Matching for Biopsy Efforts, Entangled, Injured, Sick, or Dead Right Whales

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Contents

Executive Summary

This report combines several North Atlantic Right Whale Catalog related tasks into one comprehensive report. We had a No Cost Extension (NCE) for this report through the end of February. For this reason, the data used were exported in February 2024 instead of September 2023 and the total amount of data processed nearly doubled. However, for consistency and to stay on track for subsequent reports, data reported on in each task covers similar time periods as previous reports rather than reporting on all data processed. Catalog maintenance (Task 1) reports primarily on Catalog data through 2022 using data as of February 2, 2024. The entanglement scar coding (Task 2) reports on data for 2021 and compares 2021 findings to previous years which have been updated with newly added data prior to 2021. Anthropogenic case study reports (Task 3) describe cases first documented in 2021. The near-real-time matching (Task 4) reports on matching efforts from September 1, 2022 to August 31, 2023. Finally, the visual health coding (Task 5) reports on data through 2021, with some newly added data prior to 2021 included. Combined, these tasks provide an excellent example of the amount of research that can be leveraged by maintaining a time series of images and data on identified individuals.

One factor that affects our ability to perform each of these tasks is the impact the changes in right whale distribution have had on the type of surveys conducted. While the research community has adapted 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 collecting genetic samples and assessing 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 for monitoring the effects of recently enacted and 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 a combination of genetics and more recent photographs. Using genetics collected from young calves, Hamilton et al. (2022) discovered that four calves that were thought to have died had actually survived- two of those apparently weaned by 7.7 to 8.0 months, earlier than typically documented. 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. In 2023, there were three interesting genetic results that are detailed in a new section in the report under Catalog Overview: the identification of a dead whale from 2011, the identification of a calf from 2009, and a young whale’s genetics which suggest that a calving event was missed in the 2010’s.

Finally, the large number of video sightings submitted to the Catalog continue to be cumbersome. Video sightings take 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 adds an additional time-consuming step to data processing. We are currently working with a programmer to develop software tools to improve video management. This work sets the stage for 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.

Between the last catalog report and the end of 2022, there have been 8,129 sightings added to the Catalog, 5,163 identifications confirmed (both more than double what was accomplished in the previous report due to the NCE), and 18 new whales added. There were 18 composites drawn for the new whales and 45 previous composites updated. There were no identified dead whales, 21 that became presumed dead (i.e. not seen in six years), and none that were 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. As of the export of the data for this report on February 2, 2024, there were 799 cataloged whales, 429 of which were presumed to be alive. Because the number presumed alive using the Presumed Dead classification assessment (429) is not consistent with the most reliable population estimate for 2022 of 356 (-10/+7) provided by Linden (2023), we also provide the breakdown of the age and sex just for whales seen alive in 2021 or 2022 (n=355).

With the change in right whale distribution, there have been increasing numbers of sightings reported from opportunistic sources. In 2022, there were 82 different observers (almost double from 2021) and 63% of those were opportunistic sources (i.e. not organizations trained to handle data). 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 since the last report. We updated our detailed, 96-page Photographic Data Submission protocol which contains sections on how to collect photo-ID data, how to submit different types of data, and detailed descriptions of the behaviors and standardized comments used in the database. We added new standardized codes for the different types of satellite and radio tags and then reviewed all previous tagging events to code for type. At that time, we added any other pertinent information such as the duration of tag transmissions, duration of tag implantation, and information on whether a physiological response at the tag site was observed. Finally, we added tables to the database to better integrate information on anthropogenic injuries including tables to store necropsy reports and the anthropogenic injury case studies that are found in this and previous reports, as well as a table to track whether an injury event was classified as morbidity, serious injury, or mortality according to the Unusual Mortality Event (UME) database.

Scarring data for 2021 indicate a third year of moderation 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 13.0% and an annual entanglement rate (proportion of adequately photographed whales with new scars) of 24.5%. Both of these rates are below the average crude entanglement rate of 15.5% and the 25% annual entanglement rate documented by Knowlton et al. (2012) for 1980-2009. The crude entanglement rate has steadily dropped each year from its recent peak of 24.4% in 2016 and the annual entanglement rate has been more variable but has dropped from the recent peak of 39.1% seen in 2013/2014. The proportion of the cataloged population with one or more entanglements remains high at 85.7%, a decline of 0.7% from 2020. In 2021, there were 45 entanglement events – four severe (including three with attached gear), seven moderate, and 34 minor. There was a decline in the proportion of moderate and severe injuries (25%) from a recent peak of 37% in 2016, and a slight increase in the juvenile population to 17%, up from 14% in 2020. At 1.2% of all sightings, the four serious entanglements represent the lowest level in the past 12 years and is at the average level described from 1980-2009.

Anthropogenic case studies were developed for three new vessel strike cases and three new entanglements with gear cases documented in 2021. 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 and the entanglement cases have a drawing showing where the gear is located on the body.

Under the near-real-time matching task, we were able to support the teams on the calving ground with an 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 eight yearlings. We provided new support to survey efforts in the mid-Atlantic region. We continued our near-real-time identification support for two research efforts in Cape Cod Bay and two in the Gulf of St. Lawrence – including a new tagging effort. 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, two whales with additional entanglements, two dead whales, and six with new injuries.

Finally, visual health coding for 4,176 sightings of 359 right whales was completed since the last report, bringing the Visual Health Assessment Database up to date through 2021. 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, continue to impact our ability to effectively monitor the visual health of this species, particularly for body condition. While the proportion of batches scored for body condition has remained under 50% since 2004, the proportion rose in 2021 following what was likely a COVID-19 pandemic related low in 2020. The proportion of estimated living whales scored for health, both skin and body condition, also rose markedly in 2021 as compared to 2020. The proportion of sighted right whales scored for skin condition annually remained high and, following what was observed for presumed living whales, the proportion of sighted right whales that were scored for body condition also rose markedly in 2021 as compared to 2020. Lastly, the proportion of whales with compromised body condition, while still high relative to that of skin, declined for the fifth year from a peak of 51.8% in 2016 to 22.0% in 2021. This updated information on visual 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. Current efforts 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.

Task 1: Maintenance of the North Atlantic Right Whale Catalog: 01 January - 31 December 2022

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I. Introduction

The New England Aquarium's (NEAq) right whale research team is responsible for curating the right whale identification database, herein referred to as the "Catalog". As curators, we receive photographs and video 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 2022 time period and all data reported on utilize a version of the database exported on February 2, 2024. The data exported for this report can be found at this FTP link: https://personal.filesanywhere.com/fs/v.aspx?v=8e6f63895b6473ae9da6.

This part of the report – Task 1 - 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 2022)

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 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 genetically will be re-entered as a sighting. In January 2014, records of satellite tagged whale locations (e.g. from 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 February 2, 2024, there were a total of 93,875 records from 1935 through 2022: 874 satellite tagged location sightings, and 56 sightings with either genetics and no photographs (n=5) or where there were some photographs, but the identification was made primarily through genetics (n=51). The remaining 92,945 sightings have been, or will be, identified primarily through the photographs or video (even if genetic data were also available).

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 which are captured external to DIGITS before being imported. These sightings require more time to process as we need to first capture the images and then review and delete excess images within DIGITS. While time consuming, this is an important step as it improves the efficiency of our matching and subsequent analyses.

Every year, there are some problems with timely data submission. Tracking down data and images not submitted in a timely fashion is extremely time consuming, and we can only track down data if we know it exists. One specific example recently is the data for entangled whale #4423 from 2019. 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.

In general, data submission issues in the past primarily involved 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 may be 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 undertaken this comparison. We also rarely receive the location data and images from dead whale events and will be working to improve communication and information exchange during mortality events. 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, i.e. confirming all a given year's sightings, 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 2003 to 2022 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 its 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 to catalog that whale. This delay in cataloging calves impacts our annual matching success and affects the annual count of total individuals seen.

We have completed 98% of the matching for the calendar year 2021 data and 37% for 2022 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 2022, so although the percentage of sightings matched and confirmed for the 2022 right whale year is modest, 320 unique individuals have been identified so far. This number may increase as more data are processed and as calves are re-sighted as juveniles with adequate photo-identification information to be cataloged. The details of the 2022 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 to accommodate new data types and to respond to emerging data questions. We added a behavior to denote that photogrammetry data were collected to allow researchers to request measurement data from those data collectors for specific projects. We also added tag type for satellite tagging events: Type A tags- anchored (with electronics external, i.e. limpet tags) and Type C tags - designed for the electronics to be subcutaneous with only the antenna protruding. A retrospective review of all tagging data was initiated to enter these tag types at the first sighting where the tag was deployed or documented for each tagging event (noted as “FRST SATTG”). In addition, several pieces of information were added to the sighting notes at that sighting: details of the duration of tag transmissions, duration of tag implantation, and information on whether a physiological response at the tag site was observed. This review required some clarification from data holders and a review of reports from tagging efforts to ensure pertinent information was included in the notes for each event. It also highlighted how messy data collection can be during tagging events- sometimes with no photographs of the whale being tagged, or of that whale with the tag imbedded post tagging. These data collection issues can introduce uncertainty in the subsequent analyses.

The anthropogenic data web interface that was developed with external funds and described in detail in the report from two years ago has proven extremely useful. Briefly, the Right Whale Injury and Monitoring Portal is used to view anthropogenic events of entanglements or vessel strikes entered in DIGITS and input additional data to those existing cases. It is also utilized to enter anthropogenic monitoring cases near real-time before data are fully analyzed. Eventually, we will have all data relating to anthropogenic injuries available in this one place. Since the last catalog report, we added several tables to the catalog database to advance this vision. We added a table to track whether an injury event was classified as morbidity, serious injury, or mortality according to the Unusual Mortality Event (UME) database. This makes it much easier to query the individuals and their life history events from the UME. We added tables to store and search for necropsy reports and anthropogenic injury case studies (which are currently found only in these reports and, for entanglement with gear cases, online at the Consortium for Wildlife Bycatch Reduction. With support from NMFS under a separate contract, we are in the process of developing an external website that will utilize these new data fields and provide graphical data outputs for the public and additional query options to approved users with passwords.

Since the last Catalog report, we executed 15 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.

Relevant Genetic Results

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. In 2023, there were three noteworthy genetic results:

1) In 2023, a cold case from 2011 mortality was finally solved. The dead whale involved in this case, SC1118, was discovered March 16th, 2011 on Cape Island in Cape Romain

Wildlife Refuge in Charleston County, South Carolina. It was initially thought to be a humpback whale because it was so decomposed that there were multiple folds in the carcass which were interpreted as ventral pleats. Once it was correctly identified as a right whale, the carcass was suspected to be #3993, a right whale that had last been seen with a similar entanglement configuration and in poor condition 125 miles south of the carcass on February 13th, 2011. A very degraded tissue sample was sent to Tim Frasier at Trent University (now at St. Mary's University), but his team could not extract good DNA from the sample and what they could extract did not match #3993's genetics. In 2020, the Smithsonian Institution drilled a bone from the dead whale that they had in their collection (Smithsonian Catalog #: USNM593566) and the bone powder was exported to St. Mary's. Using special methods, the team at St. Mary's was able to determine genetic sex, haplotype, and a genotype at five microsatellites- all of which were consistent with #3993. Mr. Hamilton promptly communicated with Ms. Allison Henry at NMFS to confirm that SC1118 was the same case as #3993 and not another, distinct right whale entanglement. This case underscores the importance of getting bone samples from dead whales for genetics.

2) A calf from 2009 was genetically linked to post-calf sightings of that whale through genetics. Whale #4095, previously known by its intermatch code of BK02GSC10 and first observed in 2010, had been cataloged as an unknown age whale in January 2017. In 2023, it was genetically matched to the 2009 calf of 1310 based on sex and all 22 loci for which both whales were scored. The mother calf pair had last been seen together in early March of 2009 off the Florida coast. This was well before the calf's callosity pattern had developed enough for subsequent photographic re-identifications.

3) Finally, the genetic analysis of #4810 (previously known by a season code of S080) was interesting. This whale, first seen as an apparently young whale in 2018, does not genetically match any sampled calves. That alone is not unusual as not all documented calves are genetically sampled. However, when this whale's mitochondrial haplotype (B) and genotype are compared to the haplotype and genotype of all known mothers whose calves were never identified or sampled from 2000 to 2017, all such mothers can be ruled out. This suggests that this calf and her mother went completely undetected in the calf's year of birth. Given the extensive coverage on the calving and feeding grounds, we think the likelihood of missing a calving event in a year is relatively small, but clearly not impossible. A paper by Nathan Crum entitled "Effects of Fishing Gear Entanglement on the Health, Survival, and Reproductive Dynamics of North Atlantic Right Whales" that is in review currently, provides an estimate of how often such missed calving events occur. #4810 already has a unique sighting history- seen on just one day in 2018 off the coast of Georgia, and not seen again for four years after which she was seen just twice- once about 100 miles east of Montauk, NY and then two and half months later about 55 miles east of Cape Cod, MA. It appears that wherever her elusive mother took her when she was a calf, #4810 may also use those less frequently surveyed areas.

These three cases alone underscore the importance of the genetic/photo-identification comparison at tracking lineages, age, and mortality.

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- 2022 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, 2022)

a. Summary of sightings

(n= 92,945)

Assessment Complete (94%)		Assessment Incomplete (6%)	
Matched: Confirmed	84,105	Matched: Unconfirmed	702
Not Matchable	3,395	Intermatched	639
		Not Yet Matched	4,104

Since the last catalog report, there have been 8,129 sightings added to the Catalog and 5,163 identifications confirmed.

b. Summary of cataloged whales

(n=799)

Beginning with the March, 2024 report, we've added a table below the Presumed Living table which provides the age and sex of all whales last seen alive in the last two years (i.e for this report, 2021 or 2022). The number from this analysis (n=355) is very close to the modeled population number calculated by Linden (2023) for 2022 (n=356 +7/-10). Although the Presumed Living analysis (which extends the period of last sighting back 6 years) is less accurate, we keep it here to allow for consistent comparisons with past reports.

All Whales

	Male	Female	Unknown	**Total**
Gender	388 (48.6%)	334 (41.8%)	77 (9.6%)	799

Presumed Living in 2022

	Male	Female	Unknown	**Total**
Gender	243 (56.6%)	164 (38.2%)	22 (5.1%)	429
	Adult	Juvenile	Unknown	**Total**
Age Class in 2022	363 (84.6%)	62 (14.5%)	4 (0.9%)	429

Seen Alive in 2021 or 2022

	Male	Female	Unknown	**Total**
Gender	199 (56.1%)	140 (39.4%)	16 (4.5%)	355
	Adult	Juvenile	Unknown	**Total**
Age Class in 2022	296 (83.4%)	56 (15.8%)	3 (0.8%)	355

Known Dead

	Male	Female	Unknown	**Total**
Gender	32 (42.7%)	43 (57.3%)	0	75
	Adult	Juvenile	Unknown	**Total**
Age Class at Death	45 (60.0%)	27 (36.0%)	3 (4.0%)	75

Presumed Dead through 2022

		Male	Female	Unknown
Gender	113 (38.3%)	127 (43.1%)	55 (18.6%)	**Total**
				295
	Adult	Juvenile	Unknown	
Age Class Last Seen	170 (57.6%)	88 (29.9%)	37 (12.5%)	**Total**

Catalog data- 2022 only (this is for the "right whale year", which includes data from December 1, 2021 through November 30, 2022)

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 2022 data have been fully processed, so the numbers below will change in the future.

a. Summary of sightings- 2022

(n= 3,558)

Assessment Complete (39.0%)		Assessment Incomplete (61.0%)	
Matched: Confirmed	1,366	Matched: Unconfirmed	675
Not Matchable	23	Intermatched	384
		Not Yet Matched	2,169

b. Distribution of sightings

High Use Right Whale Areas

CCB	FL/GA	GSC	GSL	MB	SNE
1,356	436	213	928	297	140

Other SEUS and Mid-Atlantic Areas

MD	NC	NJ	NY	SC	VA
1	32	2	1	26	3

Other Northeast Areas

	BOF	GB	GOM	JL
	8	60	19	31
Other Areas North and East				
	EAST	NRTH		
	1	4		

c. Summary of identified whales

With 39.0% of all 2022 sightings for the right whale year matched and confirmed, 320 individual right whales have been identified (note: the 39.0% matched reported here differs from the 37.2% matched reported in Appendix I because the latter is for the 2022 *calendar* year). The numbers in section d below are low for some areas as the data have not been fully processed. Also, section d includes some of the same individuals between areas. None of the 2022 calves are included in the counts of 320 as none have been cataloged; they are only provisionally identified by their association with their mothers. A total of 17 other 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 17 are tentatively matched to calves from various years.

Age and sex for cataloged individuals seen in right whale year

	Male	Female	Unknown	**Total**
Gender	185 (57.8%)	123 (38.4%)	12 (3.8%)	320
	Adult	Juvenile	Unknown	**Total**
Age Class in 2022	265 (82.8%)	52 (16.3%)	3 (0.9%)	320

d. Distribution of identified whales

High Use Right Whale Areas						
	CCB	FL/GA	GSC	GSL	MB	SNE
	226	21	88	58	95	49
Other SEUS and Mid-Atlantic Areas						
	NC	NJ	SC	VA		
	9	1	9	1		
Other Northeast Areas						
	BOF	GB	GOM	JL		
	3	16	7	10		
Other Areas North and East						
	NRTH					
	1					

Summary of deaths, resurrections, and new whales cataloged in 2022
(Details provided in Sections V, VI, and VII)

a.) Whales Presumed Dead	21
b.) Whales Resurrected	0
c.) Whales Added to Catalog	
i. In 2022 (Sep-Dec)	0
ii. In 2023 (Jan-Dec)	18
iii.In 2024 (Jan)	0
d.) Confirmed Deaths	
i. Cataloged whales	0
ii. Carcasses not ID'd to Catalog	0

III. Computerized Database Status

Sighting effort data
All of the NEAq survey data from December 1, 2021 to November 30, 2022 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 August 2, 2023. Dr. Kenney returned the data with questions or issues on August 31, 2023. Mr. Hamilton reviewed the 58 potential errors that needed to be investigated: all were investigated, the solution noted for those that could be resolved, and the record corrected, where necessary, in the live Catalog database. Fifty-one of the issues were related to two days in which the data submitted to the Catalog were incorrect.

Mr. Hamilton uploaded the updated fields from the sightings database into the Catalog on November 17, 2023.

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 over 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 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. We recently developed a composite template that has a black whale (instead of a white whale outlined in black) and now draw 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 18 new composites were created and 45 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 are also continuing to periodically 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. This work is conducted every couple of years.

Maintaining DIGITS requires support from external companies and requires resources for that support. All the servers and backups are managed by CTO Plus of Arlington, MA. That server is backed up to another server in the Boston area, but it is also backed up on a Datto device in in the Cloud. As for the DIGITS software itself, the basic maintenance is provided as a donation from Parallax Consulting, LLC. This basic maintenance includes small adjustments to the software interface and the underlying tables as needed.

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 over $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 this high cost and, if not renewed, the product will cease to function. This renewal cost 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 still a couple of years away.

Database structure

The database is housed in 104 tables and 14 views stored in 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 provide the results from more routine but complicated queries. We added several tables this past year which are described under the Catalog Overview above.

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 and new whales added as soon as they are cataloged). 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 with 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.

Additional web resources for the Catalog can be found on the New England Aquarium's website (https://www.neaq.org/conservation-and-research/anderson-cabot-center-for-ocean-life/identifying-right-whales/). 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 2023.

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 primary images of all cataloged whales and some intermatch whales. 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.
The E Catalog is updated at least 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. The last export was September 25, 2023.

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 18 new whales added to the Catalog: none in September through December of 2022, 18 in 2023, and none in January 2024. All of them were calves from past years born in: 2019 (n=1), 2020 (n=2), and 2021 (15).

A listing of these new whales along with their sex, birth year, and identifications of their mother and father if known (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. These 18 new whales exhibited some interesting and unusual temporal patterns when still with their mothers. There was an unusually large number of sightings of mothers with their calves in November- a time when weaning may take place but when there are generally few sightings. In the Gulf of St. Lawernce, whales #5104, #5140, and #5023 were last seen with their mothers November 5th, 10th, 12th respectively. In the George's Bank/Southern New England area, whales #4990, #5143, #5190 were last seen with their mothers November 19th, 20th, and 20th respectively. There were also some unusually early arrivals on the feeding grounds in this cohort. Whales # 5120 and #5195 had traveled to the feeding ground with their mothers by March 7, 2021 making it to New York and southern New England respectively by that time.

