A vessel speed dashboard for North Atlantic right whale management areas

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One of the primary threats to the conservation and recovery of endangered North Atlantic right whales is mortality and serious injury from vessel collisions. In October 2008, the National Marine Fisheries Service (NMFS) implemented mandatory speed restrictions in designated Seasonal Management Areas (SMAs) along the U.S. East Coast to help mitigate this threat in their U.S. habitats (50 CFR § 224.105). In January 2021, NMFS' Office of Protected Resources (OPR) released an assessment evaluating the efficacy of vessel strike risk reduction programs for North Atlantic right whales, including the mandatory speed restrictions established in 2008. A significant component of this assessment involved the analysis of vessel traffic within the SMAs, results of which were provided in an accompanying appendix. To facilitate the sharing of similar, but continuously updated, vessel traffic statistics in areas established to mitigate lethal vessel strikes involving North Atlantic right whales, NMFS' OPR has developed an online ArcGIS Dashboard that provides users with interactive, historical, and near real-time vessel traffic data aggregated by season, month, SMA, vessel type, and vessel speed class. Given the immense interest in this conservation issue and the prohibitive hardware requirements, limited access to data, and steep learning curve needed to perform sophisticated vessel traffic analyses, NMFS is striving to make this information more transparent and accessible to the public.

North Atlantic right whale sightings and group composition in the VA/NC Mid-Atlantic: 2018–2023

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As part of the U.S. Navy's Marine Species Monitoring Program, HDR Inc. has been conducting aerial and vessel surveys for large whales off Virginia and North Carolina since 2015. Non-systematic vessel surveys occurred seasonally (primarily October–March) on 184 days in nearshore and mid-shelf waters and year-round on 90 days in offshore waters. A total of 37 aerial surveys, encompassing portions of coastal, mid-shelf, and offshore waters, occurred year-round, though effort was not consistent across months or years. Between April 2018 and March 2023 North Atlantic right whales (NARWs) were sighted 19 times over 17 survey days. Sightings occurred in November (n=1), January (n=5), February (n=5), March (n=6), and April (n=2). Sightings were comprised of 46 unique NARWs. Of these, 25 (54.3%) are known males, 14 (30.4%) are known females, and sex is unknown for 7 individuals (15.2%). Ages, determined by photo-ID histories, ranged from newborn to minimum 42 years (mean=14). Group size ranged from 1–8 individuals (mean=3). Lone NARWs were observed on six occasions; four were yearlings, one was an adult female, and one was an adult of unknown sex. Paired NARWs were seen on five occasions: three unique cow/calf pairs, one adult male/female pair, and one pair with two adult females (one pregnant). The remaining eight sightings were comprised of 3–8 NARWs, four of which were in social active groups. Nine individuals were resighted two or more times, ranging from 1–1057 days between sightings. A concerted NARW focus during the winter of 2022/2023 resulted in a marked increase in the number of sightings and individual NARWs seen, with 27 unique NARWs documented (22 which occurred over a 14-day period). Data from these efforts highlight the seasonal importance of Virginia and North Carolina for all demographic groups of NARWs and the importance of long-term monitoring efforts.

Recommendations for real-time passive acoustic monitoring near offshore wind energy development activities to help mitigate risks to North Atlantic right whales

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Construction and operation of offshore wind farms has the potential to both help and harm the critically endangered North Atlantic right whale, and modifying or curtailing industrial activities when whales are present is one way the risks of noise exposure and vessel strikes are being managed. Real-time passive acoustic monitoring (PAM) will be an important component of this dynamic management, but how to best configure a PAM system for this purpose is not well understood. Monte Carlo simulations using an empirically derived acoustic detection function were conducted to evaluate the performance of various PAM sensors, configurations, and methods of triggering whale presence alerts for two industrial cases: (1) a wind turbine construction site with a 5-km radius risk zone, and (2) a 25-km by 4-km transit corridor between the coast and a wind farm. Despite achieving very low probabilities of missed alerts in risk zones for calling whales with the best PAM configurations (< 0.01), additional simulations of swimming and calling right whales suggested that there is a roughly 1 in 2 chance that a right whale will go undetected in the risk zones of construction sites and transit corridors because it will remain silent while there. These results suggest that (1) mitigation action should be triggered by the acoustic detection of whales within a buffer zone placed around a risk zone, because (a) the chances of a whale remaining silent over a larger area that takes them longer to traverse is lower (i.e., whales are more acoustically available for detection over a larger area) and (b) the chances of whales outside the risk zone subsequently entering the risk zone are reasonably high, and (2) more monitoring modalities (e.g., visual, infrared, satellite) must be employed to detect whales when they are not calling and therefore unavailable for detection by PAM.

Identifying North Atlantic right whale upcalls using a model of human auditory perception: comparison with the Low Frequency Detection and Classification System (LFDCS)

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Passive acoustic monitoring (PAM) makes it possible to assess North Atlantic right whale (NARW; *Eubalaena glacialis*) presence continuously over long time periods, but the vast volumes of data generated usually necessitate some level of automatic call recognition. Such automatic systems are almost always based on spectrograms calculated using the short-time Fourier transform (STFT). However, STFT-based detectors are usually less accurate than human analysts. Deep learning implementations can achieve impressive results in specific cases, but are dependent on large, often impractical numbers of example calls. This study investigates an alternative approach to NARW call recognition that models the human auditory system rather than calculating STFTs, an idea inspired by the fact that human analysts often *hear* differences between signals that otherwise look similar on a spectrogram. A simple auditory model was developed that produces 51 features associated with *timbre*, or the characteristic that enables humans to distinguish differences between sounds of equal loudness and pitch. To assess the effectiveness of these aural features for identifying NARW calls, generic tonal signals were autodetected from a fully-annotated 7-day recording containing NARW upcalls. These signals were classified as being NARW upcalls or not using two classifiers: a quadratic discriminant function analysis (QDFA) classifier based on aural features, and the Low Frequency Detection and Classification System (LFDCS), a STFT-based system that also uses QDFA. Accuracy was assessed by calculating precision (the proportion of predicted upcalls that were actually upcalls), and recall (the proportion of existing upcalls that were successfully identified). Preliminary results showed a precision of 0.21 for the

LFDCS compared to 0.40 for the aural classifier. Recall was 0.28 for the LFDCS compared to 0.67 for the aural classifier. Despite low scores overall, these results suggest that aural features are a viable approach to NARW call recognition that can potentially outperform current methods.

Transport Canada (TC) update on North Atlantic right whale vessel management measures

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The Government of Canada's vessel management measures for the 2023 season to reduce the risk of vessel collisions with North Atlantic right whales (NARW) in Canadian waters came into effect on April 19, 2023. The 2023 measures build off the measures from the previous years, and were developed in consultation with industry and scientists, taking into consideration past confirmed NARW detections, the latest science advice, navigational safety, and economic impacts. In addition to the large mandatory slowdown area covering much of the Gulf, measures first introduced in 2020, including a restricted area in and near the Shediac Valley and a voluntary slowdown in Cabot Strait, were once again implemented in 2023, with adjustments based on lessons learned in 2022. Surveillance technologies incorporated into the dynamic management of vessel measures in 2023, consist of aircraft from the National Aerial Surveillance Program (NASP) and underwater acoustic gliders.

Assessment of vessel strike mortality risk for North Atlantic right whales (NARW) along the U.S. coast

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Vessel strikes are one of the main causes of North Atlantic Right Whales (NARW) mortalities. Estimating annual mortality rates due to vessel strikes is important for informing potential management strategies. This study updates existing encounter-risk models by integrating regional information on U.S. vessel traffic, whale distribution, and whale behavior to quantify the spatial and temporal variability in the risk of vessel strike mortalities. Specifically, we build on Garrison et al. 2022 by updating the encounter risk model to include 1) parameters for different vessel size classes, 2) an updated probability of whale lethality given a strike, 3) an updated NARW spatial density model which reflects more recent northward shifts in foraging habitat, 4) collated NARW depth distributions across the U.S. species range, 5) a new whale probability of avoidance parameter, 6) two additional years of vessel tracking data, and 7) a correction factor for vessel size classes that are currently underrepresented in AIS data. We also simulated the effect of reductions in vessel speed on mortality risk. In winter months, when NARW are distributed throughout U.S. waters, we identified high risk areas in Cape Cod Bay, south of Martha's Vineyard and Nantucket, along the Mid-Atlantic coast, and throughout the Southeast, particularly from larger-sized vessels. Additionally, medium-sized vessels present a similar risk level to the larger classes in nearshore waters all along the coast, particularly, in the southeast U.S. In summer and early fall, we find risk is generally lower across the U.S. coast. Outputs from the model also indicate that the largest size class of vessels poses the most significant risk to NARW, however, slowing vessel speeds reduces mortality risk regardless of vessel size class.

Scaling whale monitoring using deep learning: a human-in-the-loop solution for analyzing aerial datasets

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To ensure effective cetacean management and conservation policies, it is necessary to collect and

rigorously analyze data about these populations. Remote sensing allows the acquisition of images over large observation areas, but due to the lack of reliable automatic analysis techniques, biologists usually analyze all images by hand. In this paper, we propose a human-in-the-loop approach to couple the power of deep learning-based automation with the expertise of biologists to develop a reliable artificial intelligence assisted annotation tool for cetacean monitoring. We tested this approach to analyze a dataset of 5334 aerial images acquired in 2017 by Fisheries and Oceans Canada to monitor belugas (Delphinapterus leucas) from the threatened Cumberland Sound population in Clearwater Fjord, Canada. First, we used a test subset of photographs to compare predictions obtained by the fine-tuned model to manual annotations made by three observers, expert marine mammal biologists. With only 100 annotated images for training, the model obtained between 90% and 91.4% mutual agreement with the three observers, exceeding the minimum inter-observer agreement of 88.6% obtained between the experts themselves. Second, this model was applied to the full dataset. This experiment shows that the proposed human-in-the-loop approach is suitable for processing novel aerial datasets for beluga counting and can be used to scale cetacean monitoring. It also highlights that human observers, even experienced ones, have varied detection bias, underlining the need to discuss standardization of annotation protocols.

More recently, we have applied our pipeline to detect multiple cetacean species in the Gulf of St Lawrence, including North Atlantic Right Whales. We discuss the challenges and opportunities of applying machine learning methodologies developed for one set of target species to another.

Prediction of potential foraging areas for the North Atlantic right whale in its main summer habitat

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North Atlantic right whales are currently classified as a critically endangered species. In recent decades, ship strikes and fishing gear entanglements have been the identified causes of most deaths. Meanwhile, the main prey population of historical right whale habitats, mostly large *Calanus* species, is decreasing. In correlation, right whales have been observed further north of their usual summer feeding areas, in the Canadian waters, where they are especially vulnerable to vessel activities. To allow the Canadian government to minimise this impact, it is essential to identify the areas where right whales are most likely to be encountered, at sufficiently detailed spatial and temporal scales. To support these efforts, the SIMBA project aims to use models and satellite derived information to predict right whales' movements on the Northwest Atlantic shelf.

As the location of right whales in their summer habitat is closely linked to that of their prey, the objective of this PhD thesis is to build models that predict potential aggregation areas of right whale prey in their main summer habitat.
Calanus species, like many other zooplankton taxa, are transported by currents but can voluntarily change depth by vertical migration. The different depths chosen lead them to take different vertically stratified currents, resulting in significantly different distributions over time. I will integrate the choice of depths of copepods as a function of environmental parameters within hydrodynamic models to simulate their movements and determine their potential aggregation areas.

The results of these analyses will be integrated within another PhD project that aims to create right whale distribution prediction models. Additionally, when compared with right whale sightings and satellite data on primary production and oceanic fronts distribution, they will provide a basis for a better understanding of the foraging strategies of right whales.

Development of an Integrated AIS-Based Alert System for North Atlantic Right Whales (NARW) and Vessel Collision Avoidance

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The North Atlantic Right Whale (NARW) are critically endangered and increasingly vulnerable to vessel strikes. Our project revolves around an existing network of AIS receive-only sites along the US East Coast. Software and network radio hardware will be upgraded with send-receive capability. The system will transmit virtual buoys, safety related text

messages and geographic area specific Automatic Identification System (AIS) messages. The current NOAA rule is aligned with AIS carriage requirements. Our aim is to automatically, rapidly and effectively inform mariners of their presence in seasonal management areas and, if available in near real time, presence of NARWs in their proximity. Our project integrates cutting-edge technology with AIS tranceivers delivering information directly to the mariner's primary navigation display. With permission, the core NARW dataset would be derived from curated sources (WhaleMap/WhaleAlert,etc), encompassing aerial surveys, acoustic monitoring, vessel sightings, and satellite tracking. In certain cases, select NARWs may be equipped with temporary satellite tracking devices, enabling near real-time location updates. By amalgamating this multi-source tracking data into our AIS network, we facilitate the generation of automated real-time alerts. When a NARW is detected within a predefined proximity to a vessel, our system can instantaneously dispatch targeted alerts via AIS to mariners within the vicinity. These alerts, concise and limited to 156 characters, offer safety recommendations, such as reducing vessel speed and maintaining a safe distance. Notably, the system has the capacity to overlay virtual buoys onto mariners' Electronic Chart Systems (ECS)/Electronic Chart Display and Information Systems (ECDIS) to designate on-demand gear locations. Depending on the project requirements, up to 64 buoys can be projected from each AIS tranceiver. The system also has the ability to transmit SMAs and DMAs. This information is depicted in a variety of ways, depending on the ECS/ECDIS display.

The robustness of our project lies in the seamless integration of whale tracking data with AIS technology, guaranteeing the accuracy and promptness of automated alert delivery. The use of AIS, a standard maritime communication component, often intertwined with ECS/ECDIS, ensures mariners receive immediate, actionable information that heightens their situational awareness and safety.

In summary, our project signifies a substantial leap forward in maritime safety and NARW conservation, harnessing AIS technology in novel ways. By leveraging established infrastructure, real-time data streams, active scientific and mariner engagement, we aspire to curtail the risks of vessel strikes and entanglements, contributing to the preservation of the NARW population. This AIS-centric approach serves as a template for addressing analogous conservation challenges in marine ecosystems while emphasizing the importance of real-time alerts and mariner collaboration.

The importance of fine-scale data on fishing methods to improve entanglement risk assessments

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Efforts to eliminate threats to North Atlantic right whales must be informed by sound and defensible quantitative data. Detailed information of gear configurations and fishing methods used in fixed-gear fisheries can improve entanglement prevention and alleviation initiatives. Such details include line specifications (e.g., diameter, material), set configurations (e.g., types of attachments, scope of line), or specific local practices (e.g., depth fished, soak times). In Canada, some of this information is publicly available via DFO's fishery-specific Integrated Fisheries Management Plans but little detail is known outside those who work in the industry, especially when pertaining to regional differences. Lack of this knowledge creates limitations for scientific investigations and effective management actions. Surveying fish harvesters is an effective way to record this knowledge. Previous surveys have been conducted in some fixed-gear fisheries (Bay of Fundy and Scotian Shelf regions, and Area 12 snow crab), however, details remain undocumented for fisheries outside these efforts. To begin to address these gaps, a survey was developed and distributed in Gulf of St. Lawrence lobster fishing areas (LFAs 20-26). Responses can be used to improve predictions of line densities and distribution in quantitative entanglement risk assessments to better identify priority areas for management and to assess the effectiveness of different management measures to protect whales. Characterizing fishing methods can also be used to further support regional suitability assessments of entanglement prevention (e.g., on-demand gear) or alleviation (e.g., low breaking strength rope). Ultimately, this improved knowledge broadens opportunities for harvesters to contribute to the improvement of management decisions while supporting evidence-based and regional-specific management measures for fisheries and whales.

Spring and fall right whale presence in the Gulf of St Lawrence inferred from mark-recapture aerial surveys

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Mark recapture aerial surveys targeting North Atlantic right whales provide valuable information on distribution, abundance, health, and migration patterns. The goals of this study included estimating the number of individual right whales present in the Gulf of St Lawrence (GSL) during spring and fall sampling periods, establishing the potential extent of individuals' seasonal residency, and developing timelines of individuals' movement between the GSL and US waters. We used directed aerial surveys to locate and photograph right whales for individual identification, and generated discovery curves for each sampling period. We photographically captured 25 individuals during our surveys in November 2021 and 26 in November 2022, and 26 individuals in May 2022 and 102 in June 2023. Discovery curves did not reach an asymptote in any of our sampling periods, signaling active immigration into the GSL and/or the presence of more individuals not yet identified. Of the 44 unique individuals identified during our May and November surveys in 2022, eight were photographed in both periods, suggesting potential residencies of seven months. Our photographic captures of individuals in US habitats before and after their captures in the GSL were used to further assess the timing of the whales' movements into and out of Canadian waters. We had few recaptures in both the GSL and US waters in 2021 and 2022, but during our June 2023 sampling period we recaptured 56 whales in the GSL that we had seen earlier in the year in US waters. The smallest interval between successive transboundary captures was 19 days, and averaged 77 days (SD = 26.3 days). These results provide a coarse description of right whale presence in the GSL and potential time frames of transboundary movement that could be further refined by incorporating photographic captures from other teams and additional years of sampling.

Investigating the effects of inbreeding depression on reproductive success in North Atlantic right whales

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Small populations leave limited opportunities for mating, and as such, individuals become more and more related as population size decreases. Mating with close relatives can lead to a reduction in fitness known as inbreeding depression. In North Atlantic right whales, small population size, low levels of genetic diversity, and higher levels of inbreeding compared to southern right whale raise concerns about the potential impacts of inbreeding on species recovery. In addition to a suite of anthropogenic stressors, North Atlantic right whale persistence is threatened by poor reproductive performance. Females are not producing calves as often as we expect, and there is considerable variance in reproductive output where some females successfully calve fairly frequently, while many females of reproductive age have never produced a viable calf. We used reduced representation sequencing to sequence approximately 2% of the genome of 100 North Atlantic right whale females with known reproductive histories to investigate whether inbreeding depression can help explain the variance in reproductive success. We compared measures of inbreeding to estimates of fecundity for females as calculated with a de-lifing method. Mean individual fecundity was positively associated with inbreeding history, meaning individuals that have higher levels of realized inbreeding were not as successful at producing calves as their counterparts. We also model the relationship between individual inbreeding and fecundity to better quantify how reproductive performance is being driven by inbreeding coefficients. As the population remains small, we will continue to lose genetic diversity through genetic drift, increasing the inbreeding coefficients of individuals, which could in turn lead to further reductions in fecundity.

Fortunately, the reduced fecundity is not exclusively explained by inbreeding, and therefore, other mitigation efforts to minimize threats and stressors to North Atlantic right whales may also to have positive impacts on their reproductive success.

Effects of fishing gear entanglement on the health, survival, and reproductive dynamics of North Atlantic right whales

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Fishing gear entanglements can compromise health and lower survival and reproductive output of wildlife, which can slow population growth or cause population declines. However, entanglements may go unobserved, making it difficult to quantify their effects on individuals' vital rates and a population's trajectory. Fishing gear entanglements are a leading cause of death for North Atlantic right whales; however, key sources of observation error have not been addressed when quantifying the effects of entanglement on the right whale population. We formulated a hidden Markov model that integrated 24 years of photo identification records, visual health assessments, entanglement assessments, and hormone assays to estimate body condition dynamics, and entanglement, survival, and reproductive rates of female North Atlantic right whales. The model also accounted for observation errors, including entanglements and reproductive events that were unobserved. Additionally, we used the model to conduct a counterfactual analysis to estimate the number of female right whales that would have still been alive and the number of calves that would have been born by the end of the study had no entanglements occurred during the study. We will present a summary of the model's structure and results with a focus on how fishing gear entanglements have impacted individual females' survival and reproductive rates as well as their cumulative impacts on the right whale population.

Report on the September 2023 workshop to review and evaluate current telemetry technologies for NARW conservation

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The North Atlantic right whale (NARW), one of the most endangered large whales in the world, is exposed to a high volume of vessel traffic and commercial and recreational fisheries throughout much of its range. Entanglement in fishing gear and vessel strikes are the leading causes of NARW mortality, and efforts to manage these threats have been hindered, amongst other reasons, by limited scientific information on current NARW distribution, habitat use and movements. Biologging has revolutionized our understanding of animal movement, behavior, distribution and habitat use. The use of "Type C" or consolidated satellite linked telemetry tags (Andrews et al., 2019) has done this for multiple cetacean species; however, early models have had deleterious health effects on some tagged individuals. Novel models of consolidated tags have been developed over the last decade, with field studies undertaken to evaluate performance and effects on individual humpback and Southern right whales. Here, we present the report from a workshop hosted by NOAA Fisheries, MMC, ONR, and supported by DFO, in September 2023, to review current telemetry technologies and the impacts of tags on individual whales, with an emphasis on recent Type C tag attachment improvements. The workshop included a review of the permitting requirements in the United States and Canada and a discussion of the critical management questions that might be addressed using data from biologging.

Satellite detection of North Atlantic right whales in foraging habitats

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Detection of large whales using satellite Earth observation technology is an emerging field, but numerous challenges exist and field case studies are still rare. The Government of Canada invested in the smartWhales program to fund consortia that examine the feasibility of using these data types and machine learning methods to detect North Atlantic right whales. This presentation discusses preliminary results of a 3-year project aimed at processing satellite imagery collected over right whale feeding habitats in the Gulf of St. Lawrence and Cape Cod Bay to identify right whales. We present a performance analysis on a human-in-the-loop machine learning method for right whale detection in very high-resolution (<50 cm) satellite imagery. We present general detection performance metrics of our approach and discuss challenges in two contrasting scenarios: a relatively difficult detection scenario, where rare animals spend much of their time subsurface foraging in an offshore habitat with variable weather conditions (Gulf of St. Lawrence), and a simpler detection scenario where whales are typically surface feeding in coastal, protected waters (Cape Cod Bay). Challenges we encountered include responsiveness in satellite tasking which limited imagery that could be acquired during good weather and sea state conditions in our desired sampling locations, small training dataset sample size to build a robust species-level machine learning detection algorithm, and the effective downsampling of aerial/drone based imagery to augment the training data sets. As a large-spatial-small-temporal scale detection system, satellite-based technology will contribute data from areas that are presently unsampled due range or seasonal weather limitations of our existing detection platforms. Effective development of this detection system is essential to improve our knowledge of NARW distribution and to manage the human activities that currently threaten the species.

Upcalling behavior and patterns in North Atlantic right whales, implications for wind energy development

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Offshore wind energy is rapidly developing in U.S. waters, with construction starting imminently off Southern New England, an important region for many species, including the critically endangered North Atlantic right whale (NARW). A data driven understanding of NARW upcalling behavior is presented here to help establish proper monitoring protocols for mitigating impacts. Analyses of individual upcalls from two years of acoustic recordings showed that NARWs were detected at least one day every week throughout both years, with highest NARW presence from October through April. Weeks with more days of acoustic presence typically had more hours with calling activity, but the number of upcalls within a day or hour was variable reflective of the social function of the upcall. NARW persistence showed that 95% of the time NARW upcalls will be detected again within 11 days. An evaluation of the time period over which it is most effective to monitor prior-to commencing pile driving activities showed that with one hour of pre-construction monitoring there was only 4% likelihood of hearing a NARW, compared to 74% at 18 hours. As a result, we would recommend 'situational awareness' monitoring for at least 24 hours prior to the start of construction activity.