Individuals added in 2023

Catalog No.	Sex	Birth Year	Mother
4990	Male	2019	3370
5015	Male	2020	3115
5023	Male	2020	2223
5104	Male	2021	3904
5110	Male	2021	3010
5113	Male	2021	2413
5120*	Female	2021	3720
5132*	Male	2021	3232
5140*	Male	2021	4040
5142	Female	2021	3942
5143	Male	2021	1243
5145*	Male	2021	1145
5160	Female	2021	3860
5190	Female	2021	2430
5191	Male	2021	3020
5192*	Male	2021	3520
5194	Female	2021	2460
5195	Female	2021	2420

"*" indicates a narrative is provided below

#5120 (1 y.o. female) - This whale was first seen with her mother Squilla, #3720, on January 19, 2021 off the coast of Georgia. She was entangled when she was a year and a half old and was found dead in January 2024. A narrative of her life is provided in the Entanglement section of this report.

#5132 (1 y.o. male) - This whale was first seen with his mother Lobster, #3232, on May 20, 2021 in the Bay of Fundy by a ferry passenger. Lobster is not seen frequently and she and her previous calf in 2015 were only seen on one day by an observer on a dredge off the coast of Georgia. Unlike with her 2015 calf, she and #5132 were seen multiple times in June, July, and August in the Gulf of St, Lawrence where a biopsy sample was collected from the calf.

#5140 (1 y.o. male) - This whale was first seen with his mother Chiminea, #4040, on December 4, 2020 off the coast of Georgia. The pair were seen 73 times off the southeastern U.S. from that date through March 9th. They also had one of the longest sighting spans together later in the year in the Gulf of St. Lawrence where they arrived early on May 15 and were last seen there on November 10- a remarkable half year residency.

#5145 (1 y.o. male) - This whale was first seen with his mother Grand Teton, #1145, on January 11, 2021 off the coast of Florida. The pair were seen in the region through early February and then in Cape Cod Bay in April where they were last sighted together. This whale is interesting because his mother disappeared from the sighting record for nine years from 2010 to 2019- clearly feeding in habitats that are either under surveyed or not surveyed at all. It will be interesting to see how #5145's sighting history unfolds. He was seen multiples times in and around Cape Cod Bay in 2022.

#5192 (1 y.o. male) - This whale was first seen with his mother Millipede, #3520, on December 6, 2020 off the coast of Florida. They were seen again the next day and then traveled all the way to South Carolina where they were seen on December 22 before returning south to Georgia by January 19. To our knowledge, it is somewhat unusual for a mother and calf to travel so far north and return south in the same season.

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 nascent callosities, bellies or mandibles *or* if: genetic material was obtained from them when they were calves associated with their mothers and 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. Excluding the 28 calves from 2020 onward that remain in limbo (out of 43 total), 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, or deemed to have photographs of insufficient quality to ever confidently re-identify and thus would never be added to the Catalog.

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 2022, there have been a total of 49 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 15% of the 326 presumed deaths during that time period. Many of the older resurrections occurred when gaps in sighting effort in the 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. There were only four resurrections between 2005 and 2015. But in the seven years since, there have been double that number at eight resurrections, which may be, in part, because whales shifted their habitats beginning in 2010 and it took time for survey efforts to relocate these whales during this shift. Presumed deaths have been consistently high since 2015 (122 presumed deaths from 2016 to 2022, compared to 48 for the previous seven 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 six years after it was last sighted, it does not mean that the whale actually died in that sixth 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. We continue to supply information on the presumed dead category for consistency and to allow for comparison to past reports. However, the most accurate assessment of whales alive in 2022 comes from Lindens' model (2023) which estimated 356 whales (-10/+7). Because this model allows for uncataloged whales to move in and out of the population, it is difficult to link the model numbers exactly to individual whales in the catalog. As the number of whales seen alive in the last two years (2021 and 2022, n=355) nearly matches the population estimate, it serves as a close approximation of the model results. For this reason, we provide demographic information on those whales in the Catalog Overview section. That analysis does not allow for a determination of when the whale died, so we provide information on the presumed dead whales below.

In 2022, 21 animals were classified as presumed dead (13 males, 7 females (all but one of them calving females), and 1 unknown sex) and no whales were 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). A table of the presumed dead whales is provided below including 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 first year sighted as well as their calving history (whale assumed to be at least five years old if their first sighting was with a calf). A narrative description is only provided for calving females or whales whose sighting history is sparse, thus suggesting the presumed dead categorization may be suspect. In addition, whales that were entangled at their last sighting are noted with an asterisks (n=5). 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 2022 (last sighted in 2016)

Catalog No.	Name	Sex	First Sighted	Birth Year	Age in 2016	Mother	Father	First Calving Year
1033		M	1978		A			
1152*	NECKLACE	M	1981		A			
1233		F	1974		A			1989
1239		M	1981	1981	35	1175		
1240	BALDY	F	1974		A			1974
1280	LUNA	X	1982		A			
1306*	VELCRO	M	1983		A			
1327	SCOOP	M	1956		A			
1408	COLUMBINE	F	1984	1984	32	1118	1327	1996
1604		F	1986		A			1993
1609	CRATER	M	1986	1986	30	1007		
1712		M	1987	1987	29	1619		
2608*		M	1996	1996	20	1408	1056	
3229		M	2002	2002	14	1629		
3323		M	2003	2003	13	2123	1306	
3405*	FUSE	F	2003	2004	12	1705		2016
3440	CYPRESS	F	2002	2002	14	1622	1019	2009
3620	LONE STAR	M	2005	2006	10	2503	1218	
3791	TRUFFULA	M	2007	2007	9	3360	1332	
4057*	FDR	M	2010	2010	6	3157		
4332		F	2013	2013	3	1632		

* Indicates the whale was last seen entangled

#1233 (42+ y.o. female) - This whale was first seen south of Nantucket, MA in August 1974. She was mostly seen in the years when she had calves and only seen north of Cape Cod a handful of times in the Bay of Fundy, Roseway Basin, and just once in the Gulf of St. Lawrence in 2014. She had six calves between 1989 and 2016. She was often seen in consecutive years, but also had a five-year gap from 1993 to 1997 during her 42-year sighting history. Her last sighting was in May 2016 in Great South Channel; there was some grey skin around the blowholes, but otherwise no outward indications of ill health at the time. There is a genetic sample on file for this whale.

#1240 (47+ y.o. female) - This whale, named Baldy, was first seen in April 1974 near shore south of Martha's Vineyard, MA with a young calf. She was seen regularly over her 42-year sighting span with her longest gap in sightings never longer than two years. She had nine calves between 1974 and 2014. She was seen in the Bay of Fundy frequently and was never seen in the Gulf of St. Lawrence. Her last sighting was in March of 2016 in Cape Cod Bay; there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#1408 (32 y.o. female) - This whale, named Columbine, was first seen in March 1984 off North Carolina as a calf with her mother Zipper, #1118. She was sighted nearly every year over her 32-year sighting record. She was a regular visitor to the Bay of Fundy and was never seen in the Gulf of St. Lawrence. She had five calves between 1996 and 2013. Her last sighting was in September 2016 in the Bay of Fundy; there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#1604 (30+ y.o. female) - This whale was first seen in February 1986 in Cape Cod Bay. She had numerous sighting gaps over her 30-year sighting record- a number of two and three year gaps, but none longer than that. She had five calves between 1993 and 2015. She was a regular visitor to the Gulf of St. Lawrence well before most other right whales were using the habitat. She was seen there in 1995, 2002, 2003, 2005, 2006, and 2014 with her last sighting there in August of 2016. She had numerous blister lesions at her last sighting (see Hamilton and Marx, 2005 for examples of lesion types). A genetic sample is on file for this whale.

#3440 (14 y.o. female) - This whale, named Cypress, was first seen as a calf with her mother #1622 in February 2002 off the coast of Florida. She was seen almost every year through 2016 and gave birth in 2009 and 2016. She was last seen with her 2016 calf December 27, 2015 after which time her calf was adopted and raised by #3115 Harmony. Cypress remained off the southeast U.S. through January 21, 2016- a full month after separating from her calf. Her last sighting was in March 2016 in Cape Cod Bay; there were no outward indications of ill health at the time. A genetic sample is on file for this whale.

#3405 (12 y.o. female) - This whale, named Fuse, was first seen as a young calf in December 2003 with her mother #1705 Phoenix off the coast of Georgia. While it is not uncommon for some juvenile right whales to return to the southeast U.S. when they are one or two years old, Fuse returned to Florida every year until she was five and then many years after that as well. She was often seen in Cape Cod Bay and the Bay of Fundy; never in the Gulf of St. Lawrence. She only had one calf at the age of 12 in 2016. She was last seen on December 4, 2016 a few miles south of Brighton Beach, NY entangled in rope and gillnet. A genetic sample is on file for this whale.

Resurrected in 2022

No whales were resurrected in 2022.

VI. Mortalities, Entanglements, and Significant Injuries

Overview

There were no mortalities discovered in 2022 and five right whales were confirmed first seen entangled with attached gear. One whale that had been entangled in previous years was seen still entangled in 2022 and no previously entangled whales were seen gear-free in 2022. There were three cases of significant, non-lethal injuries caused by propellers or entanglements in 2022. 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

There were no mortalities detected in 2022. The last year no right whale mortalities were detected was 1985.

Entanglements

First Reported in 2022

May 19, 2022: #3823 (14 y.o. female) - This whale, named Sundog, was first seen entangled on May 19, 2022 in the Gulf of St Lawrence Canada between the Gaspe Peninsula and Anticosti Island by two different aerial surveys- one conducted by the Department of Fisheries and Oceans Canada (DFO) and the other by NOAA's Northeast Fisheries Science Center. The event was assigned a CCS case number of WR-2022-02. She had line through her mouth and was trailing a bullet buoy and polyball over 100 feet behind. The other end of the line appeared to have weight attached. No disentanglement effort was launched due to distance from shore and time of day. This was at least her sixth documented entanglement and she has not been seen since. She had been last seen gear-free 69 days earlier on March 11, 2022 in Massachusetts Bay.

June 30, 2022: #1403 (38 y.o. male) - This whale, named Meridian, was first seen entangled on June 30, 2022 about 50 nautical miles east of Miscou, N.B. in the Gulf of St Lawrence Canada by a DFO aerial survey. Line could be seen trailing behind the body, but it was unclear if the line was through his mouth or attached to his flipper. This entanglement was given a CCS case number of WR-2022-10. He had been last seen gear-free 115 days earlier on March 7, 2022 in Massachusetts Bay. He was only seen one other time on July 7 in the Shediac Valley east of Miscou during vessel-based surveys conducted by a joint effort of the University of New Brunswick, NEAq, and the Canadian Whale Institute. They were still not able to determine how the line was attached and they were not able to attach a telemetry buoy. He has not been seen since. Like Sundog, this was Meridian's sixth documented entanglement.

August 20, 2022: #5120 (1 y.o. female)- This whale, the 2021 calf of #3720, was first seen entangled on August 20, 2022 approximately 45 nm east of Miscou, N.B. Canada by a DFO aerial survey team. Line was wrapped around the peduncle with two buoys, one green and one red, close to the tail and approximately 200 feet of line trailing. The entanglement was given a CCS case number WR-2022-17. She had been last seen gear-free 111 days earlier on May 1, 2022 in the Great South Channel east of Cape Cod, MA. She was next seen January 18, 2023 just outside of Pamet Harbor in Cape Cod Bay. A disentanglement response was mounted but was unsuccessful at deploying a telemetry buoy or modifying the gear. The entanglement around the peduncle and buoys near the tail were visible, but the trailing line was not. She was seen again in Cape Cod Bay on January 22 and 30 and there was another unsuccessful disentanglement attempt on the

30th. After that, she was seen still entangled south of Nantucket in February and in the Gulf of St. Lawrence in the summer until her final sighting dead on a beach in Martha's Vineyard on January 28, 2024. She had been entangled for more than half her life. NOAA determined the gear came from the Maine lobster fishery.

August 24, 2022: #4501 (7 y.o. male)- This whale was first seen entangled on August 24, 2022 approximately 40 nm east of Miscou, N.B. Canada by a DFO aerial survey team. He had two wraps of line around the body and appeared agitated as if entangled relatively recently. It was unclear how the line was attached and there was some question whether or not he remained entangled by the end of the sighting. He was confirmed gear free at his next sighting on March 31, 2023 south of Cape Cod. The entanglement was given a CCS case number WR-2022-18. His last sighting before he became entangled was May 12, 2022 in the Gulf of St. Lawrence suggesting that the entanglement likely occurred in that habitat.

September 21, 2022: #3560 (17 y.o. male) - This whale, named Snowcone, had been carrying gear from a previous entanglement since March 10, 2021 and on September 21, 2022 she was seen wrapped up in an additional entanglement. The description of the first entanglement was provided in the previous report. During the September 21 sighting, she had one or more new line wraps through her mouth and trailing behind. There appeared to be weight on the line given the angle of descent in the water column. Although there had been many disentanglement responses to the initial entanglement, no response was mounted for this new entanglement due to time of day and distance from shore. Her condition had deteriorated substantially since her previous sighting on July 22, 2022 in the Gulf of St. Lawrence and she has not been seen since. The new entanglement retained the original CCS case number WR-2021-124.

Reported Prior to 2022 and Still Entangled by the End of 2022

Only #3560 (described above with her 2nd entanglement) had been seen entangled prior to 2022 and was still entangled in that gear.

First Seen Free of Gear in 2022

No whales were first seen gear free in 2022.

Significant injuries

May 24, 2022: #5012 (2 y.o. male)- This whale was first seen with propeller wounds on his left back on May 24, 2022 approximately 90 nm east of Provincetown, MA by a NEFSC shipboard survey team. He had a series of at least four propeller wounds on his left body and several of the wounds were raised and infested with orange cyamids. He had last been seen without the injury on March 9, 2021 in Southern New England. He was resighted in February and March of 2023 in Cape Cod Bay with no significant change to the appearance of the wounds. He was added to the Unusual Mortality Event under the morbidity category. Whale #5012 is the 2020 calf of Juno, #1612, whose 2024 calf was struck by a vessel and eventually died in March 2024.

July 8, 2022: #4650 (6 y.o. male)- This whale, named Sebastian, was first seen on July 8, 2022 with severe entanglement wounds approximately 60 miles east southeast of Miscou, New Brunswick in the Gulf of St. Lawrence. He had open, raw wounds on his peduncle and leading fluke edges with less severe new wounds to the head and the lip. He had last been seen without the wounds May 26th, 2022 also in the Gulf suggesting that the entanglement likely occurred in that habitat. He was seen several other times in July after the injury detection date and also multiple times in 2023 into the summer. This whale was added to the Unusual Mortality Event under the morbidity category.

July 18, 2022: #3579 (17 y.o. male)- This whale was first seen on July 18, 2022 with severe entanglement wounds on his peduncle, fluke insertions, and leading fluke edges approximately 60 miles southeast of Miscou, New Brunswick in the Gulf of St. Lawrence. He had last been seen without the wounds May 12th, 2022 also in the Gulf suggesting that the entanglement likely occurred in that habitat. He was seen repeatedly in 2022 after the injury detection and also multiple times in 2023 into the summer. This whale is being reviewed under the Unusual Mortality Events protocols and morbidity determination is pending.

VII. Photographic Contributions

Photos were submitted from 82 different organizations or individuals who collected photographs between December 1, 2021 and November 30, 2022 and 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 82 organizations/individuals whose photographs were collected between December 1, 2021 and November 30, 2022.

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
AMTU*										
BOF	1	2	100%	0%	0%	0%	0%	1	0	1
ANRO*										
SEUS	1	5	100%	0%	0%	0%	0%	1	0	1
AS										
SEUS	39	98	5%	5%	0%	41%	49%	1	4	5
ASER*										
MIDA	1	3	0%	0%	100%	0%	0%	0	0	0
BOS										
JL	4	15	25%	0%	0%	0%	75%	1	0	1
BOST*										
SEUS	2	9	50%	0%	0%	50%	0%	1	1	2
BRDA*										
NE	4	72	75%	0%	0%	25%	0%	3	1	4
CCG										
NRTH	10	0	0%	0%	0%	20%	80%	0	2	2
CCS										
GOM	20	378	35%	65%	0%	0%	0%	7	0	7
GSC	26	398	69%	19%	0%	12%	0%	16	2	18
JL	6	109	83%	17%	0%	0%	0%	5	0	5
MIDA	9	178	44%	56%	0%	0%	0%	4	0	4
NE	1,099	14,562	65%	23%	0%	8%	4%	238	10	248
CHPI*										
NE	4	6	25%	25%	0%	0%	50%	1	0	1
CMARI										
MIDA	41	547	63%	5%	0%	24%	7%	16	5	21
SEUS	121	1,931	59%	5%	0%	36%	0%	19	13	32
CMWWRC										
MIDA	1	41	0%	100%	0%	0%	0%	0	0	0
COBO*										
JL	3	20	0%	0%	0%	0%	100%	0	0	0
CORU*										
MIDA	2	16	50%	0%	0%	50%	0%	1	1	2
CWI										
NRTH	30	0	0%	0%	0%	0%	100%	0	0	0
DFO										
BOF	4	11	25%	25%	0%	0%	50%	1	0	1
NRTH	512	4,951	12%	21%	0%	2%	66%	38	5	43
DIMO*										
NE	1	1	0%	0%	0%	0%	100%	0	0	0
DISA*										
NE	3	10	33%	0%	0%	0%	67%	1	0	1
DN*										
MIDA	2	46	0%	100%	0%	0%	0%	0	0	0

Table 1 (cont.)

Organization / Region	# of Sightings	# of Images	% of Total Sightings: Matched: Confirmed	% of Total Sightings: Matched: Unconfirmed	% of Total Sightings: Not Matchable	% of Total Sightings: Intermatched	% of Total Sightings: Not Yet Matched	# of Individuals: Confirmed Id'd	# of Individuals: Other Unique Id'd	# of Individuals: Total
EDCO*										
MIDA	1	2	0%	0%	0%	100%	0%	0	1	1
ERSM*										
SEUS	2	7	50%	0%	0%	50%	0%	1	1	2
FJME*										
NE	1	1	0%	0%	100%	0%	0%	0	0	0
FRBR*										
NE	2	6	100%	0%	0%	0%	0%	2	0	2
FTR										
BOF	1	7	0%	100%	0%	0%	0%	0	0	0
FWRI										
SEUS	182	2,232	40%	14%	0%	41%	4%	15	15	30
GARO*										
MIDA	2	20	50%	0%	0%	50%	0%	1	1	2
GDNR										
SEUS	46	786	50%	0%	0%	50%	0%	10	10	20
GEME*										
NE	1	4	0%	0%	0%	100%	0%	0	1	1
GEOQM										
MIDA	4	15	0%	0%	0%	0%	100%	0	0	0
GEOSUB										
MIDA	2	4	0%	0%	50%	0%	50%	0	0	0
GLL										
NE	9	124	67%	11%	0%	22%	0%	5	1	6
GOWH										
MIDA	1	4	0%	0%	0%	0%	100%	0	0	0
GREMM										
NRTH	1	10	0%	0%	0%	0%	100%	0	0	0
HDR										
MIDA	1	34	100%	0%	0%	0%	0%	1	0	1
JAPH*										
MIDA	1	7	0%	100%	0%	0%	0%	0	0	0
JASH*										
NE	1	19	100%	0%	0%	0%	0%	1	0	1
JESO*										
SEUS	2	9	50%	0%	0%	50%	0%	1	1	2
JOHI*										
NE	7	29	43%	14%	0%	0%	43%	3	0	3
JOPO*										
MIDA	1	3	0%	0%	100%	0%	0%	0	0	0
JOSE*										
NE	3	16	0%	33%	67%	0%	0%	0	0	0
JOTGR*										
NE	1	1	0%	0%	100%	0%	0%	0	0	0
JRMC*										
MIDA	2	8	50%	0%	50%	0%	0%	1	0	1
LAJA*										
SEUS	1	2	0%	0%	100%	0%	0%	0	0	0
LECO*										
NE	3	6	33%	33%	0%	0%	33%	1	0	1
MACO*										
NE	2	10	50%	0%	0%	0%	50%	1	0	1
MADM*										
SEUS	2	2	0%	0%	100%	0%	0%	0	0	0

Table 1 (cont.)

Organization / Region	# of Sightings	# of Images	% of Total Sightings: Matched: Confirmed	Unconfirmed	Not Matchable	Intermatched	Not Yet Matched	# of Individuals: Confirmed Id'd	Other Unique Id'd	Total
MAMA*										
SEUS	2	4	0%	0%	50%	50%	0%	0	1	1
MC										
NE	1	7	0%	0%	0%	0%	100%	0	0	0
MIKMO*										
NE	2	8	0%	0%	0%	0%	100%	0	0	0
MITA*										
SEUS	2	4	50%	0%	0%	50%	0%	1	1	2
MITU*										
NE	2	16	0%	100%	0%	0%	0%	0	0	0
NACH*										
NE	3	5	33%	33%	0%	33%	0%	1	1	2
NBC/NECN										
NE	1	8	0%	0%	0%	0%	100%	0	0	0
NEA										
EAST	1	23	0%	100%	0%	0%	0%	0	0	0
GOM	20	40	15%	0%	0%	0%	85%	3	0	3
GSC	10	120	50%	50%	0%	0%	0%	5	0	5
JL	3	69	67%	33%	0%	0%	0%	1	0	1
MIDA	32	262	47%	25%	3%	3%	22%	14	1	15
NE	157	2,030	21%	24%	1%	15%	39%	25	7	32
NEA/CWI										
NRTH	252	2,535	1%	0%	0%	4%	95%	2	4	6
NEFSC										
GOM	34	423	44%	35%	0%	6%	15%	13	2	15
GSC	173	2,000	65%	22%	0%	1%	12%	75	2	77
JL	10	153	50%	40%	0%	0%	10%	5	0	5
MIDA	92	974	40%	42%	0%	2%	15%	33	2	35
NE	127	439	27%	6%	0%	17%	51%	31	11	42
NRTH	70	899	69%	21%	0%	1%	9%	31	1	32
SEUS	24	39	4%	0%	0%	46%	50%	1	7	8
OA										
NE	2	44	100%	0%	0%	0%	0%	2	0	2
OTTH*										
SEUS	2	2	50%	0%	0%	50%	0%	1	1	2
PCAN										
NRTH	1	5	0%	0%	0%	0%	100%	0	0	0
PEFL*										
GOM	5	0	0%	0%	0%	20%	80%	0	1	1
GSC	4	0	0%	0%	0%	0%	100%	0	0	0
NE	91	0	0%	0%	0%	4%	96%	0	2	2
PHMU*										
JL	1	6	0%	0%	100%	0%	0%	0	0	0
PHWO*										
MIDA	1	6	0%	0%	100%	0%	0%	0	0	0
QLM										
BOF	2	39	50%	0%	0%	50%	0%	1	1	2
RIRA*										
MIDA	1	4	0%	0%	0%	0%	100%	0	0	0
RIYO*										
JL	1	9	0%	0%	100%	0%	0%	0	0	0
RYBR*										
SEUS	2	10	50%	0%	0%	50%	0%	1	1	2

Table 1 (cont.)

			% 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
RYSC*										
NE	5	47	20%	40%	0%	0%	40%	1	0	1
SBNMS										
NE	11	56	36%	36%	18%	9%	0%	4	1	5
SCCO*										
SEUS	2	20	50%	0%	0%	50%	0%	1	1	2
SCOW*										
SEUS	2	16	50%	0%	0%	50%	0%	1	1	2
SEFSC/AMPS										
MIDA	3	23	0%	33%	33%	0%	33%	0	0	0
SEUS	2	33	0%	50%	0%	50%	0%	0	1	1
SKTI*										
NE	2	13	0%	50%	0%	0%	50%	0	0	0
SP*										
NE	6	36	33%	0%	0%	0%	67%	2	0	2
STRIL										
MIDA	2	2	0%	0%	100%	0%	0%	0	0	0
TC										
NRTH	56	368	5%	43%	0%	0%	52%	3	0	3
TEBR*										
X	7	59	14%	14%	0%	0%	71%	1	0	1
UNCW										
MIDA	2	29	50%	0%	0%	50%	0%	1	1	2
UNK										
JL	1	2	100%	0%	0%	0%	0%	1	0	1
MIDA	1	10	0%	0%	0%	0%	100%	0	0	0
VIMO*										
JL	1	6	0%	0%	0%	0%	100%	0	0	0
WCVB										
JL	1	12	100%	0%	0%	0%	0%	1	0	1
NE	1	4	100%	0%	0%	0%	0%	1	0	1
WFXT										
NE	5	23	40%	40%	0%	0%	20%	2	0	2
WHOI										
NE	89	1,976	11%	52%	0%	13%	24%	9	4	13
Report Totals	3,558	39,695								

VIII. Catalog Related Publications and Reports

Since the last Catalog report on October 31, 2022, the following reports and publications that utilized data from the Catalog have been either published or submitted:

Frasier T.R., Hamilton P.K., Pace III R. 2023. How compromised is reproductive performance in the endangered North Atlantic right whale? A proposed method for quantification and monitoring. bioRxiv, pp.2023-11. https://doi.org/10.1101/2023.11.21.568115

Linden D.W. 2023. Population size estimation of North Atlantic right whales from 1990-2022. US Dept Commer Northeast Fish Sci Cent Tech Memo 314. 14 p.

Linden, D.W., Hostetler, J.A., Pace III, R.M., Garrison, L.P., Knowlton, A.R., Lesage, V., Williams, R. and Runge, M.C., 2023. A multistate capture-recapture model to estimate cause-specific injury and mortality of North Atlantic right whales. bioRxiv, pp.2023-10.

Pettis, H.M., Hamilton, P.K. 2024. North Atlantic Right Whale Consortium 2023 Annual Report Card. Report to the North Atlantic Right Whale Consortium. 17 p.

Pettis, H.M., Pace, R.M. III, Hamilton, P.K. 2023 North Atlantic Right Whale Consortium 2022 Annual Report Card. North Atlantic Right Whale Consortium, DOI: 10.1575/1912/66099, https://hdl.handle.net/1912/66099

Pirotta, E., Schick, R.S., Hamilton, P.K., Harris, C.M., Hewitt, J., Knowlton, A.R., Kraus, S.D., Meyer-Gutbrod, E., Moore, M.J., Pettis, H.M., Photopoulou, T., Rolland, R.M., Tyack, P.L., Thomas, L. 2023. Estimating the effects of stressors on the health, survival and reproduction of a critically endangered, long-lived species. Oikos. http://dx.doi.org/10.1111/oik.09801

Pirotta, E., Tyack, P.W., Durban, J..L, Fearnbach, H., Hamilton, P.K., Harris, C.M., Knowlton, A.R., Kraus, S.D., Miller, C.A., Moore, M.J., Pettis, H.M., Photopoulou, T., Rolland, R.M., Schick, R.S., Thomas, L. 2024. Decreasing body size is associated with reduced calving probability in critically endangered North Atlantic right whales. Royal Society Open Science. 11:240050. https://doi.org/10.1098/rsos.240050

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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.

Linden, D.W. 2023. Population size estimation of North Atlantic right whales from 1990-2022. US Dept Commer Northeast Fish Sci Cent Tech Memo 314. 14 p.

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, 2022 as of February 2, 2023.

A detailed breakdown of the matching status of all sightings for the *calendar* years 2003 to 2022. The numbers and percentages provided here do not match those provided in Section II for 2022 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
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	99.0%	99.0%
2008	13		4033	118	4164	99.7%	99.7%
2009	35		4552	111	4698	99.3%	99.3%
2010	25		3143	68	3236	99.2%	99.2%
2011	44		3328	107	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		1704	76	1842	96.6%	96.6%
2016	14		2179	32	2225	99.4%	99.4%
2017	46	2	2919	159	3126	98.5%	98.5%
2018	50		3667	116	3833	98.7%	98.7%
2019	66	1	4669	208	4944	98.7%	98.6%
2020	50	14	2167	105	2336	97.9%	97.3%
2021	88	0	3979	138	4205	97.9%	97.9%
2022	1507	681	1271	24	3483	56.7%	37.2%

<u>Appendix II. List of abbreviations for all areas and regions.</u>

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

Appendix III. Abbreviations for 82 data contributors from December 1, 2021 through November 30, 2022.

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

Abbreviation	Primary Contact	Organization Name (if applicable)
AMTU*	Amy Tudor	
ANRO*	Anthony Roberts	
AS	Jim Hain	Associated Scientists at Woods Hole
ASER*	Ashley Erisman	
BOS	Dianna Schulte	Blue Ocean Soc. For Marine Cons.
BOST*	Bobby Stockton	
BRDA*	Brian Danforth	
CCG	Stephanie Ratelle	Canadian Coast Guard
CCS	Brigid McKenna	Center for Coastal Studies
CHPI*	Charlie Pingree	
CMARI	Melanie White	Clearwater Marine Aquarium Research Institute
CMWWRC	Melissa Laurino	Cape May Whale Watch Reseach Center
COBO*	Colin Boyle	
CORU*	Cole Rumfelt	
CWI	Moe Brown	Canadian Whale Institute
DFO	Stephanie Ratelle & Veronique Lesage	DFO (Gulf & Quebec Region)
DIMO*	Diane Monteith	
DISA*	Diego Sampson	
DN*	Doug Nowacek	Duke University
EDCO*	Ed Corey	
ERSM*	Eric Smith	
FJME*	F Jay Meyer	
FRBR*	Frank Bradley	
FTR		Fundy Tide Runners
FWRI	Jen Jakush	Florida Wildlife Research Institute
GARO*	Gates Roll	
GDNR	Clay George	Georgia Dep. of Natural Resources
GEME*	Gerald Mercier	
GEOQM		Geoquip Marine Group
GEOSUB	Megan McManus	Geo Sub Sea

Appendix III. (cont.)

Abbreviation	Primary Contact	Organization Name (if applicable)
GLL	Gina Lonati	UNB
GOWH		Go Guice Offshore
GREMM	Michel Moisan	Groupe de recherche et d'éducation sur les mammifères marin
HDR	Jessica Aschettino	HDR Environmental
JAPH*	Jacqueline Poblete-Haubrich	
JASH*	James Sherwonit	
JESO*	Jessie Solomon	
JOHI*	Josh Higgins	
JOPO*	Jonathan Pool	
JOSE*	Jon Sepich	
JOTGR*	John Gray	
JRMC*	J.R. McCroskey	
LAJA*	Laura Jackson	
LECO*	Leonard Connolly	
MACO*	Matthew Cook	
MADM*	Madeleine Massey	
MAMA*	Mandy Mammas	
MC		Mahi Cruises
MIKMO*	Michele Keane-Moore	
MITA*	Mitchell Taylor	
MITU*	Mike Tucker	
NACH*	Nathan Chamberlain	
NBC/NECN	Miraj Budak	NBC Boston and NECN Boston
NEA	Orla O'Brien & Monica Zani	New England Aquarium (mostly aerial)
NEA/CWI	Monica Zani	New England Aquarium
NEFSC	Allison Henry & Lisa Conger	Northeast Fisheries Science Center
OA	Iain Kerr	The Ocean Alliance
OTTH*	Ottmar Thiele	
PCAN		Parks Canada
PEFL*	Peter Flood	
PHMU*	Philip Munson	
PHWO*	Phil Woniger	

Appendix III. (cont.)

Abbreviation	Primary Contact	Organization Name (if applicable)
QLM	Danielle Dion	Quoddy Link Marine
RIRA*	Richard Rahm	
RIYO*	Rich Young	
RYBR*	Ryan Braget	
RYSC*	Ryan Schosberg	
SBNMS	Dave Wiley	Stellwagen Bank National Marine Sanctuary
SCCO*	Scott Covado	
SCOW*	Scott Owens	
SEFSC/AMPS	Lance Garrison	SEFSC
SKTI*	Skyler Tibbits	
SP*	Susan Parks	Penn State University
STRIL	Tim Cole	PSOs working onboard the Stril Explorer submitted via SAS
TC	Stephanie Ratelle	Transport Canda
TEBR*	Ted Bradford	
UNCW	Bill McLellan	University of North Carolina-Wilmington
UNK		Unknown- submitted second hand
VIMO*	Vicky Montisanti	
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Task 2: Final Report on 2021 Right Whale Entanglement Scar Coding Efforts

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Overview

This report summarizes right whale entanglement scarring analyses for 2021 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 2021 to those of 2010-2020 (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 are detected 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). Two papers are in progress. First is an update of the Knowlton et al. (2012) paper that assessed 30 years of entanglement data to capture the additional years of entanglement data reported annually to NOAA and presented herein. The second paper will be focused on an approach we developed 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. A draft of the first paper is presently under review by the coauthors and for the second paper, we are actively working on refining analyses of our allocations approach for integration into a manuscript.

Other work that is underway is continued collaboration with NOAA on the Unusual Mortality Event to integrate morbidity cases (see https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2022-north-atlantic-right-whale-unusual-mortality-event). As of February 2024, a total of 51 morbidity cases have been added to the UME and this work is ongoing.

And lastly, with private foundation support, we have developed the Anthropogenic Events Database and associated Right Whale Injury Monitoring portal to facilitate integration of data related to anthropogenic injury events, including these new data from 2021, into one place. A new web-based data visualization site is in development and will allow users to interact with and view anthropogenic injury data.

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

Explanation of analyses described in this report

Scar coding was carried out for all animals sighted in 2021 and any new, pre-2021 sightings added to the catalog since the 2022 report. Scar coding was also carried out for any new whales added to the catalog with sightings up to and including 2021. In addition to calculations of annual population entanglement rates and detection of new entanglement events, an analysis to evaluate likely country of origin is also described.

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., 2020/2021) 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. Note that this NEAq definition is slightly different than NOAA’s *serious injury* definition which is described as a case of an injured whale that is more likely than not to die from its injury.

Entanglement locations

Determining the location where entanglements may have occurred was evaluated in two ways. First was a review of NOAA Fisheries 2021 Atlantic Large Whale Entanglement Report for those whales with gear attached (see https://www.fisheries.noaa.gov/new-england-mid-atlantic/marine-mammal-protection/atlantic-large-whale-take-reduction-plan); 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.

Scar coding results

A summary of all entanglements linked to catalogued individuals from pre-1980-2021 (only 7 events pre-1980) and those that were documented in 2021 only are provided below (note: an additional 5 cases that are not linked to catalog are included in certain analyses but not included in summary):

- Total number of animals reviewed in all years: **799**
    - # of batches analyzed (one batch equals all sightings of an individual grouped within each area/season in a given year) – all years: **22,482**
    - 2021 batches analyzed: **883**
- Number of separate entanglement events detected - all years pre-1980-2021: **1,813** (does not include 5 whales with gear not identified to catalog)
    - 2021 events: **45**
        - Female – 16
        - Male – 28
        - Unknown sex – 1
- Percentage of population entangled at least once: 685/799 **85.7%**
    - # of females in the population through 2021: **335**
    - % of females entangled at least once: 294/335 **87.8%**
    - # of males in the population through 2021: **388**
    - % of males entangled at least once: 358/388 **92.3%**
    - # of unknown sex in the population through 2021: **76**
    - % of unknown sex entangled at least once: 33/76 **43.4%**

- Number of entanglement events where fishing gear was photographed on the whale: **141**
- Percentage of all entanglement events with attached gear: 141/1,818 (includes 5 whales with gear not identified to catalog): **7.8%**
- Percentage of entanglements determined only from scars: 1,677/1,818: **92.2%**

An additional 15 events were added from previous years – one each in 2008, 2009, 2014, 2015, and 2016, two each in 2017 and 2019, and six in 2020. 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 2021; 2) recent identifications of older sightings; 3) recently added better quality images of animals which provided evidence that a certain scar visible prior to 2021 was from entanglement – these events were back-coded to the appropriate year.

The annual tally and proportions of entanglements according to severity and gear presence/absence is provided in Figure 1 and Figure 2e. Through 2021, a total of 29 right whale carcasses (including 3 not identified to the Catalog) that have died due to entanglement have been documented (25 with attached gear and 4 with severe injuries and no attached gear). A synthesis of most of these cases can be found in Sharp et al. (2019) and Moore et al. (2004) with recent cases documented from necropsy and sighting reports.

Crude entanglement rate

The crude rate of new entanglement scars detected 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 2010-2020 period ranged from 11.1% to 24.4% with an annual rate average of 17.5%, SD +/- 4.0%, slightly above the previous 30-year average. For 2021, this rate was 13.0%, indicating a detectable drop in crude entanglement rate from the average over the 2010-2020 time period and from the peak of 24.4% observed in 2016 (Table 1; Figure 2a). The crude rate of new entanglement scars has declined annually since 2016 (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	*61	15.9%
2013	296	33	11.1%
2014	379	*70	18.5%
2015	270	*48	17.8%
2016	328	80	24.4%
2017	380	79	20.8%
2018	363	69	19.0%
2019	361	51	14.1%
2020	314	44	14.0%
2021	**346**	**45**	**13.0%**

* The tallies of newly detected entanglements noted with an '*' include one unidentified entangled carcass in 2012, two unidentified entangled carcasses in 2014 and two live unidentified entangled whales in 2015. Note: 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).

For 2009/2010 to 2020/2021, the annual entanglement rate ranges from 22.3% to 39.1% with an average of 30.0%. SD = +/-5.6%. The rate in 2020/2021 at 24.5% falls well below the average for the past 11 years (as does the 2018/2019 rate at 22.4% and 2019/2020 rate at 25.2%) and is similar to the historical average of 25.0% (Table 2; Figure 2b).

Table 2. *Annual entanglement rate*

Two year period	Adequately photographed individuals	# of individuals entangled by year 2 (# of entanglement events)	Entanglement rate (# of entangled individuals/adequately

			photographed individuals
2009/2010	200	55 (56)	27.5.%
2010/2011	197	74 (79)	37.6%
2011/2012	142	50 (54)	35.2%
2012/2013	67	20 (24)	29.9%
2013/2014	92	36 (36)	39.1%
2014/2015	105	32 (33)	30.5%
2015/2016	111	41 (47)	36.9%
2016/2017	169	49 (52)	29.0%
2017/2018	182	62 (65)	34.1%
2018/2019	215	48 (49)	22.3%
2019/2020	159	40 (42)	25.2%
2020/2021	**139**	**34 (35)**	**24.5%**

Timeframes of entanglement

The timeframe of entanglement detection (i.e. the maximum timeframe within which the event must have occurred based on time between sightings without and then with entanglement scars or attached gear) 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 77% 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%, 88%, and 79% of cases detected within one year respectively. This pattern persisted in 2021 with 75% detected within one year (Table 3). 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 entanglement detection timeframes within 6 months to 1 in order to help us assess the effectiveness of changing management measures to mitigate entanglements and their impacts. The ability to detect entanglement events over short periods of time is dependent on high quality and detailed photographic capture of individuals throughout their range. In particular, shipboard and high quality drone imagery are the most useful types of images for detecting scars.

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 (1.5%)	1 (1.5%)
2011	96	34 (35%)	36 (38%)	12 (13%)	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*	70	15 (22%)	17 (24%)	14 (20%)	12 (17%)	9 (13%)	3 (4%)
2015*	48	13 (27%)	13 (27%)	9 (19%)	3 (6%)	7 (15%)	3 (6%)
2016	80	21 (26%)	19 (24%)	21 (26%)	5 (6%)	14 (18%)	
2017	79	28 (35%)	17 (22%)	11 (14%)	14 (18%)	9 (11%)	

2018	69	22 (32%)	31 (45%)	11 (16%)	1 (1.5%)	3 (4%)	1 (1.5%)
2019	51	31 (61%)	14 (27%)	5 (10%)		1 (2%)	
2020	43	23 (53%)	11 (26%)	8 (19%)	1 (2%)		
2021	**45**	**24 (53%)**	**10 (22%)**	**6 (14%)**	**4 (9%)**	**1 (2%)**	

* The tallies of newly detected entanglements in the years with an '*' include one unidentified entangled carcass in 2012, two unidentified entangled carcasses in 2014 and two live unidentified entangled whales in 2015. These cases were added to the unknown timeframe tally.

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 54% to 64% of all the entanglement detections involving calves and juveniles. Between 2013-2017, this pattern shifted with only 33% to 40% of entanglement events involving calves or juveniles. In 2018-2020, this dropped further with 22% to 24% of events involving juveniles. However, in 2021, the percentage of entanglement cases involving calves and juveniles increased to 49% (Table 4; Figure 2f). 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 a high of 35% in 2010 to a low of 14% in 2020 with a slight increase to 17% in 2021. This long-term decline in juveniles is likely the result of reduced reproduction in recent years but could also be related to this higher proportional rate of entanglements and undetected mortalities that may be occurring in young whales when they get entangled in strong ropes (Table 4; Knowlton et al. 2016; Pace et al. 2021).

Table 4. Entanglement events by age group.

	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%)	35% 175/507
2011 n = 96	7 (7%)	51 (53%)	33 (35%)	4 (5%)	35% 181/514
2012* n = 61	2 (3%)	37 (61%)	18 (30%)	4 (6%)	31% 158/508
2013 n = 33	3 (9%)	10 (30%)	20 (61%)		30% 158/520
2014* n = 70	2 (3%)	21 (30%)	45 (64%)	2 (3%)	28% 148/521
2015* n = 48	4 (8%)	15 (32%)	25 (52%)	4 (8%)	27% 142/525
2016 n = 80	7 (9%)	23 (29%)	49 (61%)	1 (1%)	25% 133/526
2017 n = 79	1 (1%)	31 (39%)	43 (55%)	4 (5%)	22% 113/512
2018 n = 69		16 (23%)	49 (71%)	4 (6%)	17% 83/487
2019 n = 51	6 (12%)	8 (16%)	35 (68%)	2 (4%)	15% 73/481
2020 n = 43	4 (9%)	7 (16%)	32 (75%)		14% 64/457
2021 n = 45	**6 (13%)**	**16 (36%)**	**23 (51%)**		**17% 75/453**

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

* The tallies of newly detected entanglements in the years with an '*' include one unidentified entangled carcass in 2012, two unidentified entangled carcasses in 2014 and two live unidentified entangled whales in 2015. These were all tallied in the Unknown age category.