In the strike zone? Tag data provides a better understanding of dive and surface behavior of North Atlantic right whales in the western Mid-Atlantic

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Understanding the overlap with respect to dive and surface behavior of critically endangered North Atlantic right whales (NARW) and a vessel's draft is critical to this species' survival. A multi-year study

funded by the U.S. Navy's marine species monitoring program provides an understanding of how endangered and threatened baleen whales utilize the western Mid-Atlantic Ocean waters within and around areas of high anthropogenic activity. Data collection relied on Wildlife Computers SPLASH10-F-333 dive/location LIMPET-configured dart tags designed to collect medium-scale (days to weeks) movement and dive behavior and CATS suction-cup tags recording fine-scale (hours) high-resolution dive/movement/acoustic/video data. A total of three SPLASH10-F-333 tags were attached to three NARW yearlings and one CATS tag was deployed on a pregnant adult female, all off the coast of Virginia. A combined total of 4,130 dives and surfacing events were recorded across all three LIMPET-tagged whales. Mean maximum dive depth was 19.8 m, mean dive duration was 5.4 min, and mean surfacing duration was 3.7 min. The CATS-tagged female exhibited a shallower maximum dive depth of 4.4 m, shorter mean dive duration of 2.3 min, and shorter mean surface duration of 1.9 min. Data collected suggests all tagged whales were primarily traveling; though periods of socializing, resting, and/or foraging are likely for some where directed movement was limited. Maximum dive depths combined with histogram data suggest a considerable number of dives are well within striking distance of a large ship's draft. Also of concern is the amount of time whales spent at the surface in-between dives where they are vulnerable to vessels of all sizes should they remain undetected. The dive and surface behavior data suggest a high degree of overlap with vessel draft that could lead to an unfortunate outcome should whale and vessel occupy the same waters either below or at the surface.

More than just a migration corridor: Important North Atlantic right whale surface-active behaviors observed in the western Mid-Atlantic

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Historically, the western Mid-Atlantic waters off Virginia and North Carolina have not been the focus of North Atlantic right whale (NARW) research projects. Until recent passive acoustic monitoring results showed otherwise, the conventional understanding of NARW behavior and distribution in this region was primarily thought to be travel through a migration corridor. The acoustic and visual documentation of NARWs outside of the temporal and spatial migration window began to suggest the distribution and behavior of these individuals was not just an unusual occurrence. The latest stock assessment reports state that "the location of much of the population is unknown during much of the year", leading some to speculate the Mid-Atlantic waters could be an important habitat for NARWs. Recent studies led by HDR Inc. in the western Mid-Atlantic off the coast of Virginia and North Carolina have documented sightings of NARWs from all age classes, and behaviors documented show that individuals are using the area for more than just travel between known feeding and breeding/calving grounds. Survey teams have documented surface active social behavior by groups of three or more individuals on four occasions between 2021 and 2023 using aerial and vessel platforms. Group composition of the surface active groups (SAGs) consisted of all male or male and female. Presence of focal, alpha, beta, and peripheral positioned individuals were noted. In addition to social behavior, indications of feeding have also been observed, such as fluke-up-dives by all individuals of a group in a loose aggregation; aggregating in an area with other species; observed defecations; and possible skim feeding surface movements. These observations offer support to the hypothesis that the waters of this

region are utilized by NARWs for significant activities in addition to traveling.

A comprehensive assessment of drivers of North Atlantic right whale habitat use in the Northeast United States: Beyond *C. finmarchicus*

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Understanding the drivers of North Atlantic right whale (NARW, *Eubalaena glacialis*) habitat use is crucial for conservation and management, especially in light of marked shifts in their distribution since 2010. However, less is known about oceanographic and prey drivers of NARW presence south of the Gulf of Maine (GOM), where NARW have recently been detected year-round, or about potential prey species other than *Calanus finmarchicus*. We used copepod data from the EcoMon program between 1980 – 2019 to examine changes in the abundance and species composition of prey in the Northeast US and assessed copepod trends relative to spring and fall thermal transition. While *C. finmarchicus* dominated the summer plankton community in the GOM prior to 2010, the area has since become dominated by *Centropages typicus* in the summer. These changes were driven by both a seasonal decline in *C. finmarchicus* and an increase in *C. typicus*. Since 2010, the winter abundance of *C. finmarchicus* has been higher south of the GOM (eastern Southern New England) than in other adjacent subregions, which could be linked with the increased winter occurrence of NARW in this region. We observed a spring increase of *C. finmarchicus* in the western GOM, aligning with increased spring NARW presence in the area. We also observed a spring increase in *C. finmarchicus* in the eastern GOM, which has not seen recent increased use by NARW. But since 1980, the eastern GOM has experienced faster shifts in spring and fall thermal transition dates than any other region, hinting that climatic change could be influencing NARW habitat use despite spring prey availability. Spring transition has moved earlier while fall transition has moved later, translating to longer warm seasons. This work highlights the importance of assessing broad spatiotemporal trends in the copepod community to contextualize changes in NARW habitat use.

Update on the North Atlantic right whale Unusual Mortality Event: 2017-Present

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An Unusual Mortality Event (UME) is defined under the U.S. Marine Mammal Protection Act as "a stranding that is unexpected, involves a significant die-off of any marine mammal population, and demands immediate response." The National Marine Fisheries Service declared a UME for endangered North Atlantic right whales (*Eubalaena glacialis)* starting in 2017, due to elevated numbers of dead and injured whales along the Northwest Atlantic Ocean coast in both the United States and Canada. The leading cause of this UME is human interaction, specifically from entanglements or vessel strikes. The UME is ongoing with 115 known cases to date, including 36 dead, 34 seriously injured, and 45 sublethally injured or ill individuals. Of the 36 confirmed dead whales, 15 were first documented in the United States, and 21 were first documented in Canada. As of July 31, 2023, the breakdown of mortalities by year includes: 17 whales in 2017, 3 in 2018, 10 in 2019, 2 in 2020, 2 in 2021, 0 in 2022, and 2 so far in 2023. Of the 36 dead whales, 21 (58%) were confirmed, probable, or suspected deaths as a direct result of human interactions: 9 entanglements and 12 vessel strikes; 3 were due to unknown causes; 2 were perinatal deaths; and 10 carcasses were not examined. Of the 34 serious injury cases, which involve live free-swimming non-stranded whales that are likely to die from their injuries, 33 (97%) were attributed to human interactions: 31 entanglements and 2 vessel strikes; and 1 was a dependent calf. Of the 45 morbidity cases, which involve live free-swimming sublethally injured or ill whales, 38 (84%) had injuries attributed to human interactions: 36 entanglements and 2 vessel strikes; 5 were in poor body condition; and 2 had injuries of unknown cause. Therefore, of the 115 cases documented (both live and dead), at least 80% (92/115) were the result of entanglements (76) or vessel strikes (16). The latest preliminary population estimate suggests there are fewer than 350 North Atlantic right whales remaining. The many individual whales documented in the UME underscore the gravity of the situation for this endangered species, and highlight the urgency for additional, new, and innovative recovery actions to prevent species extinction.

More information can be found at the National Marine Fisheries Service UME website: (https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2023-north-atlantic-right-whale-unusual-mortality-event).

Dive behavior of North Atlantic right whales (*Eubalaena glacialis*) in New England waters: Insights from inertial sensor suction cup tagging

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The North Atlantic right whale (*Eubalaena glacialis*) (hereafter "right whale") is known to frequent New England waters, including NOAA-designated critical habitat in the Gulf of Maine and George's Bank. Seasonal concentrations of right whales have been observed throughout management areas in the Great South Channel, as well as consistent, year-round observations in waters south of Nantucket and Martha's Vineyard, "Southern New England" (SNE). Knowledge of the movement and foraging ecology of right whales can inform policy and aid the mitigation of ship strikes and other anthropogenic stressors on

the dwindling population. To investigate the underwater behavior of right whales in and around New England waters, we deployed inertial sensor biologging tags (CATS and DTags), attached with suction cups. Between October 2021 and May 2023, we used handheld poles and drones to attach 16 tags on 13 individual right whales. Tagging locations ranged from SNE waters to the Northeast Passage in the Gulf of Maine. Archival data totaled 100+ hours, with four nighttime deployments and individual attachments ranging up to 31 hours (Mean: 6h51m). We tagged juvenile and adult whales of both sexes ranging from 2 to ~45 years of age at time of tagging. Dive behavior varied across individuals and tagging regions. Comparing the animals' position to the

regional bathymetry, the majority of tagged animals were presumably diving to or near to the seafloor, to a maximum depth of 130m. Individual dives ranged up to ~20min, with foraging bouts ranging up to 24hr interspersed with shallow, near-surface bouts, lasting up to 2hr. Analyses of the tri-axial accelerometer, magnetometer, and gyroscope sensor data, as well as corresponding video and audio data, where available, will provide further insight into the foraging ecology and underwater movement of right whales in this region of the western North Atlantic Ocean.

Sailing sector - marine mammal impacts and actions: *The Ocean Race marine mammal advisory group*

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As part of The Ocean Race 2022/23, the marine mammal advisory group was established to provide recommendations with regards to the mitigation of collisions during this global event.

The key actions outlined included:
1. SOURCE AND SHARE INFORMATION
2. RACE COURSE RISK ASSESSMENT
3. LIVE REPORTING
4. CITIZEN SCIENCE
5. FUTURE SOLUTION DEVELOPMENT

Sourcing information outlined the low reporting rate of marine mammal collisions from the sailing sector. Collaborating with IWC the group is building out an updated database of marine animal strikes.

The Ocean race commissioned a detailed numerical risk assessment for each leg of the round the world race, highlighting areas of high marine animal density, historical strikes, existing regulations, and defining exclusion areas for the race.

A Hazard reporting function was developed within the onboard navigation software to facilitate prompt and accurate reporting of observations, and hazards seen or experienced on the water.

Technical solutions to watchkeeping, and deterrence have been researched, tested and continue to be developed as part of a wider consortium of stakeholders.

The protocols developed are being used to inform guidelines for the sailing sector, through the sports Federation World Sailing, and other organizations.

The effects of North Atlantic right whale fishery closures on entanglement risk to other large whales in the Gulf of St. Lawrence

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Since 2018, time-area closures have been implemented in Canadian waters to reduce entanglements of North Atlantic right whales (NARW) in fixed-gear fisheries, particularly the snow crab fishery. Other large baleen species also occur in the Gulf of St. Lawrence (GSL) and face similar risks of entanglement from fixed-gear fisheries. These include endangered blue whales, fin whales (special concern), and humpback whales, the second most commonly entangled baleen whale in Atlantic Canada, and other studies have shown the rate of entanglement for these whales in the GSL are vastly underestimated (Ramp et al 2021). The goal of this study was to estimate the risk of entanglement in snow crab gear for these other species, and to quantitatively evaluate the potential change in risk due to the NARW time-area closures. Distributions for each species were based on annual sightings (2015-2022) using a location uncertainty model and combined with snow crab logbook data to estimate entanglement risk. The average risk of entanglement

for blue, fin, and humpback whales was estimated for the years prior to the implementation of fisheries management measures (2015-2017) and compared to the entanglement risk estimate for each year with time-area closures (2018-2022) to identify the change. These results provide important information on the effects of fisheries management measures on non-target whale species.

The probability of a lethal vessel strike for large whales: An update of available data and models to improve risk assessment

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Vessel strikes are among the leading anthropogenic sources of mortality and serious injuries for large whales globally and specifically for North Atlantic Right Whales. Models that quantify the risk of vessel strike mortality are valuable tools for assessing the spatiotemporal variability in risk and evaluating alternative management strategies. One key component of these models is the relationship between vessel speed and the likelihood that a vessel strike will result in serious injury or mortality of a large whale. The data used to inform this relationship has been garnered primarily through direct reports of the outcomes of vessel-whale interactions and were last updated in 2013. In this study, we reviewed and updated available data on vessel-whale interactions from the east and west coasts of North America. This expanded the number of available records from 90 to 239, and this larger dataset allowed us to explore the effects of region, species, and vessel size class, in addition to vessel speed, on the likelihood of mortality given a vessel strike. We applied a logistic regression model and found that species, vessel size class, and vessel speed were important explanatory factors. As expected, large ocean-going vessels had a higher likelihood of a lethal outcome given a strike than smaller vessels at all speeds. In addition, humpback whales had a lower likelihood of a lethal interaction than other large whale species; however, it is possible that this effect is confounded with vessel size. Vessel speed remained an important factor for all vessel size classes, and reducing vessel speeds is predicted to significantly reduce the likelihood of a lethal vessel strike. These updated data and models can be used to improve quantitative risk assessments and account for the effects of both vessel size and vessel speed on the lethality of vessel strikes of large whales.

Overview of the smartWhales Initiative

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Following mortalities of North Atlantic right whales (NARW) in Canadian waters in 2017 and 2019, the Government of Canada (GoC) implemented a world class surveillance and dynamic management program to support the conservation and protection of this endangered species. A variety of tools to detect and monitor NARW are employed by the GoC and its partners, including aircraft, drones, vessel surveillance, as well as acoustic and infrared technologies. The GoC also contributes to the research and development of new technologies that could support these surveillance and dynamic management measures. To that end, the Canadian Space Agency (CSA), the Department of Fisheries and Oceans Canada (DFO) and Transport Canada (TC), developed the smartWhales initiative. This $5.3 million investment in research and development directed at five industry-led consortia has the goal of advancing innovative space-based solutions that could enhance Canada's ability to detect and monitor the presence of NARW in Canadian waters and potentially predict their distribution. SmartWhales is another example of actions taken by the GoC to reduce the risk of threats to NARW, including entanglement in fishing gear and collisions with vessels.

To fuel innovation and share knowledge and expertise, each consortium has built a team of experts from academia, industry, non-governmental and international organizations to carry out their projects. The five project teams are led by: Global Spatial Technology Solutions Inc. (GSTS), Hatfield Consultants Ltd., Fluvial Systems Research Inc. (FSR), Arctus Inc., and WSP Canada Inc. The project

activities began in January 2021 and will extend to January 2024. The consortia have made significant progress and generated some interesting developments and promising preliminary results, including for example, the identification of individual NARW from satellite imagery. The results of this research may support future dynamic management and regulatory measures of NARW in Eastern Canadian waters, thereby increasing their protection and furthering their recovery.

NOAA Fisheries role in vessel strike mitigation moving forward

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Collisions with vessels continue to harm large whale species globally. The recovery of some of the most endangered whale species including North Atlantic right whales, Rice's whales and Southern Resident killer whales, is hampered by impacts from vessels. NOAA Fisheries, and our federal partners, are in a unique position to lead efforts to address this problem holistically. As we come to better understand the breadth of vessel impacts and the growing density of vessel traffic in whale habitats, NOAA Fisheries is laying groundwork to more effectively lead mitigation planning and implementation. The agency is creating a standardized national vessel strike database to archive detailed data about strike events in U.S. waters. This will help us to better quantify national, regional, and species-specific trends and identify commonalities among strike events involving certain vessel types or operational conditions. Congress has taken an interest in vessel collisions and recent legislation included requirements for NOAA Fisheries to initiate grant programs for ports and enhance monitoring for whales to support vessel strike reduction efforts. NOAA is also working to expand the tools available to address large whale collisions beyond speed reduction and vessel routing measures and is investing in organizational and research efforts to develop and operationalize technologies that may aid in reducing vessel strike risk. Frequently, ancillary benefits from vessel speed reduction programs such as ocean noise reduction, lower pollution emissions and protections accruing to non-target species, are not fully recognized or monitored. Public interest in addressing strikes remains high and the agency has received numerous petitions calling for action to address vessel strike risk across the country. NOAA Fisheries is making significant investments in, and is well positioned to lead, vessel strike mitigation efforts and serve as a template for global action on this pervasive conservation issue for large whales.

North Atlantic right whale Catalog update and whale naming results

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Each year the New England Aquarium provides an update of the status of the photo-identification Catalog which they manage for the Consortium. This update will include: the number of animals currently in the Catalog, their age and sex and whether they are presumed alive or dead; the number of sightings and images contributed in the last year; new animals added to the Catalog; the matching status of the data by year; and an overview of recent births, mortalities and entanglements (although details of the latter two will likely be provided by other presenters). Also, comparisons of data submission and number of whales alive historically will be presented. To ensure that the most up-to-date data are provided, these numbers will be calculated in mid-October and therefore the results are not provided in this abstract. Given the large number of researchers that utilize the Catalog data, it is important to provide annual summaries of the status of available data so that these researchers can determine appropriate research objectives. Lastly, the final results of the Consortium whale naming effort will be presented.

The BOEM and NOAA Fisheries North Atlantic Right Whale and Offshore Wind Strategy

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BOEM and NOAA Fisheries partnered to develop a *North Atlantic Right Whale and Offshore Wind Strategy* ("Strategy") to focus and coordinate efforts related to NARW and OSW development. In response to Executive Order 14008, both agencies share a common vision to protect and promote the recovery of North Atlantic right whales (NARW) while responsibly developing offshore wind energy (OSW). This vision reflects the combined legislative mandates of the two agencies and their commitment to developing OSW while protecting biodiversity and promoting ocean co-use. The Strategy identifies a number of actions to achieve the common vision under three goals: (1) Mitigation and Decision-Support Tools (20 actions); (2) Research and Monitoring (23 actions and 9 sub-actions); and (3) Collaboration, Communication, and Outreach (6 actions). These goals and actions will allow for co-ordinated and efficient collaborations between BOEM, NOAA, and our partners (including the OSW industry); collect and apply best available data and insights to inform future decisions, including monitoring and mitigation programs; and implement effective measures to reduce risk and avoid and minimize impacts to NARWs. Immediate impact minimization efforts include, but are not limited to, avoiding leasing is areas where major impacts to NARWs may occur, establishing noise limits during construction, and providing guidance to developers on conducting robust sound field verification to ensure the environmental impacts of OSW expected to occur are not being exceeded. In addition, the Strategy describes potential actions that require further development. This Strategy does not define new policy or regulatory actions. A draft of the Strategy was made available for public comment in October 2022 and the updated document will be made publicly available in Fall 2023. The agencies intend to keep the Strategy as a "living" document that will be regularly evaluated and updated as progress is made, and new information becomes available.

Increasing whale detection capacity in the Canadian Atlantic waters by utilizing thermal land- and vessel-based automatic detection and classification systems

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Vessel strikes are one of the major known threats to North Atlantic right whales (NARW - *Eubalaena glacialis*) and mitigation efforts are key to improve their protection in particular while they are transiting within or in close proximity to busy shipping lanes. We previously showed in many pilot studies that thermal imaging is a reliable method to detect surfacing whales within several kilometers of the observer.

To validate the effectiveness of a cost-efficient infrared (IR) detection system to inform vessel management measures and evaluate its capacity to reliably detect whales - especially NARW -, we deployed six thermal imaging whale detection systems both land- and vessel-based, for detection and identification of cetaceans in Canadian Atlantic waters, across the Cabot Strait in the Gulf of St. Lawrence, along the migration path of the critically endangered NARW.

We find that during an entire year of deployment (2022-2023), the systems reliably detect whales at distances of 3 – 4 km, with maximum detection ranges exceeding 10 km. Furthermore, preliminary results indicate the systems' capability to provide data (thermal and video) to identify up to 84% of detections on a family level and 43% on species level. Noteworthy, on over more than 2000 identified detection events, none appeared to be a NARW, hypotheses being discussed herein.
Being a cost-efficient approach with round the clock availability, our results suggest that thermal imaging-

based detection systems provide a valuable addition to traditional monitoring approaches, such as passive acoustic monitoring, survey flights and marine mammal observers by supplementing their main limitation. However, sufficient ocean coverage is needed to detect animals as rare as NARW. As such, IR systems need to be placed strategically on land, or on several vessels regularly traversing the critical habitat.

Alternative ecotourism as an example of how whale watch companies can support right whale protection

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Vessel strikes are one of the primary causes of injury and death to North Atlantic right whales. Whale watching overlaps spatially with spring right whale distribution in Cape Cod and Massachusetts Bays, but also contributes to whale-related public education, opportunistic data whale collection and the economy of eastern Massachusetts. In 2023, right whale presence prompted increased numbers of Voluntary Slow Zones in Massachusetts Bay and there were proposed modifications to the North Atlantic Right Whale vessel speed rule (50 CFR 224.105). Significantly reduced vessel speeds restrict the possible range of operation and so alternative solutions are needed to balance seasonal risks to right whales with public interest in whale watching and economic impacts to the whale watching industry. Boston Harbor City Cruises (BHCC), which operates the New England Aquarium Whale Watch, conducts whale watches in coastal waters off Massachusetts between March and November annually. This year, BHCC delayed their usual spring whale watching schedule by two months in order to avoid right whales and remain closer to Boston. The new ecotourism cruises, which focused on coastal wildlife and education about right whale conservation efforts, were provided as an alternative cruise option. These alternative cruises sold 20.8% of the passenger count compared to the prior 2022 year of typical spring whale watches. This pilot year of alternative ecotourism is an example of how whale watch companies can support right whale protection while continuing to operate. Similar programs, if adopted where needed across the whale watch industry, would benefit right whales and stakeholders, particularly in the event that proposed speed regulations become mandatory.

Understanding the energetic importance of Cape Cod Bay to the North Atlantic right whales

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Changes in the distribution of marine organisms due to shifting oceanographic conditions present a major challenge for specialist species with a narrow range of preferred prey. For one such endangered species - the North Atlantic (NA) right whale (*Eubalaena glacialis*) - the impacts are life threatening, with increased acute mortality in new and unprotected feeding grounds. The right whales' feeding morphology limits them to filtering zooplankton, particularly lipid-rich copepods. While NA right whales feed throughout the northwestern NA, Cape Cod Bay (CCB) has become their most consistent known feeding habitat. Using a 19-year zooplankton times series in CCB, we found that a succession of three dominant copepod taxa – *Centropages* spp., *Pseudocalanus* complex, and *Calanus finmarchicus* – provided a high-calorie resource over the late-winter/early spring, and that right whales targeted aggregations of numerically non-dominant prey, relative to the bay-wide zooplankton resource composition. During periods of high bay-wide *Centropages* spp. concentrations, right whales fed on high-calorie patches of *Pseudocalanus* complex and *Centropages* spp.; and when *Pseudocalanus* complex dominated the zooplankton community, right whales fed on patches of *Pseudocalanus* complex and *C. finmarchicus*. Finally, when *C. finmarchicus* dominated the zooplankton resource, in particular copepodite stage III, right whales fed upon high-calorie patches of *C. finmarchicus* stages IV and V. Between 2013 and 2022, the mean caloric density consumed by skim feeding right whales was substantially higher (3,237 – 4,590 calories m^{-3}) than the bay-wide mean caloric resource (225 – 508 calories m^{-3}). While the caloric values of both the in-path samples and bay-wide resource show an

increasing trend through the right whale season in CCB ($p < 0.001$), the annual trend is zero, indicating a stable feeding habitat. Understanding the prey resource in this region may help us predict other future feeding habitats, and whether CCB will remain a key resource for these whales.