Serious entanglements: Whales with attached gear or with severe entanglement wounds only
Knowlton et al. (2012) combined the number of animals with attached 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. In 2021, the rate dropped further to 1.2%, the lowest rate documented in the 2010-2021 timeframe (Table 5, Figure 2d).

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 2021.

In 2021, there were four whales with newly detected serious entanglements: three carrying gear and one with severe injuries and no attached gear.

- **Catalog #1803**, a 33-year-old male, was first seen entangled on January 11, 2021 off the coast of Florida. Disentanglement attempts on 11 and 12 Jan were unsuccessful and the whale was not seen again and is likely dead. The gear observed on #1803 was trap/pot gear of unknown origin.
- **Catalog #3560 (Snowcone)**, a 16-year-old reproductive female was pregnant with her second calf when first observed entangled in Cape Cod Bay on March 10, 2021. Some gear was removed by the Center for Coastal Studies in Cape Cod Bay in March and by the Campobello Whale Rescue Team in May and July 2021 in the Gulf of St Lawrence. There were additional sightings of her in August in GSL and in November in southern New England and then she was observed in December 2021 off the southeast U.S. with her newborn calf and still entangled with an embedded rostrum wrap. The pair were observed multiple times in the southeast U.S. through February and then seen in April and May off of Cape Cod. Snow Cone was sighted without her calf in the GSL in July 2022 and in declining condition. She was next sighted in September 2022 off southern New England with a new entanglement. She was in extremely poor condition and is likely dead. The origin of the gear is unknown.
- **Catalog #4615**, a 5-year-old male, was seen entangled in the Gulf of St Lawrence on 13 July 2021. He had been seen 4 hours earlier not entangled. At the initial entanglement sighting, the whale was rolling and thrashing with active bleeding observed. A single line was through his mouth with several wraps around the peduncle and rope trailing. Researchers operating in the area attached a telemetry buoy which stopped transmitting by the next morning. When he was resighted on 14 July, there was no longer rope around the peduncle but the whale was still thrashing and weighted gear appeared to be still attached. He has not been sighted since and is likely dead.

One whale **(Catalog #2223, Calvin),** a 29-year-old reproductive female who last calved in 2020, was observed with severe injuries and no attached gear on 18 March 2021 in Cape Cod Bay (Figure 3). She was seen in 2022 and her condition is being monitored. No other severe injury without gear cases were observed in 2021.

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

	With attached gear	Severe injuries only	% of all sighted individuals with serious entanglements (gear + severe injuries/sighted)	Total and % of serious entanglements dead/potentially dead
2010	5	2	1.6% (7/432)	4 (3/1) 57%
2011	10	3	2.9% (13/444)	5 (1/4) 38%
2012*	5	6	2.9% (11/384)	5 (2/3) 45%
2013	3	1	1.4% (4/296)	3 (1/2) 75%
2014*	7	7	3.7% (14/379)	9 (2/7) 64%
2015*	4	3	2.6% (7/270)	5 (0/5) 71%
2016	7	7	4.3% (14/328)	12 (2/10) 86%
2017	9	6	3.9% (15/380)	7 (2/5) 47%
2018	6	11	4.5% (17/363)	7 (3/4) 41%
2019	5	4	2.5% (9/361)	2 (1/1) 22%
2020	3	4	2.3% (7/314)	3 (1/2) 43%
2021	**3**	**1**	**1.2% (4/346)**	**3 (0/3) 75%**

* The tallies of newly detected entanglements in the years with an '*' include one unidentified entangled carcass in 2012, two unidentified entangled carcasses in 2014 and two live unidentified entangled whales in 2015.

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 annual entanglements resulting in moderate to severe injuries remains high with an average of 30% (range 25-37%). The rate in 2021 was slightly below the average with 25% of all cases with moderate and severe injuries combined (Table 6; Figure 2c). And the proportion of 2021 cases resulting in severe injuries was the lowest seen since 2013 at 9% (2010-2021 range: 6-23%; Table 6; Figure 2d).

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 = 96)	67 (2); 70%	23 (5); 24%	6 (4); 6%
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 = 70)*	47 (0); 67%	9 (0); 13%	14 (7); 20%
2015 (n = 48)+	33 (0); 69%	8 (0); 17%	7 (4); 14%
2016 (n = 80)	50 (0); 63%	17 (1); 21%	13 (6); 16%
2017 (n = 79)	51 (1); 65%	16 (3); 20%	12 (5); 15%
2018 (n = 69)	46 (1); 67%	7 (0); 10%	16 (5); 23%
2019 (n = 51)	39 (1); 76%	4 (0); 8%	8 (4); 16%
2020 (n = 43)	32 (0); 75%	4 (0); 9%	7 (3); 16%
2021 (n = 45)	**34 (0); 75%**	**7 (0); 16%**	**4 (3); 9%**

* The tallies in 2012 include one unidentified entangled carcass 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 both the US and Canada work towards understanding and mitigating entanglement risk in their respective countries and fisheries, it is important to monitor not just the cases with attached gear but also the cases that result in scars only. This, along with the other analyses described in this report, can help us to understand whether we are seeing a reduction in risk overall and within each country.

For the 42 cases involving entanglement scars only and no gear, 23 cases occurred within a 180-day (~six-month) period as shown in Table 7. Nine of these likely occurred in US waters, 11 in Canadian waters, and for the remaining three cases, country of origin could not be determined.

With all gear and scarring-only cases combined, 47% or 21 of 45 cases could be attributed to likely country of origin - 12 in Canadian waters, 9 in U.S. waters, and the remaining 24 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, SEUS = southeast US, SNE = southern New England. Note: For cases noted as SEUS and in italics, these are known age whales that were not seen prior without injury. To calculate the potential timeframe of occurrence, the date of 12/1/XXXX of the year just prior to the calving season year was used and the pre-injury area was assumed to be the southeast U.S. calving ground.*

EGNo	Age at injury	Minimum Age	Gender	Injury Severity	Injury Time Frame (days)	Pre Injury Date	Pre Injury Area	Detection Date	Detection Area	Likely country of origin
4640	5		F	Minor	4	2021-07-13	GSL	2021-07-17	GSL	Canada
4633	5		F	Moderate	7	2021-06-29	GSL	2021-07-06	GSL	Canada
5042	1		F	Minor	12	2021-03-11	NY	2021-03-23	CCB	US
3904	12		F	Minor	28	2021-07-11	GSL	2021-08-08	GSL	Canada
4650	5		M	Minor	29	2021-07-18	GSL	2021-08-16	GSL	Canada
5012	1		M	Minor	30	2021-03-10	NC	2021-04-09	SNE	US
3860	13		F	Minor	32	2021-06-17	GSL	2021-07-19	GSL	Canada
3960	12		M	Moderate	33	2021-06-21	GSL	2021-07-24	GSL	Canada
5142	0		F	Minor	34	*2020-12-01*	*SEUS*	2021-01-04	GA	US
3550	16		M	Moderate	36	2021-05-16	GSL	2021-06-21	GSL	Canada
5145	0		M	Minor	41	*2020-12-01*	*SEUS*	2021-01-11	FL	US
3510	16		M	Moderate	48	2021-06-21	GSL	2021-08-08	GSL	Canada
5192	0		M	Minor	49	*2020-12-01*	*SEUS*	2021-01-19	GA	US
1820		33	M	Minor	52	2021-05-17	GSL	2021-07-08	GSL	Canada
1429	39		M	Moderate	59	2021-07-19	GSL	2021-09-16	GSL	Canada
5192	0		M	Minor	76	2021-04-28	CCB	2021-07-13	GSL	Unknown
4605	5		M	Moderate	82	2021-07-13	GSL	2021-10-03	GB	Unknown
5191	0		M	Minor	93	*2020-12-01*	*SEUS*	2021-03-04	FL	US
4041	11		F	Moderate	114	2021-03-30	SNE	2021-07-22	GB	US
3101	20		F	Minor	117	2021-07-18	GSL	2021-11-12	GSL	Canada
4342	8		M	Minor	136	2020-10-31	GB	2021-03-16	SNE	US
4903	2		M	Minor	140	2020-09-24	SNE	2021-02-11	GSC	US
3845	13		M	Minor	155	2020-12-20	SNE	2021-05-24	GSL	Unknown

<u>Discussion</u>

A total of 45 new entanglement events were documented in 2021, four of which were classified as serious entanglements according to the New England Aquarium criteria (i.e. seen with attached gear or severe injuries). Of the four whales with a serious entanglement, two are male and two are female. Both of these females are reproductively active – one is likely dead as she was seen in September 2022 with a new entanglement and in very poor condition. The fate of the second female with severe injuries only is uncertain, although she was seen alive in 2022. The two seriously entangled males are likely dead as they were last observed in 2021 still entangled. These four cases, along with the seven cases with moderate injuries, indicate that despite a reduction in some entanglement metrics (see below), the level of mortality and serious injury are exceeding PBR and sublethal impacts to this critically endangered species are still occurring (Knowlton et al. 2022, Pirotta et al. 2023).

An evaluation of all the metrics described in this report indicates that the frequency and severity of entanglements may have improved in recent years. As shown in Figure 2a-f, most entanglement rates have declined. Although this suggests that management changes in both the U.S. and Canada may have had a positive impact, it is important to recognize that the situation for right whales in relation to entanglements remains concerning. For example, despite efforts in the Gulf of St. Lawrence to implement dynamic fisheries closures where right whales are observed, these findings show that for all 12 cases that occurred in Canadian waters in 2021, the whales were sighted in the Gulf of St Lawrence before and after entanglement detection. In addition, 6 of the Canadian entanglements occurred after the snow crab fishery had closed for the season on June 30, 2021 suggesting that either gear had been lost or illegally fished, or the gear was from another fishery. For the 9 U.S. cases, the cases ranged from the southeast U.S. to the southern New England area further indicating that entanglements happen throughout the right whale's range. And as shown in the Unusual Mortality Event, in 2022 and 2023 there were 8 entanglement events of concern added in each year respectively and these assessments are not yet complete as data are still being analyzed.

Recent publications highlight the role that entanglements have on population health. 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 moderate and severe entanglement injuries are more pronounced in reproductive females, resulting in reduced fecundity. Pirotta et al. (2023) also found a strong effect of severe entanglements on health and survival. 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. Reed et al. (2024) further suggest that even minor entanglements are having a negative impact on female right whales' transition to breeding.

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 longer females as a result of diminished energy reserves (Stewart et al. 2022). This was further highlighted in a study by Pirotta et al. (2024) where the modeled length of all females in the population were evaluated in comparison to calving success. This study found an overall decline in right whale lengths over five decades and a concurrent decline in reproductive success. The authors noted that recovery of this species will require urgent management changes to address the preventable anthropogenic threats, including those at sublethal levels, this species is facing.

This report and the studies mentioned above make it clear that the recovery of this species will require considerable and persistent changes in how fisheries are prosecuted to reduce the frequency of moderate and severe entanglements that have both lethal and sublethal impacts. The progress described here is encouraging to see but the reality remains that the recovery of right whales will require a transformative change into how humans operate on the ocean, especially along the eastern seaboard which is highly industrialized. The nature of the management changes needed going forward have been outlined in a recently published population viability assessment and this important work is ongoing (Runge et al. 2023).

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

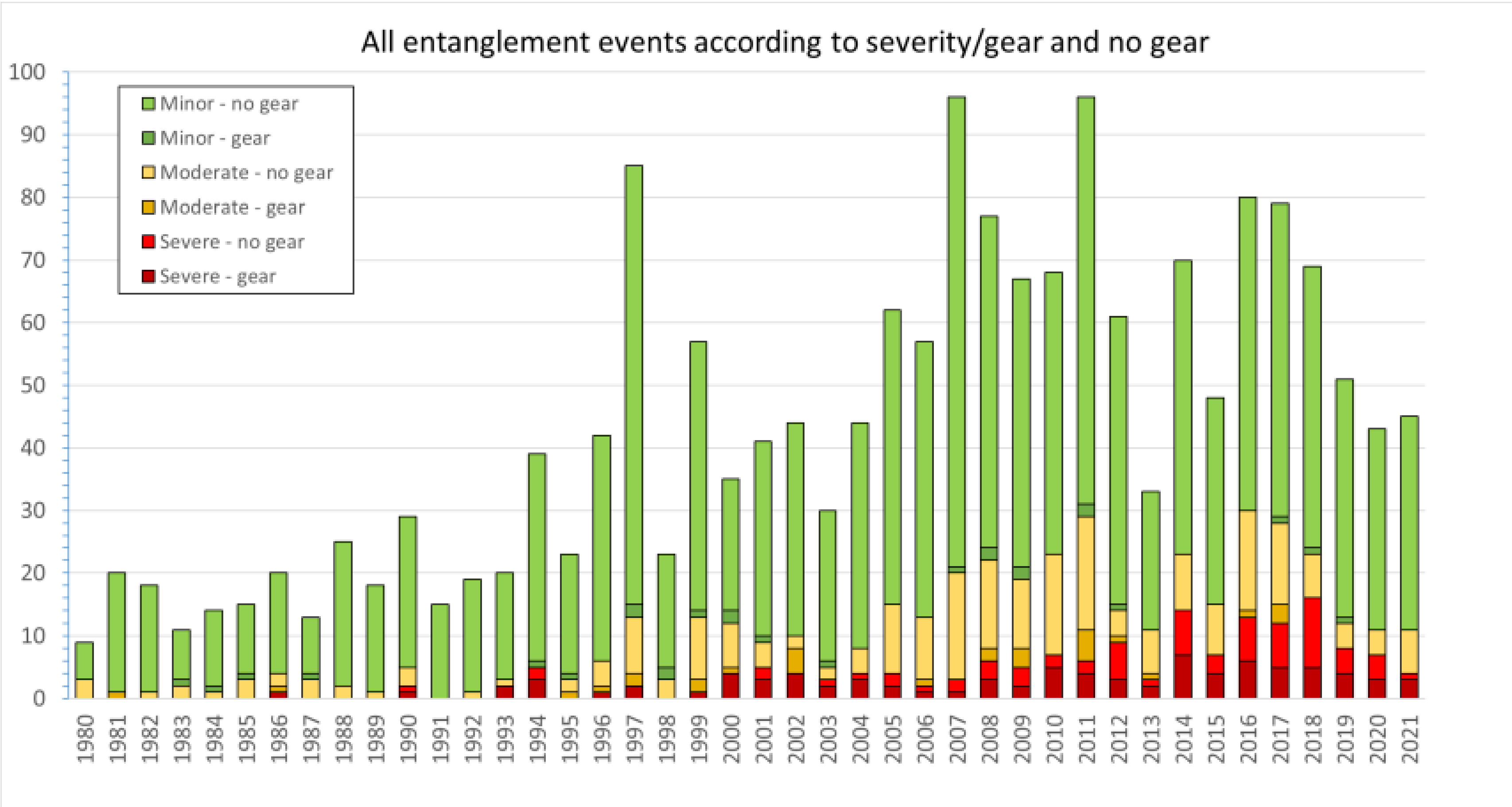


Figure 2. *Graphic representation of various metrics presented in the text. a) Crude entanglement rate, b) Annual entanglement rate, c) proportion and number of moderate and severe entanglements, d) rate of serious entanglements, e) percent of injuries by severity level, and f) proportion of entangled 0-8 year old versus population level*

a)

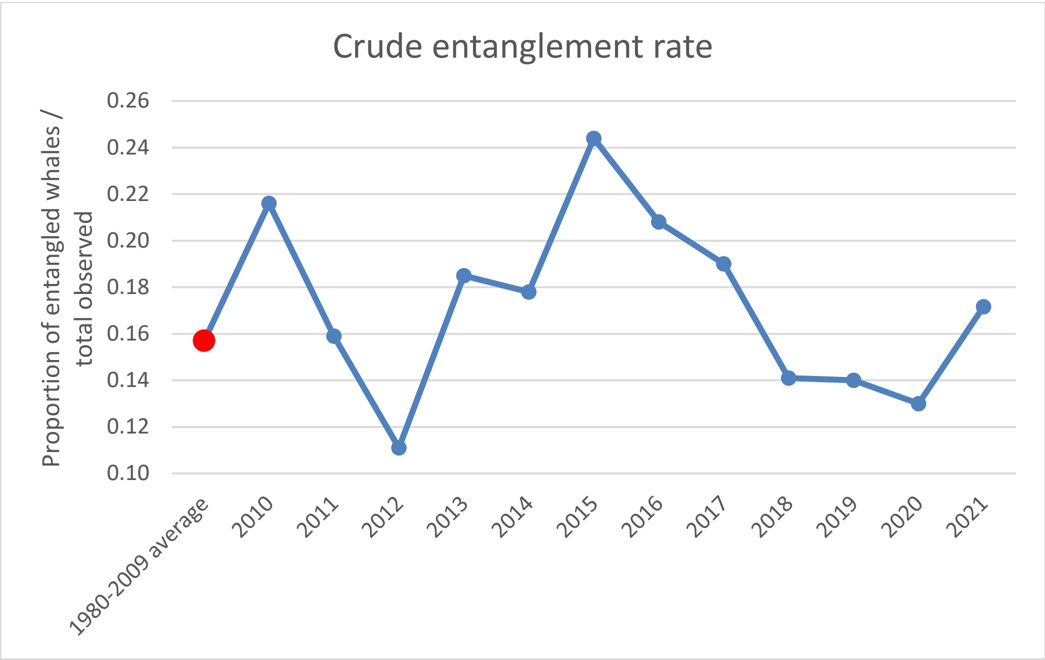


Figure 2 (cont.)
b)

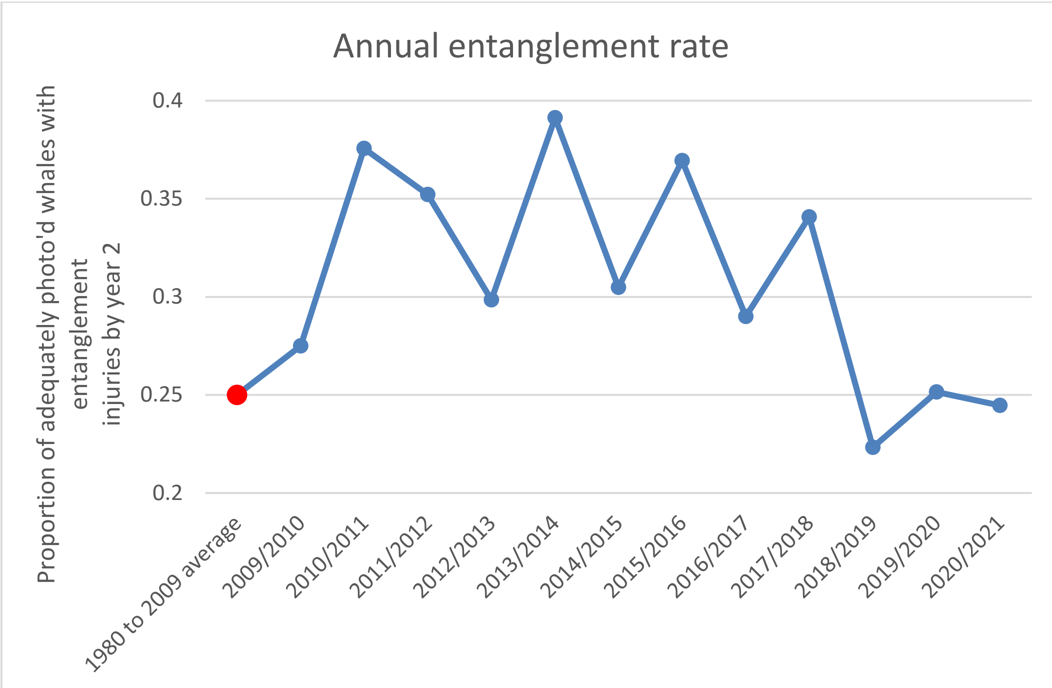


Figure 2 (cont.)
c)

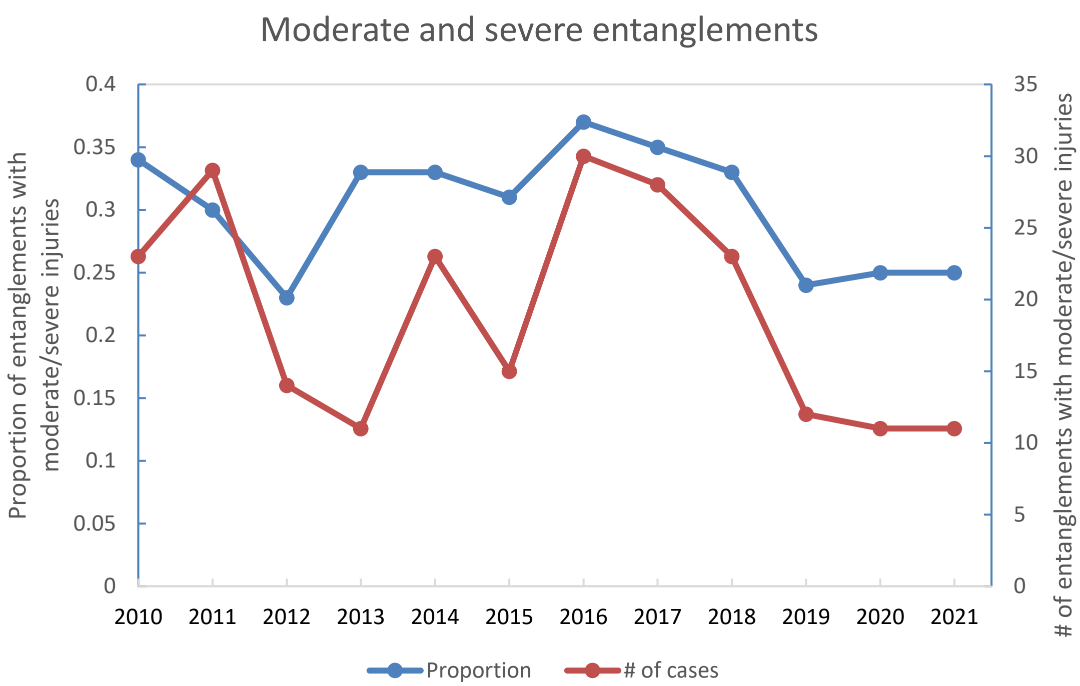


Figure 2 (cont.)
d)

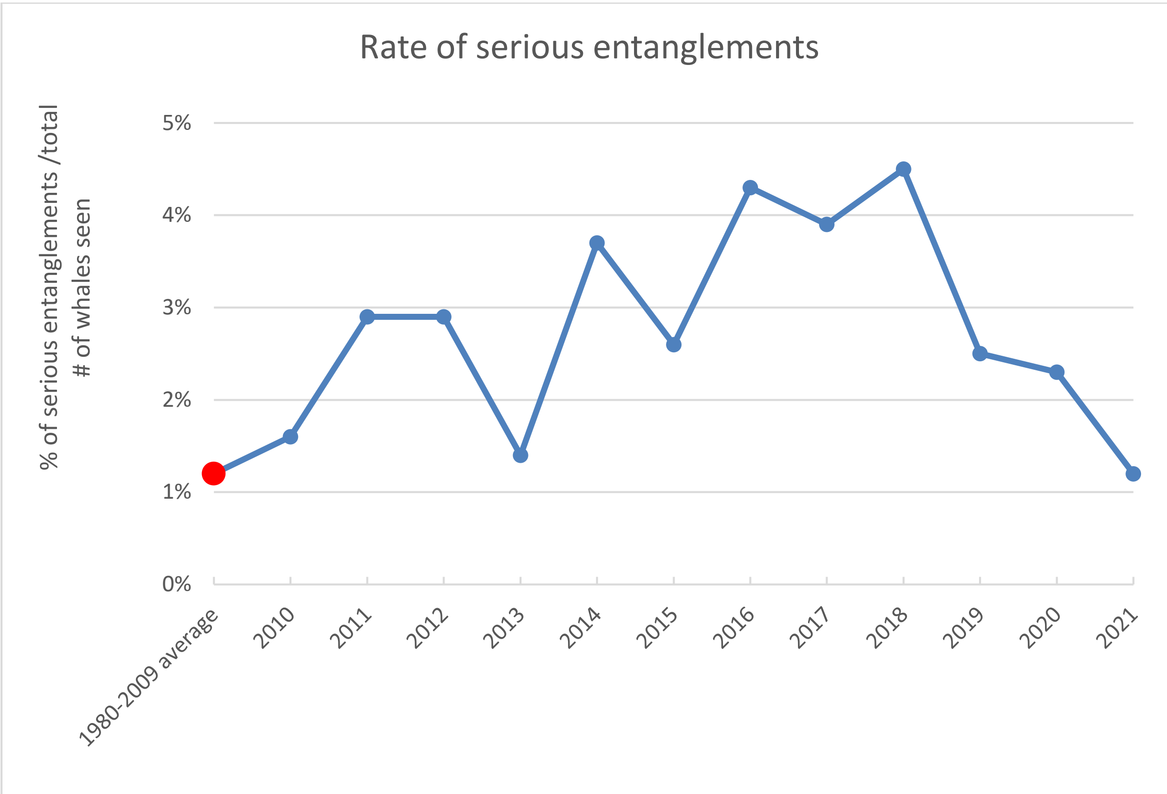


Figure 2 (cont.)
e)

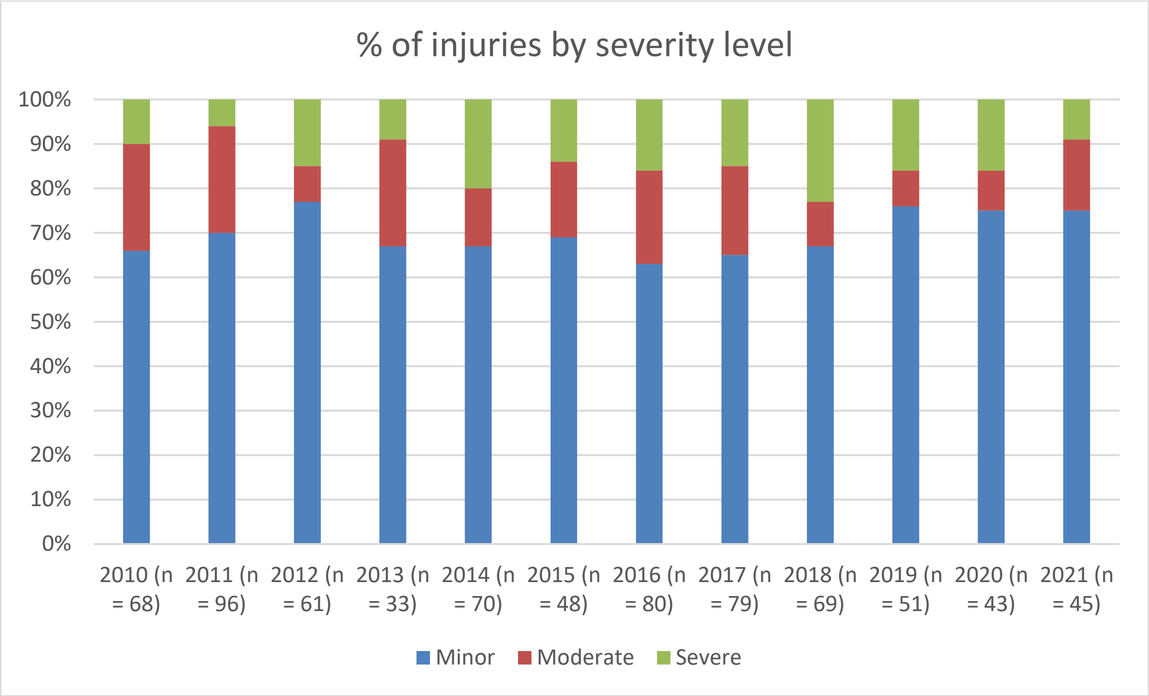


Figure 2 (cont.)
f)

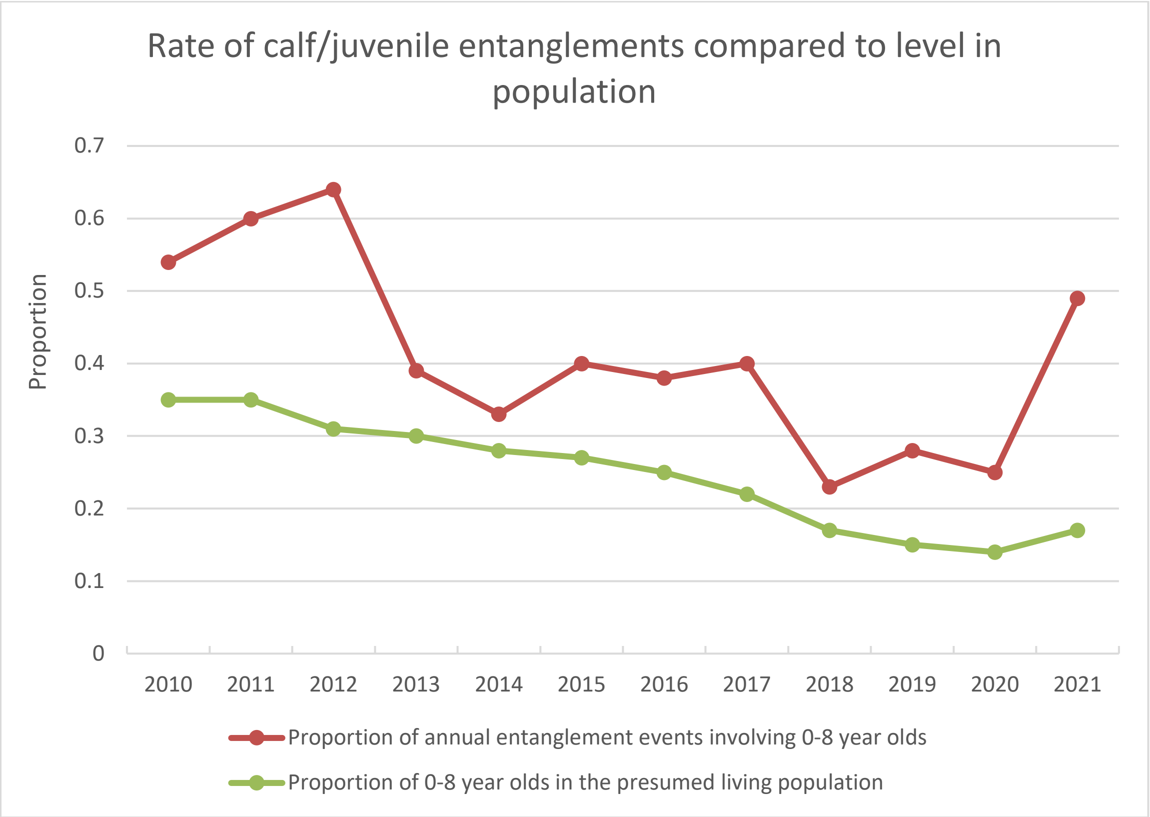


__Figure 3.__ Severe injuries caused by entanglement (no attached gear) documented in 2021. Note: NEA/WHOI = New England Aquarium/Woods Hole. Photos are noted with observer and date.

Catalog # Name	**Sex**	**Birth year**	**Date of entanglement detection (date seen prior to injury)**	**Age at entanglement detection**	**Location when detected/Observer**
2223 Calvin	Female	1992	18 Mar 2021 (27 Jun 2020)	29 years old	Cape Cod Bay/ NEA/WHOI

Description:
This 29-year-old female was seen with granulated, nearly healed severe scarring around the peduncle with additional minor scarring at the head. There remained some deeper areas tinged with red indicating the injuries were not fully healed. She was seen in 2022 and did not not appear to be in declining health although the peduncle region was not well documented. She has experienced seven previous entanglements, one with attached gear in 2000 which led to moderate injuries with the remaining six cases resulting in minor injuries.

Nearly healed peduncle injuries-30 Mar 2021 (CCS)

Ped injuries at 6 mths still with red areas - 9 Aug 2021 (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

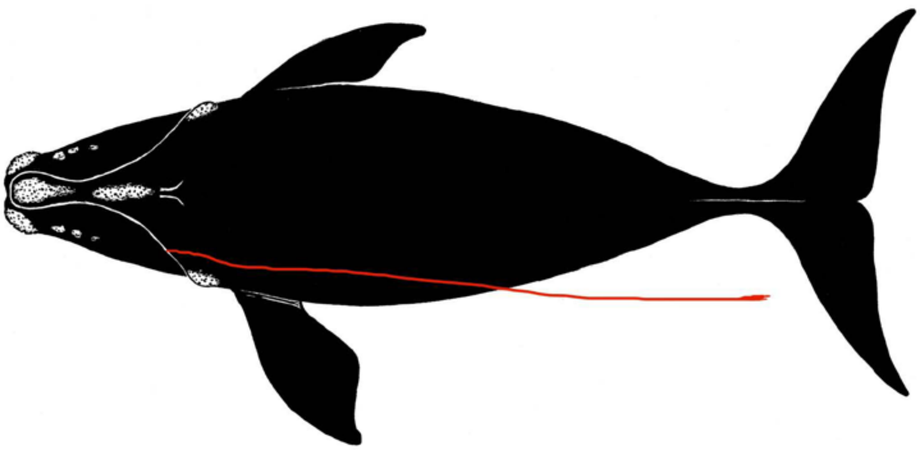
This assessment describes the layout of gear on a whale and does not take into account associated wounds. The configuration of gear on whale is generally used to assess the need for intervention, indicates how the whale may have become entangled, and may be used to make predictions about the fate of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

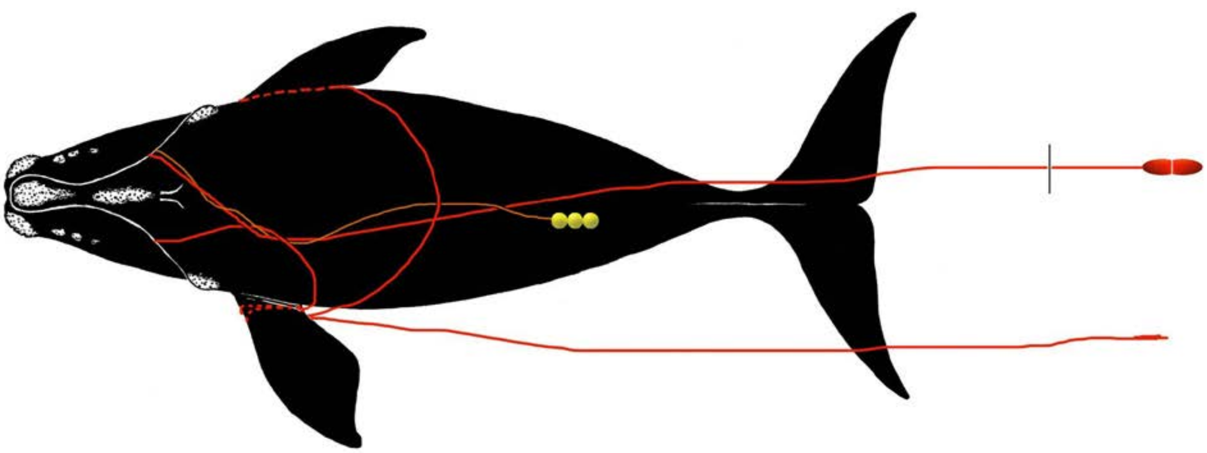
Low risk cases were those involving no tight wraps, only one attachment point, gear trailing less than one body length, and no heavy gear attached. In these cases, gear was often shed.

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

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Introduction

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

The main avenues of communication that presently exist are:

1) 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) Dead right whales – when a right whale carcass or an emerging situation that could result in a carcass occur, initial emails are sent by NOAA Fisheries or DFO to a list of persons who will be involved in coordination of a necropsy and to assist with identification of the individual whale. Near real-time identifications of the individual whales involved in these cases (Task 4 of this report) are disseminated to the initial email inquiry as soon as they are made by the NEAq team.
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 – since 2022, we have been providing NOAA Fisheries with images and sighting information of entanglement and vessel strike cases that were not included as a serious injury under NOAA criteria, i.e. more likely than not to die from their injuries. These included all living right whales with moderate or severe entanglement injuries or shallow or deep propeller cuts or other whales in 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 as a morbidity 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/2017-2024-north-atlantic-right-whale-unusual-mortality-event) and we will continue to provide updates. As of early 2024, a total of 51 morbidity cases have been added during this UME and additional cases are under evaluation.

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 the UME site 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. To calculate these durations, the most recent information available for the given case is used and reflects 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 without gear to either date with line gone if known 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 NOAA Fisheries under this Task, we have continued to develop entanglement case studies for all right whales seen with attached gear regardless of whether gear was collected or not. These case studies, which date 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 2021 events, there are now 141 case studies posted.

For 2021, we have created three entanglement case studies. We also reviewed one whale that had severe entanglement injuries and no attached gear. We did not do a case study for this animal;

instead, we included pertinent information about her life history and condition along with images of her injuries under Task 2.

In addition, we have continued to create vessel strike case studies and present three case studies for the 2021 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. With NOAA Fisheries support, this work is underway by NEAq with the expertise of a naval architect and mechanical engineer, Paul Kamen, of Surface Propulsion Analysis, who is familiar with vessel strike injury forensics.

The evolution of the Anthropogenic Events Database continues. Case studies, necropsy reports and findings, 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.

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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 observed prior without injuries**	**Date/area first observed entangled**	**Last date seen and comments**
1803	33	Male	No	Unknown/pot/trap	07 Apr 2019 / CCB	11 Jan 2021 / GA	Not seen/likely dead
3560	16	Female	Yes	Unknown/ unknown	24 Jul 2020 / GSL	10 Mar 2021 / CCB	21 Sep 2022/ SNE New entanglement, poor condition and likely dead
4615	5	Male	No	Canada/ unknown	13 Jul 2021 / GSL	13 Jul 2021 / GSL	Not seen/likely dead

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

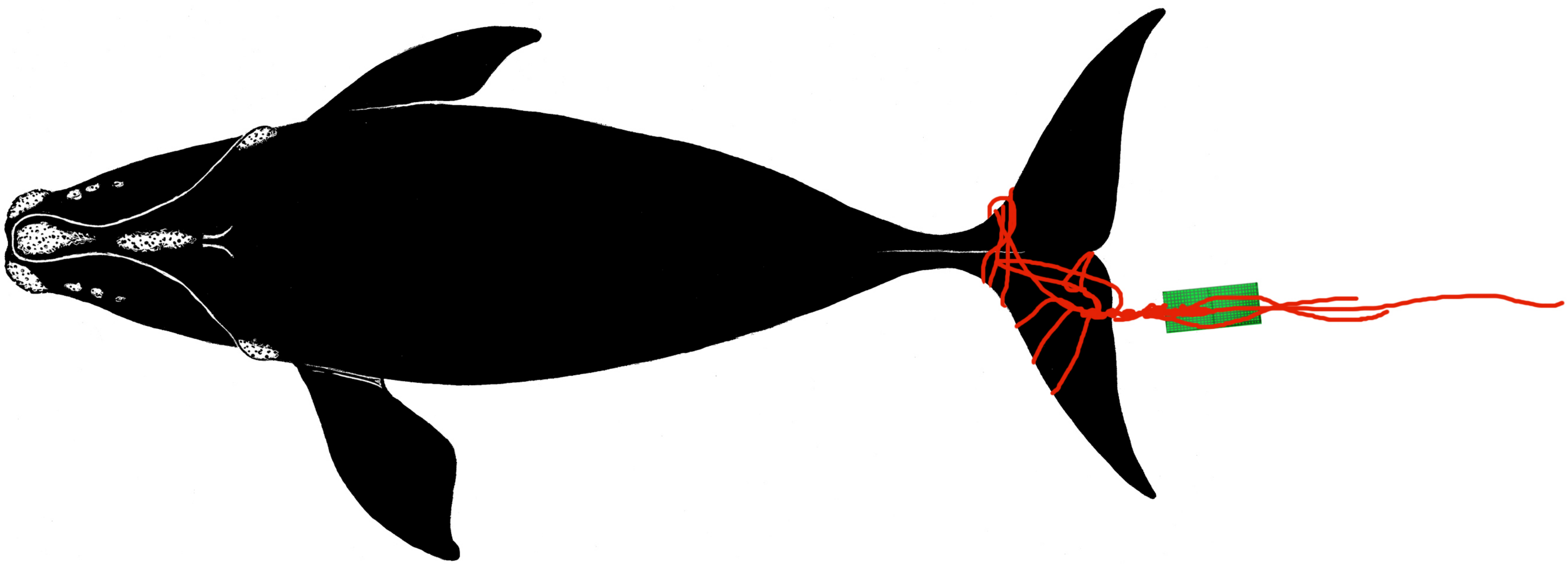
Right Whale Catalog #	Age	Sex	Country of origin	Estimated or known vessel size	Date/area observed prior without injuries	Date/area first observed with injuries	Last date seen and comments
1209	41+	Female	Unknown	Likely <40 feet	5 Sep 2020 / GSL	7 Mar 2021 / MB	22 Nov 2022/ alive
3230	19	Female	US	54 feet	12 Feb 2021 / FL	16 Feb 2021 / GA	Not seen/fate uncertain
5130	0	Male	US	54 feet	12 Feb 2021 / FL	13 Feb 2021 / FL	Dead