A glider-mounted shadowgraph camera for measuring pelagic copepod abundance and distribution in North Atlantic right whale habitat

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Calanoid copepods make up much of the diet of the critically endangered North Atlantic right whale (NARW, *Eubalaena glacialis*), who has been known to seek out patches with high densities of large, late-stage, lipid-rich copepods in the genus *Calanus.* NARW forage in underwater fields comprised of *Calanus* patches, and these fields are challenging to sample over wide areas or long (e.g., seasonal) periods. Our understanding of the scales at which these fields occur, and their dynamics, are therefore limited. Our laboratory has been experimenting with using zooplankton sensors on profiling gliders as a tool to sample whale prey fields because gliders can sample continuously for months. This study aims to test the performance of a Slocum glider-mounted shadowgraph camera system to quantify pelagic copepod distribution and abundance from images collected *in-situ*, with a special focus on late-stage *Calanus finmarchicus*. Test deployments in September 2022 collected image profiles in Grand Manan Basin, Bay of Fundy, Canada. A multiple opening-closing net system and an Underwater Vision Profiler 6 (UVP6) collected ship-based biological samples and image data, respectively, in tandem with shadowgraph-glider deployments. Taxonomic composition and concentration were obtained from the biological samples via microscopy, the UVP6 via manual annotation in EcoTaxa, and the shadowgraph via manual annotation in Video and Image Analytics for Multiple Environments (VIAME). We present preliminary data comparing the vertical distribution of copepods across the three sampling devices. The medium-term goal of this project is to add the shadowgraph camera as a sensor to a fleet of gliders operating in Atlantic Canada to autonomously sample zooplankton communities concurrently with NARW.

Detection range estimates of glider-recorded baleen whale calls in proximity to Gulf of St. Lawrence shipping lanes

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Acoustically equipped underwater gliders are an integral tool for determining the presence, distribution, and behavior of vocally active cetacean species. However, translating acoustic detections into meaningful management action often requires knowledge about the proximity of calling animals to the recording platform and, therefore, the threat being managed (e.g., vessel presence in shipping lanes). Nevertheless, many factors (e.g., environmental conditions, bathymetry, recording platform depth, calling whale depth, detection methodology, and the acoustic properties of a call) influence the detection distance of any given call, meaning that estimates of detection probability are often regionally specific and only generally applicable across study sites. In the fall of 2019, a Slocum glider and two bottom-mounted acoustic recorders were deployed across the Honguedo Strait and associated traffic separation scheme in the Gulf of St. Lawrence (GoSL), Canada. We conducted a manual analysis of the archival audio, to examine variations in the spatial, temporal, and acoustic distributions of North Atlantic right, blue, and fin whale calls. Analyses of detections highlight that their movements in this seasonally important region overlap with a high volume of vessel traffic, putting them at increased risk for ship strike. To better quantify this risk, we are developing a model to estimate the volumetric detection range of glider-recorded baleen whale calls that is

parameterized for conditions in the Laurentian Channel of the GoSL. This will give us a finer-scale understanding of whale distribution in relation to the shipping lanes based on acoustic detections, and the model itself may be a widely applicable post-deployment tool in both this and other regions. As such, these results could aid continued efforts to minimize vessel-related morbidity and mortality of vulnerable baleen whale species in the Gulf of St. Lawrence.

Quantifying entanglement risk of North Atlantic right whales in Canadian lobster fisheries

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The first fisheries management measures aimed at mitigating entanglement of North Atlantic right whales (NARW) in Canadian waters primarily focused on fishing gear from the southern Gulf of St. Lawrence (GSL) snow crab fishery. Since then, the Government of Canada has extended these measures to include all non-tended fixed gear, which includes lobster gear. A quantitative evaluation was conducted on entanglement risk contributed by Canada's lobster fisheries from the Bay of Fundy, Scotian Shelf, Cape Breton, and the southern Gulf of St. Lawrence. This study examined 23 lobster fishing areas (LFAs 20-38) that are actively fished by more than 6,000 harvesters. Lobster buoyline (i.e., vertical lines connecting surface buoys to traps on the seafloor) distribution was calculated by combining the results of a survey of fish harvesters with commercial logbook data. The survey provided regionally specific information on the use of single traps (single endline) versus trawls (two endlines per trawl), the number of traps per trawl, seasonal differences in gear configurations, and the average depth fished. This evaluation provided the first estimate of endline distribution in the Canadian lobster fishery, which was combined with a NARW occurrence model using sightings from 2015-2021 to produce quantitative entanglement risk estimates for lobster fishing throughout the Maritime provinces. These were used to assess changes in risk during this study period. Our results make important contributions to knowledge of the entanglement risk landscape of Canadian trap fisheries to NARW.

The southern Gulf of St. Lawrence as foraging habitat for the North Atlantic right whale

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The spatial distribution of North Atlantic right whales (NARW) on northwest Atlantic foraging grounds shifted in the early 2010s, with more observations during spring and summer in the southern Gulf of St. Lawrence (sGSL) since 2015. The sGSL is a shallow shelf bounded by the Québec, New Brunswick, and Nova Scotia coasts and the deep Laurentian Channel. In this presentation, we synthesize recent DFO field- and model-based research on NARW prey dynamics in the sGSL, focusing on prey supply and aggregation processes. Three species of *Calanus* spp. copepods, the preferred prey for NARW, are seasonally abundant in the sGSL. During fall and winter, when *Calanus* spp. are in diapause in deep water, *Calanus* spp. abundances are low in the sGSL. Transport from the Laurentian Channel, mainly via the Gaspé Current, resupplies the sGSL when *Calanus* emerge from diapause and return to the near-surface. *Calanus hyperboreus* and *C. glacialis* are transported into the sGSL first during their active period (ca. March-June), while immigration of *C. finmarchicus* extends from ca. March through the summer months. The magnitude of resupply depends on upstream concentrations and circulation patterns during the *Calanus* spp. active periods. Aggregation of copepods to high densities required for NARW feeding can occur through interactions of vertical movements and local circulation features or barriers (*e.g.*, the seafloor). Dense near-bottom layers of *C. hyperboreus*, with energy levels near the threshold for profitable NARW foraging, are observed in the sGSL as early as mid-May, and dense mixed-species layers are observed locally in the sGSL in summer. The density of near-bottom prey layers can be dynamic at short time scales, likely due to low local

retention. Characterizing processes driving distribution and dynamics of *Calanus* spp. in the sGSL provides a basis for assessing foraging habitat and its vulnerability to future change.

Vessel strike forensics of right whales - a review of methodology and new findings

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One significant human impact to right whales is propeller strikes. Wound dimensions have been be approximated in some cases using whale growth curves and crude photogrammetric assessment or by direct measurement on carcasses. By linking wound dimensions to propeller diameter and other details, these can be tied to likely vessel characteristics and their typical mode of operation. Using techniques that have been applied in human and manatee forensics and a prior right whale study, three approaches are further investigated in the current study.

Method 1: Propeller size is estimated by assuming a circular disk swept by the propeller blades, and projecting this circle into the plane of the whale injury surface so that it matches the visible length and estimated/known depth of the wound. Graphically, this will appear as an ellipse with a segment that is mostly congruent with the wound trace on the whale. The diameter of the ellipse is the estimated propeller diameter.

Method 2: When significant curvature of the wound is not evident, the depth to which the propeller blades embed in the whale can be estimated by the degree of "sigmoid" shape in the wound trace. This is a consequence of the helical generating shape of all propellers; the direction of the cut through the whale tissue changes as the propeller becomes more deeply embedded.

Method 3: Propeller diameter and vessel size can be very roughly approximated as a function of longitudinal wound spacing and typical ratios of propeller parameters.

None of these methods has proved to be particularly precise in that they do not yield the propeller and vessel "fingerprint" that is desired. However, by employing various rules of thumb about propellers and vessel length, some useful, if highly approximate, estimates regarding the size of vessel involved in a given whale strike can be inferred.

Preliminary results from the deployment of high-resolution inertial sensing tags and collocated prey field analysis of North Atlantic right whales in the Gulf of St Lawrence

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In the summer of 2023, the Fortune lab at Dalhousie University in collaboration with the University of New Brunswick and Canadian Wildlife Federation began a multi-year biologging and prey field assessment project in the Gulf of St Lawrence. Along with collaborators from NOAA, New England Aquarium, the University of New Brunswick and Canadian Whale Institute our research team was able to deploy 4 high resolution biologging tags for a total of 21 hours and 21 minutes. Individual tag deployments lasted 1h4m; 2h1m; 7h16m and 11h. To this point one individual tagged has been photo-identified by NEAq staff, the 7h16m deployment on a reproductively active 15-year-old female Bocce (#3860) the 2008 calf of 2040. Preliminary analysis of the time-depth recorder from the tagged whales indicates near continuous deep dives to near the seafloor. During these presumed feeding bouts, the whales spent the majority of their time within 5m of the surface or sea floor, with steep ascents and descents between the two. Only the 11h deployment indicated different movement patterns, displaying a shift in behaviour at approximately 18:30 local time when the individual ceased continuous deep diving and shifted to shorter dives to approximately 10m, this behaviour continued until the tag detached at approximately 23:50 local time, with only three dives deeper than 10m in the intermediate time. Tagged and untagged whales were focal followed and oceanographic sampling was undertaken in the fluke print of whales exhibiting high fluking dives, an indicator of foraging. Oceanographic sampling consisted of a cage which included a conductivity-temperature-depth sensor (CTD) and optical plankton

counter (OPC); a second cage mounted with an underwater vision profiler (UVP); and a bongo net.

Two overnight stations were established at locations where whales were observed to be feeding, preliminary analysis of these stations indicates the presence of diurnal vertical migration. Oceanographic sampling also occurred at previously sampled stations and at stations identified as within or near to suspected biogenic slicks.

A review of vessel strikes of right whales- when, where, what types of vessels, and impact to whales

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Vessel strikes of right whales have resulted in blunt force trauma, gashes, and propeller cuts. Based on necropsies and photographs of whale injuries, a total of 113 cases interactions have been documented from 1972 through July 2023. Very few cases can be directly linked to the vessel involved unless the strike was reported. In some of cases, forensic techniques have been applied to determine estimated propeller diameter and vessel size range when propeller cut dimensions are available. For the 92 cases with external propeller cut injuries, less than half the cases were able to be forensically assessed by Alex Costidis with additional analyses provided by Paul Kamen to determine vessel size range. We compared the estimated findings with the small number of known right whale cases to evaluate the three different approaches described by Kamen. Using these findings, we clustered images of cases into estimated vessel size ranges from less than 40 feet to greater than 400 feet to see if patterns emerged that would allow us to categorize cases where the collection of cut measurements was not feasible. Based on these estimated vessel sizes, we assessed the nature of the impacts observed and their effect on individual whale outcomes as well as the impact on reproduction. We also applied an allocations approach to provide insights into where these strikes have occurred. Although measurements of propeller cut dimensions has its challenges, especially when a carcass is not in hand, there are patterns that have emerged with these studies which may be valuable for estimating the vessel size range of strikes of all large whales.