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

Species	Right Whale	Whale ID	1803

Date first observed entangled (date seen prior without gear)	11 Jan 2021 (7 Apr 2019)				
Sex	Male	Birth year	1988	Age at entanglement	33

Case study ID	CCS	NMFS	GEAR ID
	WR-2021-02	E02-21	
Gear sample collected?	No	Gear type	Trap/pot, unknown



Reproductive prior to/after entanglement detection					
Entanglement injury severity	Severe				
Entanglement configuration risk	High				
Wound severity	Mouth	Head/ rostrum	Flippers	Body	Flukes
	Low	None	Low	None	High
Duration of time carrying gear	Minimum 1+ day, maximum 644 days				
Disentangled?	No				
Status	Likely dead, no additional sightings				
Number of prior entanglements	3				

Entanglement configuration	Tight wraps around peduncle and left fluke blade, single trap aft of flukes, and line trailing ~60 ft
Anchoring points	Tail
Gear configuration confidence	High
Remaining questions	
Comments	Whale in poor condition

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

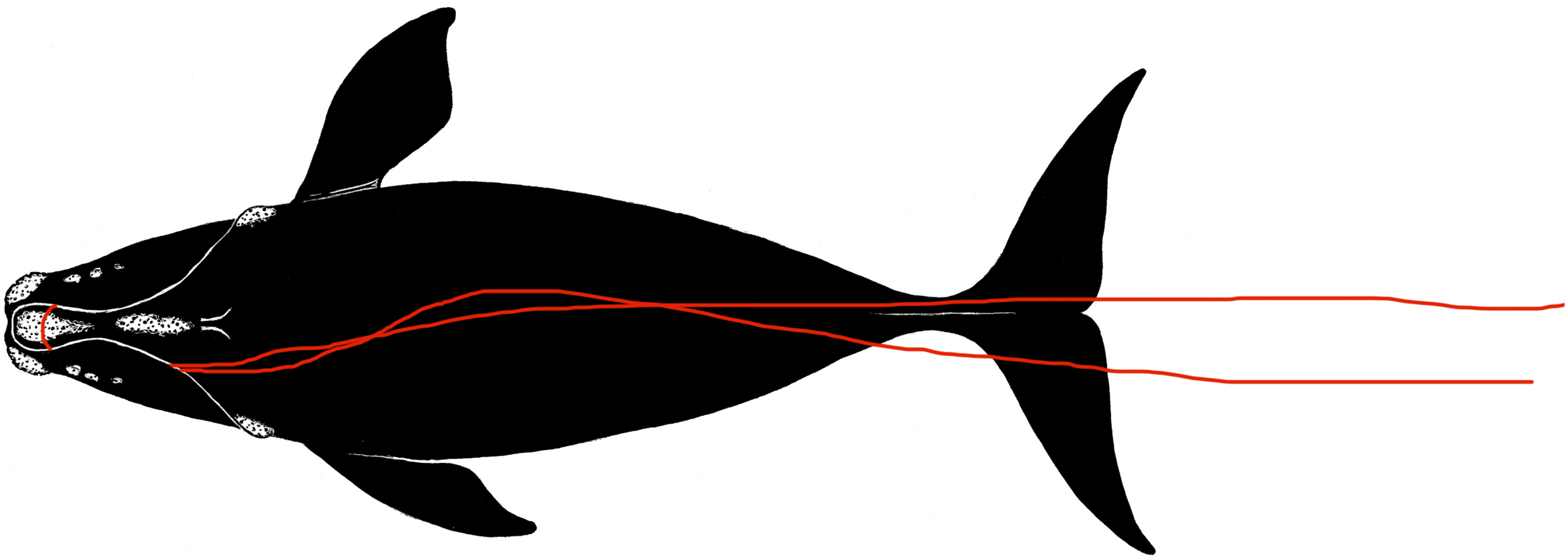
This case study was developed at the New England Aquarium with financial support from NOAA Fisheries. Whale data were provided by the North Atlantic Right Whale Consortium (www.narwc.org). All images are listed with appropriate credit information and taken under permit. Retrieved gear is assessed and 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 Jan 2021   CMARI

Species	Right Whale	Whale ID	3560

Date first observed entangled (date seen prior without gear)	10 Mar 2021 (24 Jul 2020)		
Sex	Female	Birth year	2005
Age at entanglement	16		

Case study ID	CCS	NMFS	GEAR ID
	WR-2021-04	E04-21	
Gear sample collected?	Yes	Gear type	Unknown



Reproductive prior to/after entanglement detection	Yes/ No				
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 560 days, maximum 787 days				
Disentangled?	Yes, partial in Mar and May 2021				
Status	Likely dead, new entanglement on 21 Sep 2022				
Number of prior entanglements	4				

Entanglement configuration	Single tight wrap embedded in forward rostrum, two lines trailing, one at least 300 feet
Anchoring points	Mouth
Gear configuration confidence	High
Remaining questions	Seen with calf in Dec 2021; calf disappeared by Jul 2022
Comments	3560 in very poor condition in Sep 2022

Polymer type	Copolymer	
Gear component	Likely endline	
Rope diameter (inches)	5/8	
Breaking strength (lbs)	Tested	
	New	9 000

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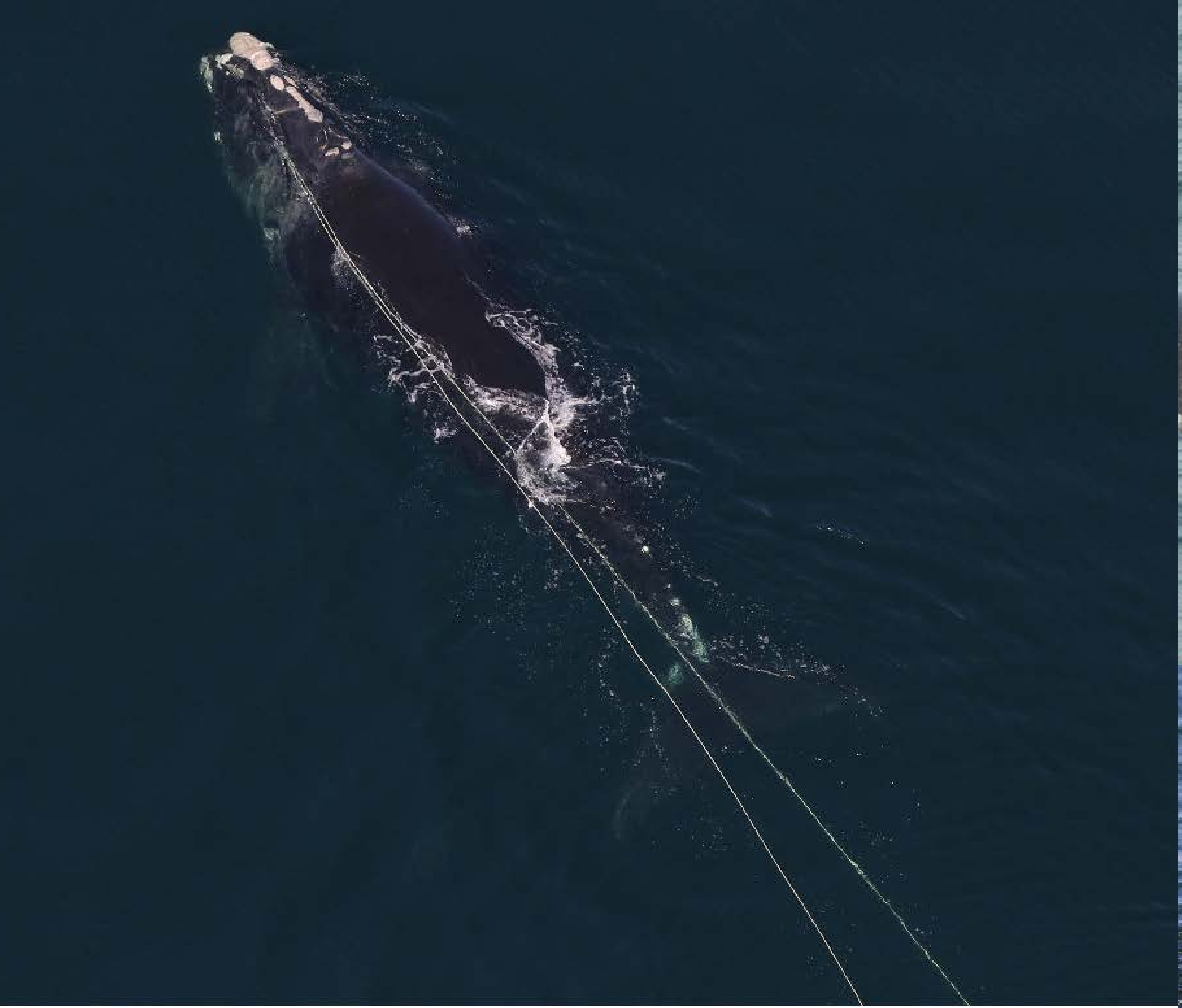


10 Mar 2021 CCS

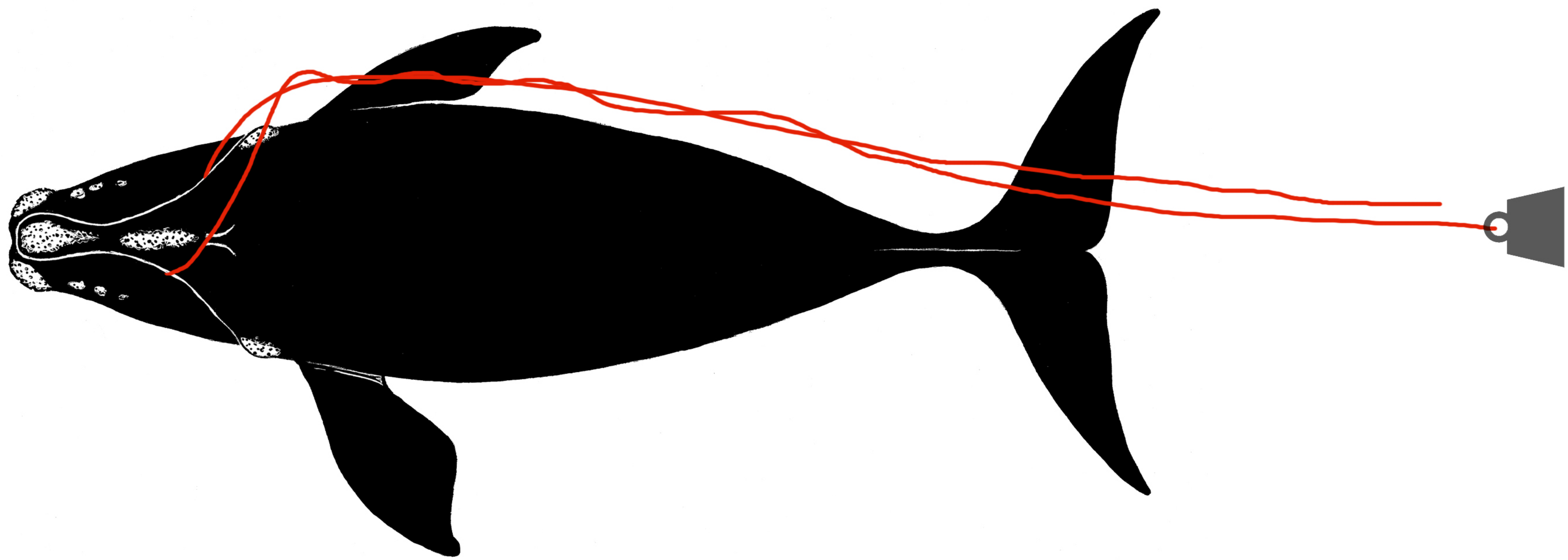
5 Aug 2021 NEA/CWI

19 Jan 2022 FWRI

Species	**Right Whale**	**Whale ID**	**4615**

Date first observed entangled (date seen prior without gear)	13 Jul 2021 (13 Jul 2021)		
Sex	Male	Birth year	2016
Age at entanglement	5		

Case study ID	CCS	NMFS	GEAR ID
	WR-2021-13	E13-21	
Gear sample collected?	No	Gear type	Canadian, unknown



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	Low	High
Duration of time carrying gear	Minimum 2 days, maximum unknown				
Disentangled?	No				
Status	Likely dead, no additional sightings				
Number of prior entanglements	4				

Entanglement configuration	Single tight wrap over aft rostrum with rope trailing. Initially wraps at peduncle but gone by day 2
Anchoring points	Mouth, tail (initially)
Gear configuration confidence	High
Remaining questions	Likely weighted gear attached
Comments	Same day entanglement; active thrashing, rolling, head raises, blood at tail stock; still thrashing next day

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

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13 Jul 2021 GLL-DR

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

Species	**Right Whale**
Whale ID #	**1209**
Necropsy/Other ID #	

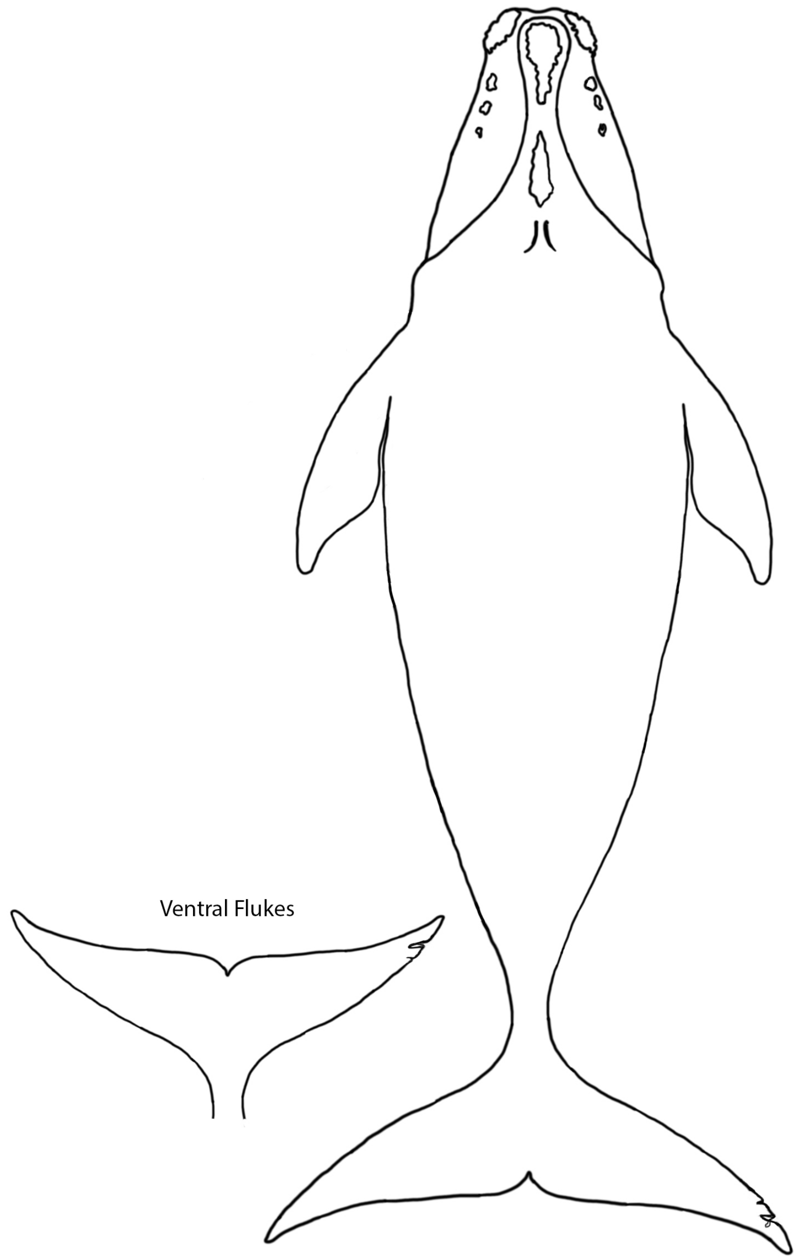
Sex	Female
Birth Year	

Age at Detection w/ Injury	41+
Date First Detected w/ Injury	7 Mar 2021
Date Seen Prior w/o Injury	(5 Sep 2020)

Reproductive Prior Injury Detection	No
Reproductive After Injury Detection	No

Relative Wound Depth	Shallow
Body Region(s) With Injury	Tail
Description of Injury	Two cuts at leading edgge of right fluke tip
Status/Year Last Seen	Alive / 2022
MMPL Vessel Size Category	
Vessel Size Range	
Max Wound Length (cm)	

Vessel Related Comments	Unknown vessel size although wound pitch is low and may reflect a small sized vessel
Whale Related Comments	A few inches of right fluke tip at vicinity of cuts have fallen off



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2 Apr 2021 P. Flood

3 Apr 2021 P. Flood

Species	**Right Whale**
Whale ID #	**3230**
Necropsy/Other ID #	

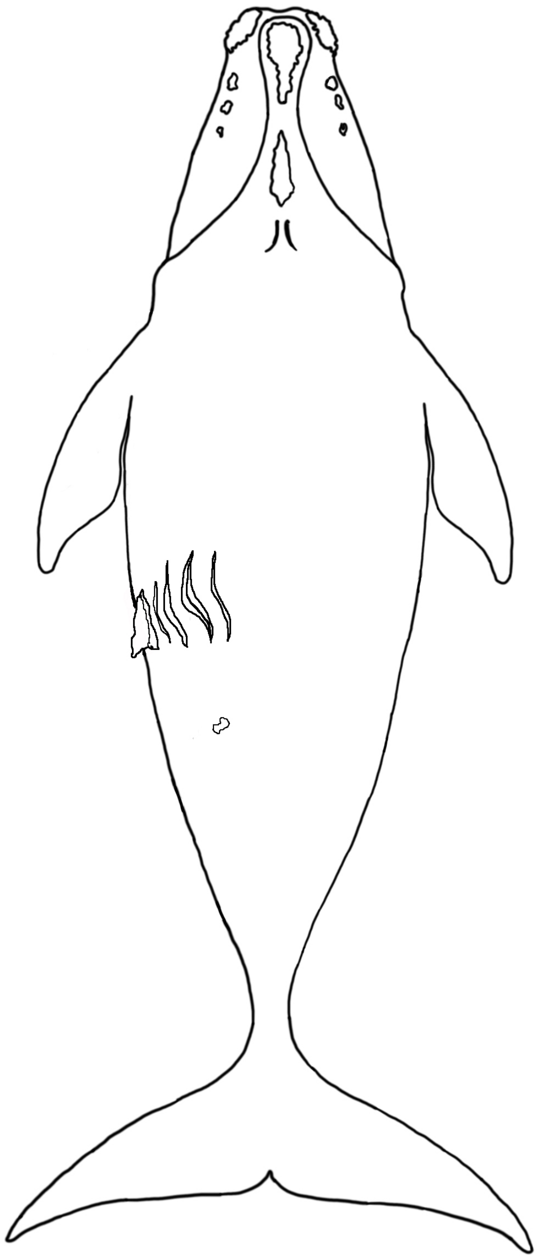
Sex	Female
Birth Year	2002

Age at Detection w/ Injury	19
Date First Detected w/ Injury	16 Feb 2021
Date Seen Prior w/o Injury	(12 Feb 2021)

Reproductive Prior Injury Detection	Yes
Reproductive After Injury Detection	No

Relative Wound Depth	Deep
Body Region(s) With Injury	Body
Description of Injury	Several deep propeller cuts on lower left flank
Status/Year Last Seen	Likely dead / 2021
MMPL Vessel Size Category	Category III (40-65 feet)
Vessel Size Range	54 foot twin engine sportsfisher
Max Wound Length (cm)	

Vessel Related Comments	Vessel was operating at 21 knots at dusk on Feb 12 off St Augustine, FL when strike occurred. Strike caused the vessel to take on water and captain had to run it onto sandbar to avoid sinking. Passengers were on board.
Whale Related Comments	This female's calf was also struck by same vessel on Feb 12 and died. Difficult to get good images of this whale's injury because of its location on body.



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.