Exploring overlap between NARW and ocean features: An autonomous-based oceanographic and ecological baseline

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The U.S. federal government has set a goal of deploying 30 GW of offshore wind electricity generation by 2030. On the continental shelf off New Jersey, including the planned offshore wind energy areas that will play a critical role in achieving this goal, the ocean is characterized by remarkable variability across time scales from days to seasons to decades. This drives an equally variable ecosystem from primary producers to highly migratory marine mammals. With offshore wind construction scheduled to begin within the next year, it is critical that oceanographic and ecological monitoring begins quickly and considers time scales of natural variability from seasons to years. Our team has collected decades of data from satellites (e.g. surface temperature, surface chlorophyll), high-frequency radar (surface currents), and gliders (e.g. sub-surface temperature). Several glider deployments have been equipped with passive acoustic whale monitoring systems, providing whale detections that can be associated with concurrent measurements of surrounding environmental features. Building on this effort, we are initiating a more comprehensive "ecoglider" program that will contribute to the existing baseline dataset of oceanographic and ecological parameters to provide information relevant to ongoing change in this productive ecosystem. Deployed gliders will include a full complement of sensors to map oceanographic and ecological variables from phytoplankton to marine mammals, including temperature, salinity, pH, chlorophyll-a, dissolved oxygen, and others. Ecological sensors include a passive acoustics sensor for North Atlantic Right Whale (NARW) detection, echo sounders to detect fish and zooplankton, and telemetry to track

tagged species. These data, with additional concurrent NARW and ocean observatory data, offer

an unprecedented opportunity to explore the overlap between oceanographic features and the distribution of NARW. This presentation will share initial results of habitat feature overlap with NARW seasonal migrations through the New York Bight and an overview of the upcoming baseline monitoring effort.

High variability in Bay of Fundy zooplankton 2006-2022

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Zooplankton form the foundation of the food web in many marine ecosystems, and are particularly important for filter-feeding species such as the North Atlantic Right Whale (NARW). We monitored the summer zooplankton community in one of the NARW's historically critical habitats, the Bay of Fundy (BoF), from 2006-2022. We sampled zooplankton weekly or biweekly in August and September in the Grand Manan Basin (~180 m) using a vertically deployed bongo net. Traditionally, the BoF's zooplankton community has been dominated by *Calanus finmarchichus*, specifically the C5 stage that contains an energy-rich oil sac reserve and is targeted by NARW for their high caloric value. From 2006-2010, C5s were dominant (representing >60% of all zooplankton) and present in fairly consistent numbers, but after 2010, three big changes were observed. First, C5 average annual abundance became highly variable from year to year, ranging from ~10% to 170% of the 2006-2010 values. Second, tows in some years (2012, 2018, 2020, and 2022) were dominated by other species, namely *Centropages*, which is a much smaller zooplanktor without an oil sac. Third, individual C5s were smaller than in previous years. In the most recent years (2021-22), average C5 numbers were 46% of the 2006-2010 C5 values. Since 2006-2010, C5 abundance has declined at an average rate of 3.6% per year, and C5s now only represent 28% of total zooplankton. Other authors have suggested that the C5 decline has led to the shift of NARW from the BoF to the Gulf of Maine, and it would appear in recent years that copepod populations not recovered to the stable and predictable high numbers of 2006-2010, and are still declining overall. In addition, *Centropages* and other species are now dominating this system, likely having large implications for nutrition in NARW and other filter feeders in the BoF.

Applying an individual movement model to quantify dynamic habitat use of North Atlantic right whales

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Rapid warming in the Northwest Atlantic has caused declines of North Atlantic right whale prey, late-stage *Calanus finmarchicus*, in historic and protected foraging areas. To improve our understanding of habitat selection and inform future monitoring efforts and protections, an investigation of right whale movement patterns and foraging success in a warming environment is needed. Annual right whale distribution and number of births in the population have been linked to fluctuations in the abundance of late-stage zooplankton prey; however, patterns of individual foraging behavior and reproductive success in relation to changes in the physical oceanographic environment have not been investigated. The North Atlantic right whale population has been monitored since 1980, and individuals can be identified by unique callosities and markings. Using consecutive sightings of these known individuals from 1977-2021, Brownian bridge movement models have been applied to quantify potential habitat use for each track incorporating movement variance and time in between sightings of tracks with ≥ 2 consecutive sightings (number of sightings = 59,429; number of tracks = 18,284). By summing the habitat utilization produced from these tracks, movement patterns emerge as individuals transition between habitats, allowing habitat use to be quantified beyond stationary sightings. By comparing estimated residence time in known habitats as well as expected habitat use between sightings on seasonal, annual, and decadal timescales, provides insight into right whale behavior in response to environmental changes, such as prey availability. This modeling approach provides a non-invasive method to improve spatial distribution predictions and understand habitat use in intermittently observed animals, which is valuable for populations such as right whales for which tagging studies are not feasible due to logistics, cost, or risk of infection.

Whale Insight: A tool in support of advancing science communication for the North Atlantic right whale in Canada

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Whale Insight was launched in May 2022 by Fisheries and Oceans Canada (DFO) to support the near-real time dissemination of validated North Atlantic right whale (NARW) detections, both visual and acoustic, to decision makers, researchers, stakeholders, and the public. Modeled after WhaleMap (Johnson et al. 2021), Whale Insight is a publicly accessible, online visualization tool focusing on displaying near-real time detections of NARW in Eastern Canadian waters made by a variety of contributing partners. Detections for other large whale species are also displayed although visual observations are not consistently available in near-real time. Canadian resource managers at DFO and Transport Canada use these detections daily to trigger fishing area closures and vessel slowdowns. As such, Whale Insight continues to be instrumental in facilitating the dynamic management and protection of NARW in Canadian waters, while also serving as a survey planning resource and communication, education, and outreach tool for the general public, maritime and fishing industries, and their communities. Here we provide an overview of the Whale Insight tool and highlight the successes, challenges, and lessons learned over the past year while facilitating the visualization of near-real time data to inform dynamic decision making for the NARW. We also present our future plans for the platform, which include architecture improvements and options to build and export customized maps.

Fisheries and Oceans Canada (DFO): An adaptive fisheries management approach

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The North Atlantic right whale (NARW) is listed as Endangered under the Canada's *Species At Risk Act*. Primary threats to the survival and recovery of this population in Canadian waters include fishing gear entanglement and vessel strike. The Department of Fisheries and Oceans Canada (DFO) implements adaptive fisheries management measures with the primary objective of entanglement prevention for NARW throughout its Canadian range. Changes to fisheries open and close dates, near real-time adaptive fisheries closure protocols and other regulations are used to meet this objective. DFO is also working with Indigenous partners, fish harvesters, non-government organizations and academia to develop a whalesafe fishing gear strategy. Advances in gear technology can be used to prevent marine mammal entanglements by removing line from the water, and to alleviate the intensity of an entanglement with gear that promotes animal self-release. Additionally, the Department addresses entanglement threats posed by abandoned, lost and discarded fishing gear through the Ghost Gear Program, including by supporting lost gear retrieval. The DFO also supports a network of expert marine mammal emergency responders through the Marine Mammal Response Program to respond to marine mammals in distress, and conducts analyses of the origin of gear removed from disentangled NARW to inform future management approaches. Canada's approach is driven by innovation, informed by the feedback of partners and stakeholders, and evolves with new information to ensure entanglement risk to NARW is reduced as much as possible in Canada's commercial fisheries.

U.S. Army Corps of Engineers updates on conservation and protection measure implementation in the South Atlantic region

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The U.S. Army Corps of Engineers' (Corps) oversees maintenance dredging for navigation supporting America's vital ports, military readiness, recreation, and performs beach nourishment for coastal storm protection. These missions coincide with areas where NARW migrate – through the Carolinas – and calve each winter – in Georgia through Northeast Florida. The 2020 SARBO incorporated the Corps' and the BOEM NARW Conservation Plan (Plan) which significantly expanded protective measures, including aerial surveys. Surveys are coordinated with the NMFS to send alerts to mariners to reduce the likelihood of vessel strikes. Aerial surveys also collect further valuable data for NARW researchers, such as migration patterns and trends in calving grounds.

The Corps continues working towards fully implementing the 2020 SARBO and the Plan by updating environmental compliance documents to reflect the changes from the 1997 to 2020 SARBO. A few of the NEPA documents that included SARBO have resulted in litigation, slowing this process. However, the Corps remains committed to fully implementing the Plan once the updates are complete. The Corps has successfully used the Plan to fund aerial surveys during calving season and is pushing to move work outside of areas and times when calves are present to further reduce risk to NARWs.

The status of whales along the East Coast is currently threatened due to unknown causes and ongoing UMEs. The Corps is staying informed and involved in the news as it impacts the ongoing work along this vital path of commerce. The Corps is also involved in public outreach events across the Southeast coastline to increase the public's awareness of NARW occurrences and the status of the NARW population.

In this presentation, the Corps will present details on the 2022-2023 calving season aerial surveys completed as part of the Plan, outreach and education efforts, and our commitment to protection of the species.

Interannual and spatial heterogeneity of North Atlantic right whale diving behaviour presents challenges for estimating availability bias to aerial surveys, entanglement and collision risks in the Gulf of St. Lawrence

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North Atlantic right whales (NARW) summer in the Gulf of St. Lawrence (GSL), where they are exposed to threats such as vessel collision and entanglement in fishing gear, and are regularly monitored for their abundance and distribution using aerial surveillance. Abundance estimates and risk assessment require adequate estimation of heterogeneity in diving behaviour, both temporally and spatially, in order to be reliable. In this study, we examined the interannual and spatial heterogeneity of NARW diving behaviour in the GSL using 26 satellite-linked time-depth/fastlocGPS Argos transmitters deployed in June-July (2022), July (2023), and August (2019). A state-space model applied to combined movement and dive data indicates a tendency for NARW to perform shallower dives while in transit, making them more prone to collision risk and more available for detection by survey platforms compared to when they are foraging. The data also reveals a high interannual variability in diving behaviour. In 2022, tagged whales displayed around-the-clock diving near the seabed and barely any surface active groups (SAGs). In contrast, tagged whales in 2019 remained near the surface (< 12 m) at night and dove near the seabed during the day, with SAGs regularly observed. In 2023, SAGs were detected and a diving pattern similar to 2019 observations prevailed for all but one individual, the latter spending almost the entirety of its time near the surface. The difference in diving patterns observed between years (and months),

individuals, and behaviours emphasizes the challenges with capturing variability when estimating collision and entanglement risks, and when estimating the adjustments for animals unavailable to survey platforms (availability bias), which are required to obtain reliable estimates of abundance.

Diel patterns in the vertical distribution of North Atlantic right whale prey in the southwestern Gulf of St. Lawrence, Canada

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An ocean regime shift in the traditional foraging habitats of North Atlantic right whales (NARWs) has coincided with an increase in summertime NARW sightings in the southwestern Gulf of St. Lawrence (sGSL), Canada since 2010. NARWs typically feed in areas characterized by oceanographic processes that concentrate their small plankton prey enough to satisfy daily energetic demands. More research is currently needed to understand the fine-scale mechanisms that concentrate prey in the sGSL. The objective of this study is to characterize the preyfield of NARWs in specific areas of the sGSL where groups of whales aggregate. In 2019, 2021, and 2022, our team conducted daytime and nighttime oceanographic sampling within groups of NARWs (3 or more whales) in the sGSL. Stations included photo-identification and distance sampling (daytime only) as well as the deployment of oceanographic sensors and nets to estimate the abundance and vertical distribution of plankton relative to physical features of the water column and demographics of nearby NARWs. Preliminary results indicate that late-stage *Calanus* spp. were often concentrated most densely within 10 m of the seafloor during the daytime, likely because the shallow bathymetry of the sGSL acted as a barrier to the vertical migration of plankton. During the night, however, prey were more dispersed (and more available to our plankton sampling equipment) at shallower depths. Our results provide context for explaining the diel diving behavior of NARWs in the water column in the sGSL.