16 Feb 2021 CMARI

16 Feb 2021 GA DNR

Species	**Right Whale**
Whale ID #	**5130 (2021 calf of 3230)**
Necropsy/Other ID #	

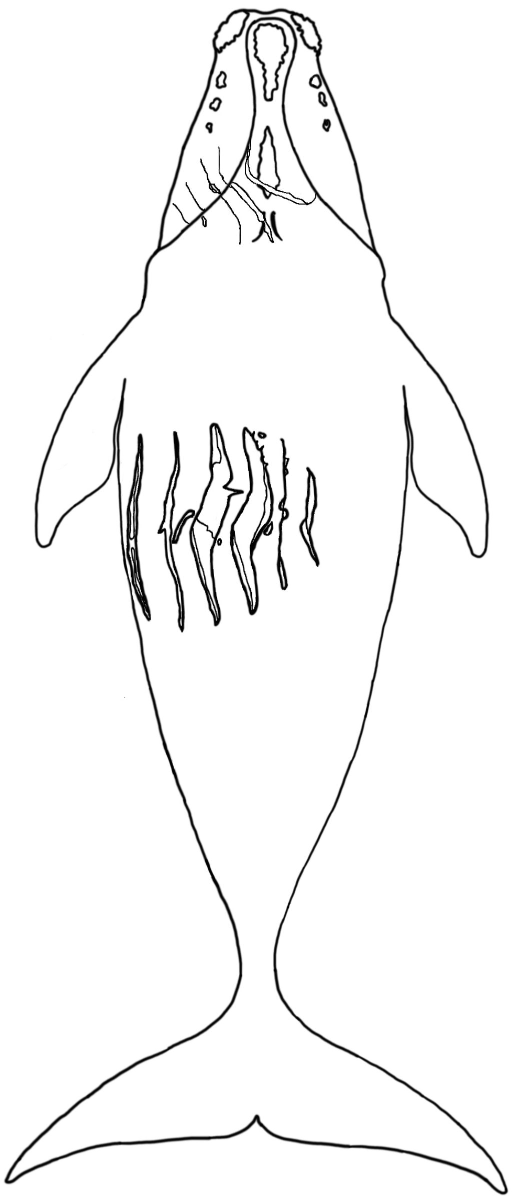
Sex	Male
Birth Year	2021

Age at Detection w/ Injury	0
Date First Detected w/ Injury	13 Feb 2021
Date Seen Prior w/o Injury	(12 Feb 2021)

Reproductive Prior Injury Detection	n/a
Reproductive After Injury Detection	n/a

Relative Wound Depth	Deep
Body Region(s) With Injury	Body
Description of Injury	Propeller cut
Status/Year Last Seen	Dead
MMPL Vessel Size Category	Category III (40-65 feet)
Vessel Size Range	54 foot twin engine sportsfisher
Max Wound Length (cm)	85 cm (head); 107 cm (body)

Vessel Related Comments	Vessel was operating at 21 knots at dusk on Feb 12 off St Augustine, FL when strike occurred. Strike caused the vessel to take on water and captain had to run it onto sandbar to avoid sinking. Passengers were on board.
Whale Related Comments	Calf struck and killed with two propeller cut series at head and body. Carcass found on shore the next morning. Mother also struck and suffered propeller cuts at left flank. She was last observed alive on 16 Feb 2021



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All images are listed with appropriate credit information and taken under permit. Please contact Amy Knowlton (aknowlton@neaq.org) for potential use.

13 Feb 2021   Associated Scientists

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

Prepared by:
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Objectives

The goals of this work were to provide near real-time matching for biopsy efforts, entangled, injured, sick, or dead right whales sighted from September 1, 2022 to August 31, 2023. 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.

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). Near real-time matching also supports NEAq's efforts to track and monitor whale injury (work conducted with support from a foundation) and, beginning in 2023, those analyses are now provided to the Unusual Mortality Event team for determination of whether they constitute serious injury or morbidity. 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 (CMARI) 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 2022/2023 season was sent to all survey teams on November 2, 2022, 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 was sent to team leaders to download it. In the past, we also provided 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 from the Carolinas or points south, not counting calves of the year. We were able to match/confirm 39 to currently cataloged whales and eight to calves from previous years – all of which will be cataloged in the near future. One of those eight whales was originally given a season code (S083) but was later tentatively matched to a yearling. In addition to the 47 whales plus 11 calves associated with a mother, there was also an additional lone calf with no visual matching features that died shortly after its first sighting. 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. All 11 calves of the year, two adults, and two possible yearlings were biopsied on the calving ground. Aside from the mother/calf pairs, three of the other 38 whales still needed to be biopsied by the end of the season, and those whales were only sighted off the Carolinas. A list of biopsied animals is included as Appendix II.

In the past couple of years, HDR Environmental has been contracted by the U.S. Navy to monitor marine mammals along the coasts of Maryland and Virginia. In previous years, they had occasionally notified us of sightings. Beginning in January 2023, HDR began consistently sharing their sightings with the Florida Fish & Wildlife's (FWC) aerial survey team, and those sightings were subsequently added to the southeast U.S. matching table. FWC performs most of their initial matches, but NEAq is occasionally asked to match or confirm particular sightings. We provided confirmations for nine of the 25 right whales sighted by HDR. Only six of the 25 were also seen by southeast U.S. teams. One whale that required our expertise was a small whale that we matched to a calf from the previous season. That yearling, the 2022 calf of Arpeggio (#2753), was later documented inside Chesapeake Bay.

Feeding grounds

We continued our rapid matching work to support darting efforts in Cape Cod Bay (CCB) and the Gulf of St. Lawrence (GSL). In Cape Cod Bay, the Northeast Fisheries Science Center (NEFSC) biopsy effort went forward and we continued our photo-identification support for the Woods Hole Oceanographic Institution photogrammetry work. In March of 2023, NEFSC initiated a shared folder on Google Drive for survey teams working in New England waters. Through this folder, we provided updated biopsy lists, and a table was created to track recent sightings of whales that need to be biopsied.

Generally, all survey groups working in Cape Cod Bay are able to identify their whales, but good communication between teams both on and off the water continues to be important. One example is when a juvenile whale was seen by multiple boat teams in Cape Cod Bay, but with some communication, it was matched to a young whale that had already been biopsy sampled in the southeast U.S. just a couple of months prior. This avoided unnecessary duplicate sampling.

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 2023, as well as providing our assessments of which whales should not be tagged due to apparent poor health. Two of our team members joined on board with two research groups in the summer of 2023. One joined a Dalhousie University tagging effort aboard the *J.D. Martin* and support vessel by providing identifications and health assessments on potential tagging targets. The other team member continued a joint survey effort with the Canadian Whale Institute to identify biopsy candidates. This team member was able to identify and photograph a whale with a concerning wound at the site of a recent tagging. The identification and images were promptly shared with the tagging crew.

Finally, we also provided matching assistance to the Department of Fisheries and Oceans Canada (DFO)- providing matches or confirming their tentative matches upon request. This allowed them to maintain a comprehensive list of all the whales seen in the Gulf.

Entangled or Entrapped Whales
During this contract period, there were five reports of newly entangled live right whales and two previously entangled or entrapped whales that needed rapid identification (Table 1).

Table 1. List of five newly entangled or entrapped whales, and two whales with additional entanglements that were first reported between September 1, 2022, and August 31, 2023, for which matching attempts or confirmations were made quickly.

Date	Incident	ID	Location and comments	ID Date	Darted Previously?
9/21/2022	Additional entanglement	3560	SNE - second set of gear on top of previous entanglement	9/21/2022	Yes
1/8/2023	First entangled	4904	NC - SEUS EWS sighting. Whale's poor condition made ID more challenging.	1/9/2023	Yes
1/20/2023	First entangled	3812	GA - EWS sighting	1/20/2023	Yes
1/27/2023	First entangled	1218	NC - EWS sighting	1/27/2023	Yes
2/9/2023	First entangled	4545	SNE - NEFSC/T sighting	2/9/2023	Yes
7/15/2023	First entangled	4042	GSL – Sighted by JDM (DU/SF)	7/15/2023	Yes
7/30/2023	Additional entanglement	4545	GSL – second set of gear	7/31/2023	Yes

All identifications were made within one or two days, and those identifications were relayed to all relevant parties as soon as they were confirmed.

Dead Whales
During this contract period, two dead right whales were discovered.

Table 2. List of dead whales that were reported between September 1, 2022, and August 31, 2023, 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?
1/7/2023	dead	D-VGT-449	NC - Neonate calf floating under a pier (seen alive & alone 4 days prior)	n/a	no
2/12/2023	dead	3343	Virginia Beach, VA – necropsy determined blunt force trauma	2/12/2023	yes

Details of the neonate can be found in the discussion section.

Injured or Sick Whales
In addition to the entangled whales above, there were six sightings of injured whales for which rapid identification attempts were made during the reporting period (Table 3).

Table 3. List of sick or injured whales, other than those seen entangled in fishing gear, that were reported between September 1, 2022, and August 31, 2023, 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?
12/22/2022	Entanglement scars	4310	FL - with new entanglement scars	12/22/2022	yes
3/22/2023	injuries	4446	SNE with head wound. Also seen in GSL in July	7/20/2023	yes
6/12/2023	injuries	2930	GSL - Overall poor health	6/12/2023	yes
6/13/2023	injuries	4510	GSL - Overall poor health	6/13/2023	yes
7/9/2023	tag site	5046	GSL - Tag site looking poor	7/9/2023	yes
7/21/2023	injuries	4040	GSL - new fluke injuries	7/21/2023	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 60 opportunistic sightings during this contract period. Some of the interesting rapid match results, or attempts, for these sightings include:

1) Video of a whale off Cape Breton was taken on September 3, 2022, and shared with DFO. This was then forwarded to our team as the thrashing behavior of the whale was concerning of a potential entanglement. The distant video was insufficient to confirm an entanglement or an identification but was important to know about in near real-time in case a later sighting could be connected.
2) Two whales, Catalog #4143, and Babushka (#3890) were sighted in the Bay of Fundy in early September 2022. Given the near abandonment of this feeding habitat, we are always interested in whales that still visit the area on occasion.
3) Tripelago (#2614) and calf were seen by a whale watch company in the Bay of Fundy on September 25, 2022. In addition to the reason stated above, fall sightings of calves with their mother can be extremely valuable as the calf's callosity is more established than in younger sightings, which helps match future sightings.
4) The 2022 calf of Arpeggio (#2753) was seen near the mouth of Chesapeake Bay on January 18, 2023. There was concern about further bay incursion at the time, but ultimately this sighting will be helpful to match future sightings to the calf.
5) Smoke (#2605) and calf were documented in the Cape Cod Canal on April 2, 2023. This caused the canal to be shut down and, after matching the pair, we realized they had not yet been detected by research teams in the area. This discovery highlights the importance of these opportunistic sightings.

Discussion

Our matching support for the broader calving ground region included the match or confirmation of the 47 whales seen (Appendix I) and 15 darting events (Appendix II). In addition, there was one unidentified days-old abandoned calf that had never been seen with its mother and had no identifiable features. This calf was originally reported by the public on January 3, 2023, off the coast of North Carolina and was later documented by the CMARI North Carolina aerial survey team that was already flying in the area. The survey team documented the calf well and then searched the area to locate a potential mom. No adult whales were found to be in the area, and the vessels who had been following the calf had also lost sight of the calf. On January 7, 2023, the calf was found dead underneath a pier in NC, near its original sighting location, and a necropsy was conducted 2 days later. Genetic samples were collected in hopes of matching it to a known female; the initial results discovered one potential candidate, but a more thorough statistical analysis is underway before determining the maternity.

For a fourth year in a row, several of the calves from the previous year were seen during the calving season; eight of the 15 (53%) calves from 2022 were photographed in the southeast U.S. in the winter of 2022/2023. These high-quality images of yearlings have proven to be significant in the ability to catalog the young whales in a shorter timeframe. With our prompt communication with the SEUS research teams, we can request certain body parts be photographed at future sightings to help confirm tentative identifications. One of the yearlings seen was originally given the season code S083. This sighting was discovered by NEFSC's vessel team. After being unable to match it to any known yearlings, they darted the whale. We were unable to match it from the initial sighting. After taking more time with the photographs, and subsequent sightings, it was tentatively matched to a 2022 calf, but the genetic sample will help confirm that uncertain match. This whale and her mother Cyclops (#3220) had only been seen together through the calf's first month; neither were seen after January 2022. Matching calves that were only photographed when they were very young is extremely challenging, thus warranting another biopsy.

In the above example, the young whale had likely been biopsied as a calf, but these duplicate samples continue to be helpful during the challenging efforts of matching a young whale to its younger self. Given how much variation there is in a whale's physical features in its initial years, photographic matches remain a challenge and a lack of information often leads to delays in the cataloging of whales. Duplicate samples have been very effective in looking for any photo-identification errors in the Catalog in the past (Frasier et al. 2009). Because of this, we continue to encourage biopsy teams to dart any young-looking whales that can't be easily identified.

The in-season communication with field teams is especially valuable for adding young whales to the catalog. We can help identify and keep track of young whales as they are sighted, and all these sightings are referenced when determining when a new whale can be cataloged. Given that teams do not submit data until the end of their season, if we were to wait until sightings are officially submitted there would be a much longer delay in cataloging whales. An example of this is the cataloging of #5015. Several sightings of a whale known by season code M120 had been shared with us from several areas including Cape Cod Bay and the Gulf of St. Lawrence (GSL). This whale was given the season code when we were unable to match it to any cataloged whale. Thanks to a vessel sighting by our team member in GSL in 2023, we were able to finally connect the sightings of M120 to the 2020 calf of Harmony (#3115), and confidently add it to the catalog- even before all sightings data had been fully processed.

In addition to our relationships with various research groups, there is great value in having our team members in the field alongside our colleagues. Our vast and detailed knowledge of the individual whales in the Catalog provides prompt real-time identification, especially when vessels are too distant to communicate with shore-based teams. In the 2023 GSL season, two of our team members provided valuable on-water feedback. One researcher worked on a small vessel deploying suction cup tags and they were able to make quick decisions on whether a whale looked healthy enough to tag. This allowed us to protect unhealthy whales from unnecessary stress from a tagging event. Another researcher was on board with the Canadian Whale Institute (CWI) identifying whales for biopsy sampling and health assessments. Their real-time matching alerted us to several new injuries and helped us to narrow down the timing of injuries. The CWI/NEAq team did not come across any whales that needed to be biopsy sampled but one example of an injury was Jagger (Catalog #5046) who was seen with a blister erupting on its back. With some work by our team, it was determined that the injury was likely caused by an implantable tag that had been placed 2 weeks prior. This led to feedback to the tagging team and a priority to monitor other tagged recently tagged whales.

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, Lisa Conger, Heather Foley, Alison Ogilvie, and Allison Henry (Northeast Fisheries Science Center); Brigid McKenna (Center for Coastal Studies); Orla O'Brien (New England Aquarium); Liz Thompson, Mylene Dufour, Stephanie Ratelle, and Christian Ramp (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
1012	>45	2017	Y	Y	Calf born between Dec 18 and Jan 20	2022-12-18-CMARI-NC Eg A	19-Dec-22
1204	>41	2019	Y	Y	With calf at her first sighting	2023-01-07-CMARI-GA Eg A	08-Jan-23
1208	>42	2012	Y	Y	With calf at her first sighting	2022-12-7-CMARI-GA Eg C	07-Dec-22
1701	36	2015	Y	Y	With calf at her first sighting	2022-12-29-CMARI-GA Eg A	30-Dec-22
1711	36	2017	Y	Y	Calf born between Dec 7 and Dec 17	2022-12-07-CMARI-GA Eg B	07-Dec-22
1812	>35	2016	Y	Y	Calf born between Dec 7 and Dec 29	2022-12-07-CMARI-GA Eg A	07-Dec-22
2029	33	2011	Y	Y	Calf born between Dec 7 and Dec. 29	2022-12-17-FWRI-A Eg A	07-Dec-22
2605	27	2015	Y	Y	Calf born between Nov 22 and Dec. 26	2022-11-22-CMARI-NC Eg A	23-Nov-22
3293	>21	2011	Y	Y	Calf born between Dec 6 and Dec. 17	2022-12-06-CMARI-GA Eg A	07-Dec-22
3370	>20	2019	Y	Y	With calf at her first sighting	2022-12-08-FWRI-A Eg A	08-Dec-22
4340	10	N/A	Y	Y	With calf at her first sighting	2022-12-30-MRC Eg A	01-Jan-23

Appendix I (cont.)

Other whales						
Whale ID	Age	Sex	Darted?	Comments	Confirmed sighting	Date confirmed
1158	>42	F	Y		2023-1-3-CMARI-GA Eg C	4-Jan-23
1934	34	F	Y	Only Carolinas- first off SC, then off NC	2023-2-7-CMARI-SC Eg A	8-Feb-23
3194	26	F	Y	First seen off SC then GA and FL	2022-12-17-CMARI-SC Eg D	18-Dec-22
3292	21	C	Y		2023-1-11-FWRI-A Eg C	12-Jan-23
3503	18	F	Y	First seen off NC then SC, GA, FL	2022-11-22-CMARI-NC Eg B	23-Nov-22
3520	18	F	Y	Only seen off NC	2023-2-19-CMARI-NC Eg A	20-Feb-23
3730	16	F	Y		2023-1-28-CMARI-GA Eg B	29-Jan-23
4170	12	F	Y	Only seen off NC	2023-1-2-CMARI-NC Eg D	3-Jan-23
4310	10	F	Y		2022-12-22-FWRI-A Eg C	23-Dec-22
4612	7	F	Y	Only Carolinas- first off SC, then off NC	2023-2-7-CMARI-SC Eg B	8-Feb-23
1423	>43	U	N	Seen by HDR off VA/NC. Not seen by EWS.	2023-2-26-HDR- Eg	27-Feb-23
1177	>42	U	N	Only seen off NC	2023-1-10-CMARI-SC Eg A	11-Jan-23
1218	>42	M	Y	Seen and disentangled off NC	2023-1-27-CMARI-NC Eg A	27-Jan-23
1250	41	M	Y	Only seen off SC	2023-1-29-CMARI-SC Eg A	30-Jan-23
1328	>40	M	Y	Only seen off NC	2022-12-27-CMARI-SC Eg A	28-Dec-22
2920	>24	M	Y	Only seen off NC	2023-2-9-CMARI-NC Eg C	10-Feb-23
2950	>24	M	N	Only seen off NC	2023-1-20-CMARI-NC Eg A	21-Jan-23
3343	20	M	Y		2022-12-26-CMARI-GA Eg D	27-Dec-22
3617	17	M	Y	First seen off NC then FL	2022-12-30-Public- Eg A	2-Jan-23
3651	17	M	Y	Only seen off SC	2023-1-29-CMARI-SC Eg A	30-Jan-23
3812	15	M	Y		2023-1-20-FWRI-A Eg C	20-Jan-23
3981	14	M	Y	Only seen off NC	2023-1-2-CMARI-NC Eg C	3-Jan-23
4130	12	M	Y		2023-1-17-FWRI-A Eg B	18-Jan-23
4440	9	M	Y		2022-12-26-CMARI-GA Eg C	27-Dec-22
4539	8	M	Y	Only seen off NC	2023-2-9-CMARI-NC Eg D	10-Feb-23
4650	7	M	Y	First seen off NC, then FL	2023-1-2-CMARI-NC Eg B	3-Jan-23

Appendix I (cont.)

Other whales							
27	4904	4	F	Y	Only seen off NC, entangled	2023-1-8-CMARI-NC Eg A	9-Jan-23
28	4980	4	U	Y		2023-1-30-CMARI-GA Eg J	31-Jan-23
29	2022CalfOf1245	1	U	Y		2023-2-2-FWRI-A Eg A	3-Feb-23
30	2022CalfOf1817	1	U	Y	First seen off NC, then GA	2023-1-29-CMARI-NC Eg B	30-Jan-23
31	2022CalfOf2040	1	U	Y		2023-1-10-CMARI-GA Eg B	10-Jan-23
32	2022CalfOf2614	1	U	Y	Only seen off NC	2023-1-8-Public- Eg A	10-Jan-23
33	2022CalfOf2753	1	U	Y		2023-1-28-CMARI-GA Eg A	29-Jan-23
34	2022CalfOf3220*	U	U	Y	AKA S083	2023-2-8-NEFSC-S Eg A	14-Feb-23
35	2022CalfOf3157	1	U	Y		2023-1-17-FWRI-A Eg A	20-Jan-23
36	2022CalfOf3430	1	U	Y		2022-12-18-FWRI-A Eg A	11-Jan-23

* ID tentative due to limited photo-identification data from 2022

Appendix II. List of 15 right whales biopsied off the southeastern U.S. from December 1, 2022 to March 31, 2023.

Count	Whale	Biopsied as:	Date Confirmed
1	2023CalfOf1208	07DEC2022 EgD GDNR	07-Dec-22
2	2023CalfOf3370	09DEC2022 EgB GDNR	09-Dec-22
3	2023CalfOf3293	17DEC2022 EgB GDNR	18-Dec-22
4	2023CalfOf4340	02JAN2023 EgB FWRI/V	03-Jan-23
5	2023CalfOf2029	03JAN2023 EgB GDNR	04-Jan-23
6	2023CalfOf1701	03JAN2023 EgD GDNR	04-Jan-23
7	2023CalfOf1711	05JAN2023 EgB GDNR	06-Jan-23
8	2023CalfOf1812	07JAN2023 EgB FWRI/V	08-Jan-23
9	2023CalfOf1204	07JAN2023 EgB GDNR	08-Jan-23
10	2022CalfOf3430	10JAN2023 EgA FWRI/V	11-Jan-23
11	2023CalfOf2605	11JAN2023 EgB GDNR	13-Jan-23
12	2023CalfOf1012	01FEB2023 EgC FWRI/V	02-Feb-23
13	S083*	08Feb2023 EgA NEFSC-S	09-Feb-23
14	3194	15Feb2023 EgB NEFSC-S	17-Feb-23
15	3503	01MAR2023 EgB GDNR	03-Mar-23

*Later tentatively ID'd as 2022CalfOf3220

Summary

15 biopsied whales

- 11 calves of the year
- 2 adults
- 2 juveniles

Task 5: Final Report on 2021 Right Whale Visual Health Assessment

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Introduction

The Visual Health Assessment (VHA) method was developed as a means to non-invasively assess right whale visual health using photographs routinely taken for photo-identification purposes (Pettis et al. 2004). Analyses of visual health assessment data have allowed us to clarify links between health, reproduction, anthropogenic impacts (fishing gear entanglements and vessel strikes), and survival (Pettis et al. 2004; Rolland et al. 2007; Schick et al. 2013; Rolland et al. 2016; Pettis et al. 2017; Knowlton et al. 2022; Pirotta et al. 2023; Pirotta et al. 2024). 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 protocols and morbidity criteria under the ongoing North Atlantic right whale Unusual Mortality Event.

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 2022. 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 2. 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 area(s), 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 2021 data, pre-2021 data that were added since the last funding period, and a limited number of 2022 batches) were analyzed and the VHA Database is considered complete through 2021.

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. 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 946 batches consisting of 60,947 images from 4,176 sightings of 359 individual right whales were evaluated and scored for visual health parameters for this update, including 39 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 2022 sightings assessed, scored, and entered into the VHA Database, that year is not considered complete and so VHA data through 2021 are summarized in this report.

Database Overview
The updated VHA Database contains 22,451 batches consisting of 82,840 sightings from 1935-2022. The number of batches and associated sightings available to be assessed has varied annually (Figure 1, sample period 1980-2021 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 40% 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 2021 at ~70%. Though relatively insignificant in number, sightings of right whales from land and drones are represented in the Health Assessment Database (total of 1,051 and 814 of 82,840 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
2007	1	6	1
2008	1	15	1
2009	3	8	2
2010	1	5	1
2012	1	1	1
2016	3	16	3
2017	4	17	4
2018	5	27	2
2019	10	76	8
2020	34	124	27
2021	878	3828	343
2022	5	53	5
Total	**946**	**4176**	**398***

*The total number of individual right whales assessed during this update was 359, including repeat samples of 39 individual whales in multiple years.

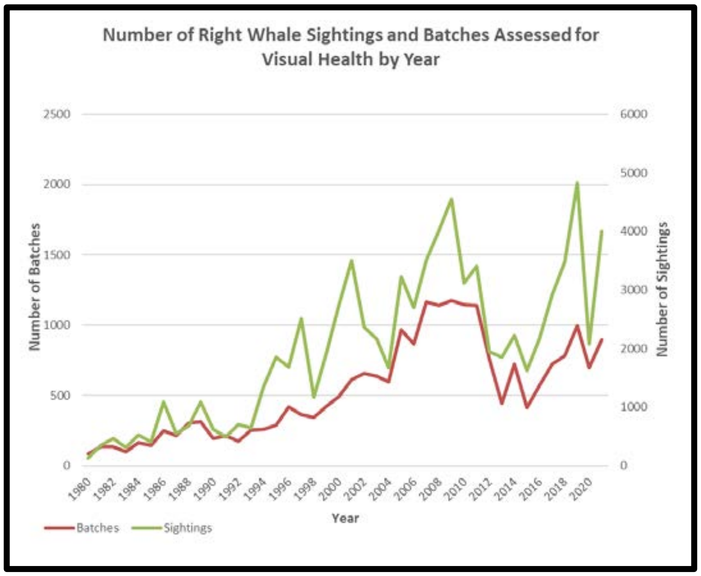

Figure 1. Count of North Atlantic right whale sightings and batches by year in the Visual Health Assessment Database 1980-2021.

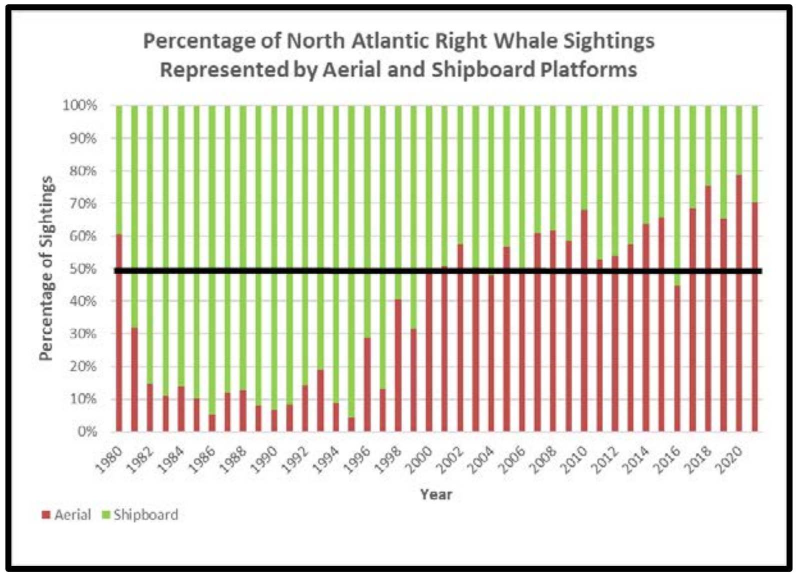

Figure 2. Percentage of North Atlantic right whale sightings scored for VHA represented by aerial and shipboard platforms between 1980- 2021. 50% line included in black. Land and drone-based sightings are excluded from this analysis as they represent a relatively insignificant number of annual sightings.

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 =8278), shipboard sightings only (n =7013), or a combination of both aerial and shipboard sightings (n = 4772). 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 poor 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, ~99% 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 (88.7% and 72.2%, respectively). The proportion of batches scored for skin condition remains high for shipboard only and mixed platform batches (90.4% and 97.6%, respectively).

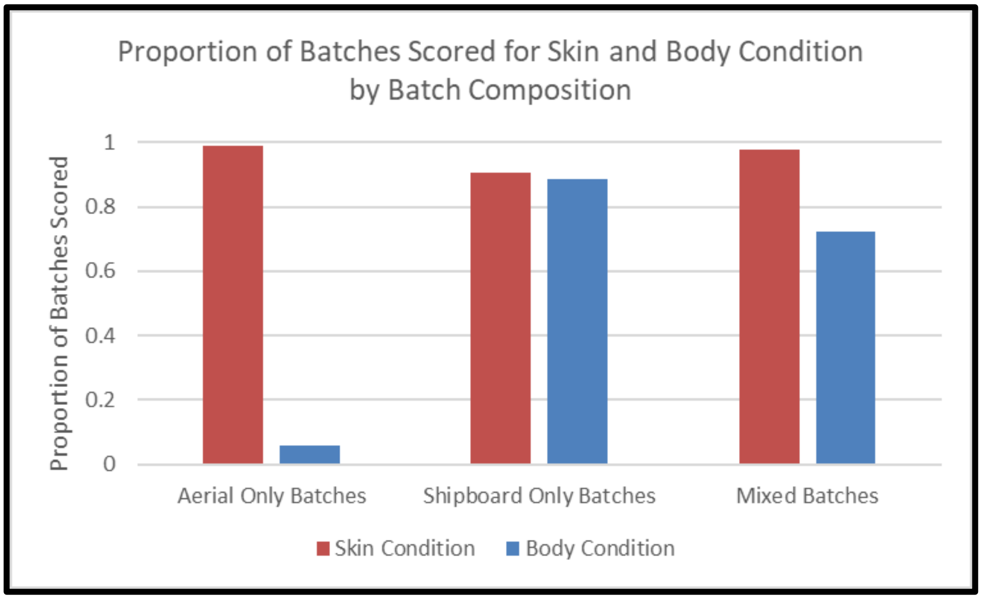

Figure 3. Proportion of right whale sighting batches scored for skin and body condition for each batch composition type, 1980-2021.

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). The proportion of batches scored for skin condition rose slightly in 2021 compared to 2020 (from 90.1% to 91.1%) as did the proportion of batches scored for body condition, up from 29.9% in 2020 to 40.5% in 2021.

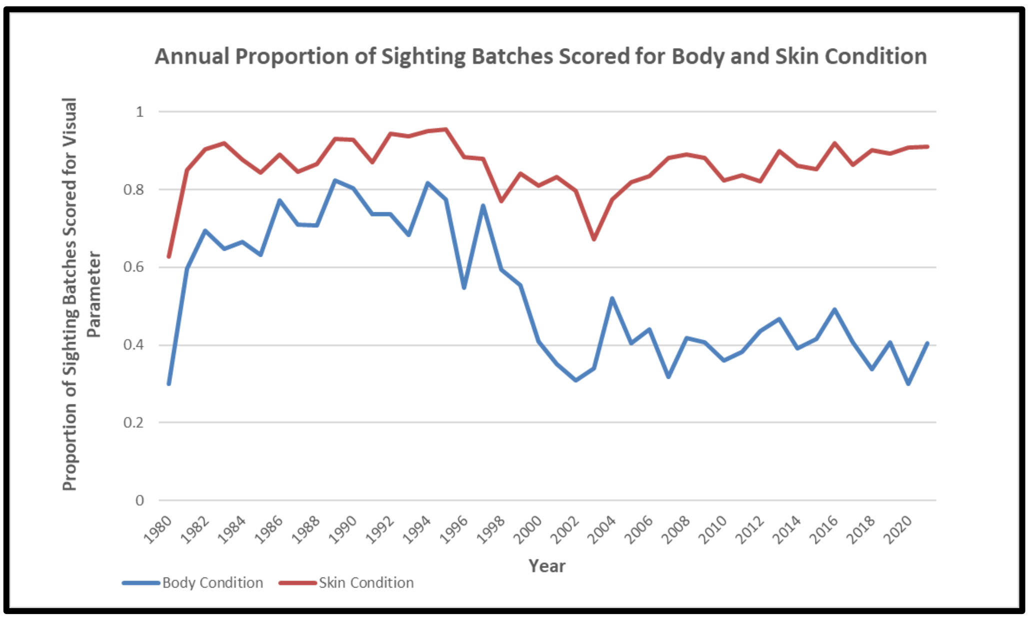

Figure 4. Annual proportion of right whale sighting batches that were scored for skin and body condition, 1980-2021.

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 2021, the annual proportion of estimated living right whales with at least one batch of scored skin condition was consistently higher (min/max% 46.2/92.6) than the proportion of estimated living whales with scored body condition (min/max% 27.5/74.8).

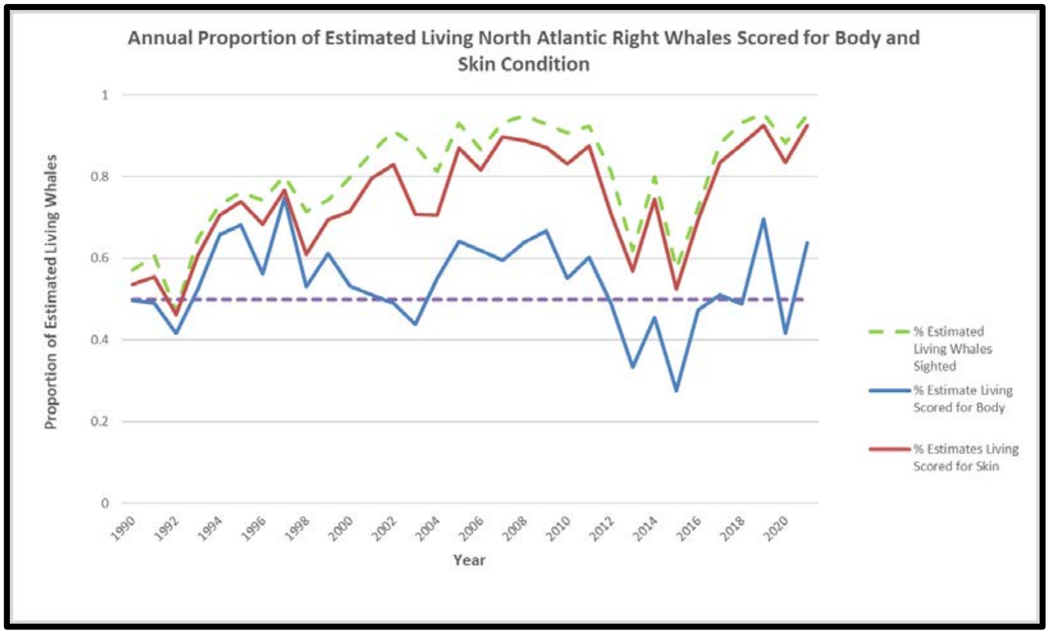

Figure 5. Annual proportion of estimated living right whales that were scored for skin and body condition by year, 1990-2021. Analyses including estimated living population encompass 1990 forward as that is the time frame of the available data. The proportion of estimated living whales sighted each year 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. The proportion of sighted whales scored for body condition rose to 67.1% in 2021 following an all-time low of 47.1% in 2020.

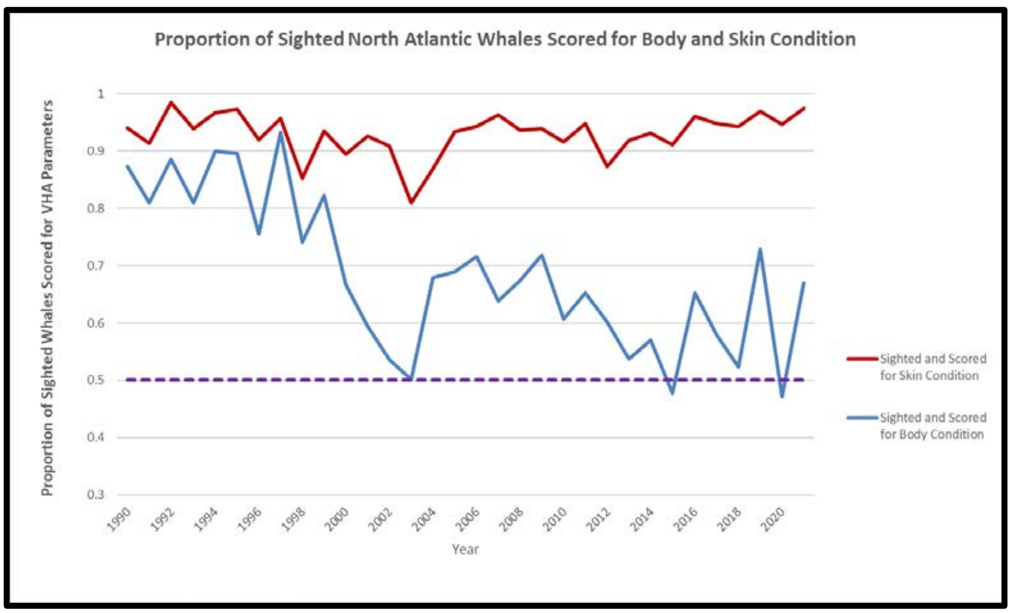

Figure 6. Annual proportion of sighted right whales that were scored for skin and body condition in one or more batches by year, 1990-2021. The dashed purple line represents 50% sighted whales.

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 has declined since 2016, with 22.0% of scored right whales in 2021 showing compromised condition. The prevalence of compromised skin condition also declined in 2021 to 8.9% from 18.5% in 2020.

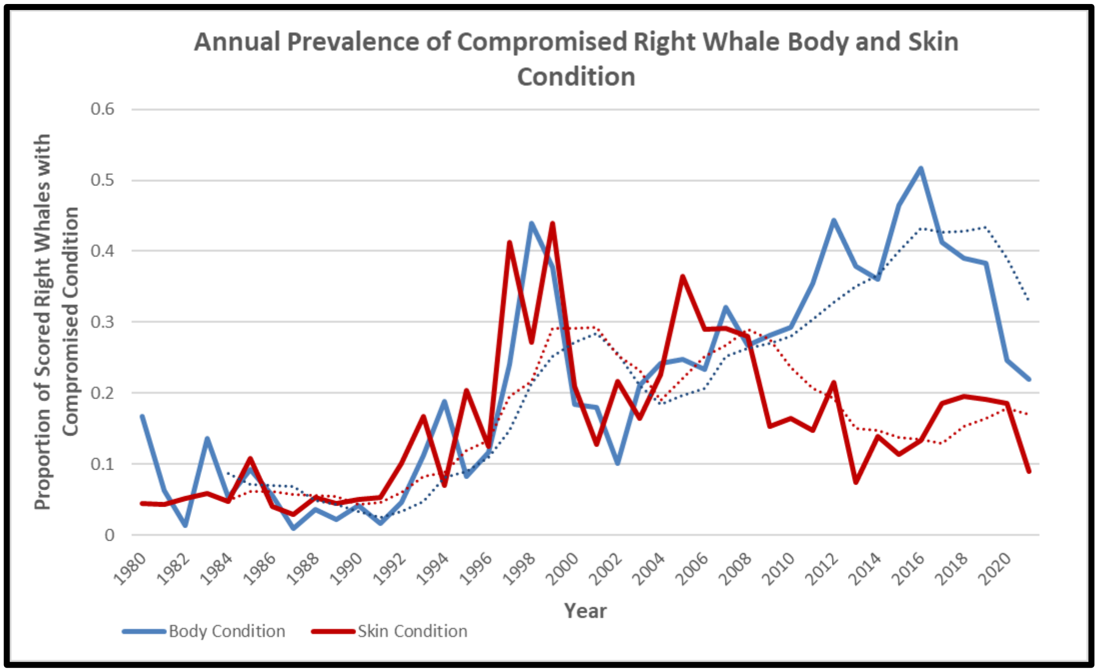

Figure 7. Annual proportion of right whales with at least one record of compromised skin and body condition. Prevalence was defined as at least one sighting batch for an individual right whale scored as compromised for skin or body condition by year, 1980-2021. Reproductive females were excluded from the body condition analysis in each of their calving years. Stippled lines represent 5-year rolling average.

Discussion

Visual health data for 359 right whales across twelve years were added/updated to the Visual Health Assessment 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 to support those efforts. 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.

Recent publications utilizing the VHA Database include:

1. Pirotta, E., Schick, R.S., Hamilton, P.K., Harris, C.M., Hewitt, J., Knowlton, A.R., Kraus, S.D., Meyer-Gutbrod, E., Moore, M.J., Pettis, H.M. and Photopoulou, T., 2023. Estimating the effects of stressors on the health, survival and reproduction of a critically endangered, long-lived species. *Oikos*, p.e09801.

2. Pirotta, E., Tyack, P.W., Durban, J.L, Fearnbach, H., Hamilton, P.K., Harris, C.M., Knowlton, A.R., Kraus, S.D.,

Miller, C.A., Moore, M.J., Pettis, H.M., Photopoulou, T., Rolland, R.M., Schick, R.S., and Thomas, L., 2024. Decreasing body size is associated with reduced calving probability in critically endangered North Atlantic right whales. Royal Society Open Science. 11:240050. https://doi.org/10.1098/rsos.240050

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 and/or high quality drone images. 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 was undoubtably related to impacts of the COVID-19 pandemic on survey efforts. The relative percentage of aerial sightings decreased in 2021 but remained high at over 70%. The impact of predominantly aerially based sightings on our ability to assess body condition is clear; fewer than 50% of sighting batches have been scored for body condition since 2004. While the proportion of batches scored for body condition increased in 2021, it remained relatively low at 41.5%.

The shift in right whale 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, and, following a drop in 2020 that was likely related to the COVID-19 pandemic, rose above 50% in 2021. The trend holds true for the proportion of sighted whales that are scored for skin and body condition; there was a rebound in both in 2021 over 2020, including an increase from 47.1% to 67.1% for body condition. 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.

In addition to increasing the proportion of right whale sightings we can 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 have discussed 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. During the recent scoring of 2021 batches, we flagged sightings and images as examples for code refinement. Next, we will collate these sightings and representative images and develop a proposed score refinement protocol. Once protocols are in place, we will use the refined scoring protocol moving forward, making sure to maintain a means to compare new scoring criteria with historical criteria.

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 2021 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 and dropped from 18.5% in 2020 to just under 9% in 2021. 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. Additionally, it may allow us to examine impacts of changing environmental conditions, including temperature and salinity, on right whale skin condition and examine potential impacts of climate change on right whale health.

The Visual Health Assessment Database remains an important tool for 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 most useful to important monitoring and management efforts (i.e. health assessment and scarring assessments) is effectively and efficiently collected.

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