Modeling changes in vessel strike risk to North Atlantic right whales as a result of Canada's traffic management measures in the Gulf of St. Lawrence

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Vessel collisions are a major threat of mortality and injury to North Atlantic right whales (NARW). Since 2017, 16 vessel collisions with NARW have been reported, causing injuries and/or death. To mitigate the risk of vessel strikes, while ensuring safe navigable waters, the Government of Canada has implemented vessel traffic measures in the Gulf of St. Lawrence (GSL), including static, dynamic, and seasonal 10-knot speed limit zones, a restricted area, and a voluntary slow-down zone. We conducted a quantitative assessment of each annual vessel management scheme to evaluate the effectiveness of the marine traffic measures to protect NARW and to estimate the average risk reduction achieved. Risk considers the probability of encounter between NARW and vessels, and the probability of lethality if a collision were to occur. Using automatic information system (AIS) data, we compared the spatial distribution and density of vessels in the GSL in each year where vessel measures were established (2017-2022) to the average traffic before measures were implemented (2015-2016). This was combined with whale occurrence estimates to calculate probability of an encounter. The probability of a lethal collision was calculated using AIS data and a biophysical model that accounts for vessel size, shape, and speed, to simulate a collision with an average adult NARW (Kelley et al 2021). Preliminary results from 2015 to 2019 showed cargo vessels and tankers representing 57% of the average annual total number of transits in the study area (71% of unique vessels), fishing vessels 15% (11% of unique vessels), and ferries 11% (2% of unique vessels). The results of this study will provide a quantitative estimate of the efficiency of marine traffic management to protect NARW in the GSL as they are currently implemented and will help inform future management measures.

North Atlantic right whale distribution in Southern New England during the winter and spring of 2023

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Southern New England (SNE) is one of the few habitats where North Atlantic right whales (*Eubalaena glacialis*) have been documented year-round. Right whale presence has been recorded in SNE every season since 2017, with peak abundance occurring in the winter and spring. The New England Aquarium (NEAq) has conducted systematic aerial surveys in SNE since 2011 to collect baseline data on marine species, including right whales, in and around the waters currently being developed for offshore wind farms. The Northeast Fisheries Science Center (NEFSC) conducts surveys throughout Northeastern United States waters, and also targets right whale aggregations to maximize photographic capture of individual right whales for monitoring the population. Both teams survey in SNE, and primarily overlap south of Martha's Vineyard and Nantucket. High observed turnover of individual right whales between surveys in winter and spring 2023 prompted us to explore the dynamics of SNE right whale aggregations from January to May 2023. We used sightings from both survey teams, which totaled 495 photo-documented sightings of 201 individual right whales, or approximately 60% of the population. During the winter and spring, right whale aggregations shifted across three key areas: the Nantucket Shoals, south of Muskeget Channel, and north of Block Canyon, yet few individuals were seen in all three areas. Interestingly, the north of Block Canyon aggregation had a much higher adult:juvenile ratio than the other two areas. Our investigation showed that a large percentage of the right whale population visited SNE in early 2023, and that movements of both individuals and aggregations are dynamic. These findings support previous studies in SNE showing the importance of this habitat to right whales, particularly in the winter and spring, and underscore the need for increased monitoring and protection in SNE especially as construction of commercial scale wind farms in the area begins.

Distribution patterns of North Atlantic right whale aggregations in the Shediac Valley

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Whale sightings data suggest that there is at least one non-random pattern in the distribution of North Atlantic Right Whale foraging groups within the Shediac Valley, where groups of whales periodically aggregate along the eastern slope. This is interesting because right whales often aggregate over sloped boundaries in other habitats. We are analyzing four years of sightings data collected by aerial and shipboard surveillance over summertime feeding months to search for spatial patterns in whale aggregations on an intra-habitat scale (10s of kilometers), focusing on the slope region. We are defining whale aggregations by the interval in which the observation platform breaks from the track to photograph individual whales within a group. We are characterizing the area, shape, and orientation of whale aggregations in relation to the Orpheline Trough. One of the challenges is accounting for bias introduced by variation in survey effort and non-systematic track-line surveys. We expect to find along-isobath patterns of aggregations on the eastern slope of the Shediac Valley, in areas where bathymetry is deeper. Identifying spatial patterns of distribution may lead to hypotheses on the physical and biological oceanographic mechanisms that create favorable conditions for foraging right whales, such as dense and persistent concentrations of copepods. Characterizing these mechanisms and the intra-habitat variability in critical foraging grounds in the southern Gulf of St. Lawrence will be the next step in our study.

From wind to whales: Potential hydrodynamic impacts of offshore wind on Nantucket Shoals region ecosystems

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Offshore wind is in the early stages of implementation in the US, with only two offshore wind farms in operation - one offshore Virginia and one offshore Rhode Island. However, plans exist to build additional offshore wind farms on the East coast and construction has begun at lease sites in the Nantucket Shoals Region. Part of the permitting process required to install and operate offshore wind farms includes assessing any potential ecosystem impacts; regulated by the Bureau of Ocean Energy Management. One challenge is to understand how the oceanography might be altered by the presence of offshore wind farms. An offshore wind turbine can alter flow by interrupting wind-driven circulation processes and by causing wake effect-induced turbulence in the water column surrounding the pile. These hydrodynamic changes may potentially affect the ecosystem, from phytoplankton to marine mammals. This presentation details findings from a National Academy of Sciences committee on how offshore fixed-bottom wind turbine generators in the Nantucket Shoals Region may alter physical processes such as seasonal stratification, tidal fronts, waves, and currents on local to regional scales, which in turn may impact zooplankton supply, abundance and aggregation. North Atlantic right whales (*Eubalaena glacialis*) have been observed foraging on zooplankton in the Nantucket Shoals Region year-round, and hydrodynamic impacts of turbines may affect their foraging patterns and success. Given the uncertainty in the effects of wind energy operations on right whale prey availability, and thus right whale behavior, distribution and demography, the approach to mitigate negative impacts on this critically endangered species should be broad, and accompanied by robust monitoring efforts. Improved understanding of foraging dynamics in this first large-scale wind energy site will provide critical information for planning future wind energy development to avoid large-scale population impacts.

Habitat use of North Atlantic right whales in traditional lobster fishing grounds: Insights from a five-year fishermen-led data collection program

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The North Atlantic Right Whale (NARW) is an endangered species facing critical conservation challenges, particularly in the context of its potential interaction with human activities, such as fishing. In response to the urgent need for comprehensive data to inform conservation efforts, a pioneering five-year data collection program was established, led by lobster fishermen operating in these coastal areas. This presentation highlights the key findings and insights obtained from this unique collaboration between scientists and fishermen, aimed at assessing the habitat use of NARWs in traditional lobster fishing grounds. The program's design prioritized the

active engagement of fishermen, capitalizing on their local knowledge and expertise to collect essential data on NARW sightings, behavior, and distribution patterns. This survey in Baie des Chaleurs was conducted each summer from 2019 to 2023, in depths of less than 20 fathoms, where all the fishing effort for lobster is happening. For each transect, information was collected on environmental and weather conditions, marine mammal and seabird species diversity and location, and human activities (presence of boats, their activities, speed, etc). Leveraging their unique vantage points and familiarity with the area, fishermen served as crucial collaborators, gathering data through standardized protocols. We are presenting results on the spatial and temporal distribution of NARWs in relation with fishing grounds, shedding light on the actual interplay between their movements and the lobster fishing. It also provides an opportunity to better understand the coexistence challenges for endangered species and harvesters, and solutions to these. By integrating the perspectives and expertise of local stakeholders with rigorous scientific methodologies, this collaborative program yields an innovative and robust dataset that significantly contributes to our understanding of NARW habitat use dynamics, emphasizes the importance of such cooperative efforts in advancing marine conservation strategies, and highlight the immense potential of fisherman-led initiatives in augmenting scientific research and marine conservation.

Explaining the spatial and temporal distribution of right whales in the Gulf of St. Lawrence: A modelling approach

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The Gulf of St. Lawrence (GSL) is an important feeding ground for several whale species, including North Atlantic right whales (NARW). In recent years, more than half of this population has been observed in this area from spring to fall, where risks of entanglement in fishing gear and vessel collision are considered high. For mitigation measures to be effective, there needed to be an in-depth knowledge of the spatial and temporal distribution of NARW, including seasonal and interannual variability. Currently, the factors leading to the observed variability in NARW distribution within the GSL are not fully understood. This study examines the physical and biological oceanographic factors driving NARW distribution using habitat modeling and NARW observations collected during systematic line-transect aerial surveys conducted between 2017 and 2022 in the Estuary and GSL. Results from a model based on physical oceanographic parameters alone indicate that seafloor depth and topography, sea surface temperature, and the occurrence of fronts are good predictors of NARW occurrence; the addition of other variables, such as copepod abundance and NARW dive parameters, are likely to further improve our ability to predict the spatial and temporal distribution of this highly endangered species.

Recommended lanes for North Atlantic right whale conservation: An assessment of design and mariner cooperation

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Vessel routing measures are one of many tools available to managers to minimize vessel strike risk to North Atlantic right whales. NOAA established the voluntary recommended lanes in the Cape Cod Bay, MA and Southeast US Seasonal Management Areas (SMAs) in 2006 for this purpose. Routing measures, including the recommended lanes, can be effective conservation tools when they reduce the co-occurrence of whales and vessels and when mariners cooperate with them. Therefore, it is important to understand both aspects of the lanes to determine their usefulness in vessel strike reduction efforts. When the recommended lanes were designed, a limited number of candidate routes were considered based, in part, on how the routes overlapped with right whale density. However, by considering only a limited number of routes, alternatives that could have further reduced risk may have been overlooked. Furthermore, little is known about how well mariners cooperate with the recommended lanes. To evaluate the design of the recommended lanes, we used the *k* least cost path (KLCP) algorithm to find all alternative lanes that could reduce vessel strike risk and vessel transit time as compared to the existing recommended lanes. To assess mariner cooperation with the recommended lanes, we analyzed Automatic

Identification System (AIS) data collected from 2017 through 2019. We will present a comparison of the existing and alternative lanes identified with the KLCP algorithm. Additionally, we will present results describing how mariner cooperation with the recommended lanes varied across SMAs, vessel types, routes traveled, and time of year. Minimizing vessel strike risk to right whales is essential to the conservation of the species. Recommended lanes can be a valuable tool to reduce this risk, and to be effective, their design should account for right whale density patterns and expected mariner cooperation.

Aerial line-transect survey efforts for North Atlantic right whales in eastern Canada from 2017 to 2022 – data exploration

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Since 2017, the Department of Fisheries and Oceans (DFO) Canada has been conducting systematic line-transect aerial surveys to monitor the abundance and the distribution of the North Atlantic right whales (NARW) in eastern Canada. Following the report of twelve carcasses, systematic surveys were conducted in August and September 2017 over fifteen zones where high densities of Calanus had been detected on DFO scientific missions in the previous decade to complete the coverage of the Shediac Valley, in the southern Gulf of St Lawrence (sGSL) that was provided by the NOAA. Wider systematic aerial survey were initiated in April 2018 to provide seasonal monitoring of areas where NARW had been detected in previous years, particularly the sGSL, and provided extended coverage of Canadian waters in late summer. From August 2017 to November 2022 cumulative survey hours reached a total of 6,692 h 58 mins with up to three aircraft simultaneously flying for up to seven months a year, for an average of 1,115 h 29 mins ± 466 h 44 mins per year. A total of 614,345 km were surveyed over 20 different strata and 1,285 NARW groups were detected. Between 5 and 11 passes of surveys were completed in the sGSL per year and most of the NARW detected (1,215) were from this area. Each year, the first sighting of NARW from aerial survey in the GSL was between April 25th and May 13th, while the last sighting occurred between October 28th and November 14th. NARW sightings with associated systematic survey effort represent an ideal source of data for habitat modelling that will be used to increase our understanding of whale distribution across the sGSL and to improve and measure the efficiency of management measures for fisheries or shipping.

Co-occurrence of North Atlantic right whales and vessel traffic in emerging and existing habitats

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While vessel strikes are a prominent threat to the critically endangered North Atlantic right whale (*Eubalaena glacialis*), changes in the species' distribution increase the challenge of assessing the risk of vessel strikes. By comparing the density of whale sightings with vessel traffic patterns, this study assesses the risks posed to North Atlantic right whales by vessels. The co-occurrence of Automatic Identification System (AIS) vessel traffic data and right whale sightings was evaluated in 2019 to compare the relative risk of vessel strikes across time and space. AIS vessel traffic data from fishing vessels were used as a proxy for entanglement risk. Risk was assessed year-round throughout right whale North Atlantic foraging habitats and during the winter months in the Southeast US calving ground. High-risk areas were identified when right whales and vessels were present at high densities, as defined by their respective classification schemes. Risk maps indicate where anthropogenic stressors, including vessel strikes, vessel noise, and entanglement in fishing gear, potentially impact right whales. Throughout known right whale habitats, high levels of vessel traffic persisted year-round, with fishing effort peaking from late spring to late summer. On average, vessel strike risk was highest in the Cape Cod Bay, Massachusetts Bay, and the emerging Southern New England habitats. In the Southeast US, vessel strike risk occurred throughout the calving ground from November to March, but risk was elevated during the earlier portion of the calving season. Right whale sightings were sparse in the Mid-

Atlantic region, but right whales utilize this area as a migration corridor, so vessel densities were examined during peak migration periods. By mapping the co-occurrence of vessel traffic and right whales, this analysis identifies critical areas for mitigating the risk of vessel strikes in emerging and existing right whale habitats.

Where the whales go for spring break: Recent North Atlantic right whale observations near the shelf break south of New England and potential oceanographic drivers behind these distributions

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North Atlantic right whale distributions have shifted from many traditional foraging grounds, and even during periods with known primary foraging locations, much of the population's location goes unaccounted for at any particular point in time. In May of 2023, the U.S. Coast Guard reported right whale sightings near the continental shelf break. NEFSC surveys responded to this initial sighting report and observed approximately 70 individual right whales in the area. A multi-institutional collaboration then helped guide surveys returning to the area after poor weather to find additional whales. These recent sightings suggest that this area may provide an additional important foraging habitat, in part driven by recent changes to climate and oceanographic patterns. We hypothesize that the northward shift in the Gulf Stream and an increase in the number of warm core rings interacting with the shelf break may be creating conditions that concentrate zooplankton prey. When a warm core ring interacts with the continental slope, it can pull streamers of continental shelf water to the Slope Sea. These rings may be pulling streamers of water off the shelf, concentrating prey near the northeastern edge of warm core rings, while at the same time interacting with upwelling driven by the shelf break jet and creating areas of high biological productivity. We discuss the patterns of sightings from recent years and how they relate to the changes in oceanography over the continental shelf and slope.

Genome-wide patterns of mutation load indicate genetic purging through inbreeding in the endangered North Atlantic right whale

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One of the chief consequences of small population size is the rapid accumulation of deleterious genetic variation that reduces fitness (mutation load). Mutation load particularly imperils small and inbred populations because inbreeding causes the inevitable expression of recessive deleterious variation through increased homozygosity. However, inbreeding can also expose recessive genetic variation to natural selection that purges deleterious mutations from populations. In turn, the genetic purging of deleterious variation allows some populations to persist despite small size. Here, we use whole genome resequencing data to quantify and characterize genome-wide patterns of inbreeding and mutation load in the endangered North Atlantic right whale (*Eubalaena glacialis* [NARW]). Due to differences in genetic architecture, we assess inbreeding and mutation load independently for the autosomes and X chromosome. We also quantify inbreeding and mutation load in the southern right whale (*E. australis*) and the eastern Arctic bowhead whale (*Balaena mysticetus*) for comparison. Unlike the NARW, these populations show signs of recovery following commercial whaling that ended in the 1980s. Our data reflect evidence of genetic purging in the NARW despite increased inbreeding and mutation load compared to both southern right and bowhead whales. Notably, signals of genetic purging appear to be amplified for the X chromosome relative to the autosomes, which could indicate a reduced mutation burden placed on females. We have therefore also leveraged differences in genomic characteristics between NARW females with high and low reproductive success in order to identify genetic mutations putatively linked to reduced

fecundity. The results of this study suggest that the "genetic health" of the NARW may improve over time, highlighting the importance of reducing mortality from anthropogenic sources.

Using synthetic NARW upcalls and deep artificial neural networks for acoustic detection

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Passive Acoustic Monitoring (PAM) has emerged as an important tool in monitoring North Atlantic right whales (NARW). However, analyzing the vast quantities of acoustic data collected through passive monitoring poses significant challenges. Deep Artificial Neural Networks (DANNs) are effective algorithms for automated detection and classification software. However, training these networks requires vast amounts of annotated data, which can be difficult to produce. We explore the use of synthetic data mimicking to drastically reduce the amount of data necessary to train DANNs capable of detecting the NARW upcall. To generate realistic upcalls, we first created signals with a modulated sine function and used acoustic propagation modeling to transmit the synthetic signals through a virtual underwater environment. Then, to enhance the realism of these synthetic upcalls, they were embedded into real environmental background samples extracted from recordings. In this way, we can simulate various underwater conditions. For comparison, we trained a DANN only on synthetic data and contrasted it with a DANN trained only on recordings collected in the Emerald Basin, off the coast of Nova Scotia, which contained real NARW upcalls. The synthetic dataset yielded inferior but similar performance (60% of upcalls were found with 6 false detections per hour) to the real data (70% with 5 false detections per hour). When adding 30% of the real calls to the synthetic dataset, 75% of upcalls were retrieved with 5 false detections per hour. This method allows researchers to tailor the dataset to various environments, with different sources of transient sounds/noise, geological features, ambient sounds, and hardware-induced system self-noise, producing detectors and classifiers that are better adjusted to target soundscapes even when annotated data is lacking. Finally, we present free and open-source tools that researchers can use to create and adapt similar detectors and classifiers with little to no coding.

Autumn acoustic behavior of right whales in Southern New England

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Conservation efforts for North Atlantic right whales include extensive passive acoustic monitoring (PAM) to detect right whale sounds to determine when they are present in a given area. PAM for right whales often focuses on a single stereotyped call type, the upcall, a call produced by both sexes and all age classes. Right whale acoustic behavior varies across age/sex classes, habitats and seasons, therefore focused studies of acoustic behavior are needed to aid in interpretation of PAM recordings across their range. Recent habitat shifts have resulted in data deficiencies regarding right whale acoustic behavior in previously unstudied regions during certain times of the year. In this study, archival acoustic biologging tags were attached via suction cups to North Atlantic right whales in October 2021 in Southern New England waters south of the island of Nantucket. A total of 38 hours of tag data were collected from eight individuals. A range of behaviors were observed in the habitat, including visual observations of travel and social behavior and tag sensor data indications of feeding at or near the seafloor. Call rates of individual whales were extremely low during periods of presumed foraging, with higher call rates detected during periods of travel and social activity. Assessment of all right whale call types, produced by both the tagged whale and others in the immediate vicinity recorded on the tag, suggest that passive acoustic monitoring for right whale presence in this habitat will be improved by expanding the call types used for detection to include gunshot and more variable tonal calls that are produced during social behaviors.

Estimating the effects of multiple stressors on the health, survival, and reproduction of North Atlantic right whales

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Quantifying the cumulative effects of stressors on individuals and populations can inform the development of effective management and conservation strategies. We developed a Bayesian state-space model to evaluate the effects of multiple stressors on individual survival and reproduction. In the model, stressor effects on vital rates are mediated by changes in underlying health, allowing for the comparison of effect sizes while accounting for intrinsic factors that might affect an individual's vulnerability and resilience. We applied the model to the 50-year dataset of sightings, calving events, and stressor exposure of North Atlantic right whales (*Eubalaena glacialis*). The viability of this population is threatened by a complex set of stressors, including vessel strikes, entanglement in fishing gear and fluctuating prey availability. We estimated that both blunt and deep vessel strike injuries, as well as severe entanglement injuries, had the largest effect on the health of exposed individuals, reinforcing the urgent need for mitigation measures. Prey abundance had a smaller, but protracted effect on health across individuals, and estimated long-term trends in survival and reproduction followed the trend of the prey index, highlighting that long-term ecosystem-based management strategies are also required to protect this species. Building on this approach, we included a process model for individual length, informed by photogrammetry data, and investigated its effect on female calving probability. The results indicate that decreasing length over the study period accounts for a large portion of the decline in female calving probability. We are currently working on incorporating spatial structure to account for the heterogeneous distribution of stressors across the species' range, and on the assessment of stressor interactions.

An active learning pipeline for identifying whales in satellite imagery at scale

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Knowledge of the distribution of whales is increasingly important for the development of the blue economy, as well as meeting NOAA's statutory requirements under the Marine Mammal Protection Act and Endangered Species Acts. In addition, climate change is shifting marine mammal distribution and therefore increasing the need for more real time understanding of species distribution. In the western Atlantic, much of this concern focuses on the endangered North Atlantic right whale, which has been experiencing a population decline for over 10 years and has only an estimated 368 individuals remaining. In the Pacific, the endangered Cook Inlet beluga population is estimated at 279 individuals

(95% probability interval 250 to 317) and is experiencing a ~2.3% decline in abundance per year. There is increasing demand to track these species at finer spatial and temporal resolution to inform the application of protective measures legally mandated under the Marine Mammal Protection Act.

Commercial satellites capture images of the Earth's surface at a spatial resolution of 30cm per pixel, and previous work has shown that this is sufficient for identifying and classifying multiple species of whales in clear conditions at relatively small scales (i.e. over 100s of square kilometers for a single point in time). In this work we investigate the technical problems around scaling the identification and classification of whales across many scenes and under a variety of image conditions. Specifically, we develop a human-in-the-loop (active learning) pipeline that automatically identifies parts of satellite imagery may contain a whale and delivers these image patches to expert annotators for review. We show how this approach reduces the time taken to analyze 730 square kilometers of imagery over Cape Cod Bay from approximately 24 hours of annotation time to 20 minutes.

Incorporating prey information into North Atlantic right whale density surface models used in decision support

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Predictions of North Atlantic right whale distributions are an increasingly important tool used in policy and management decisions for this critically endangered species. Incorporating prey distributions and characteristics into right whale density surface models (DSMs) has the potential to improve predicted whale distributions, and therefore the resulting policy decisions. Currently, right whale DSMs used in decision support are partitioned regionally and seasonally to best capture whale distributions. Ideally, spatial and temporal information pertinent to resolving the fine-scale patterns in whale prevalence could be provided by a unifying set of model covariates. To explore this, we tested different possibilities for parameterizing primary and secondary production to represent prey within the right whale DSM. We then assessed the information provided by each primary and secondary production covariate and determined which covariates reduced model uncertainty the most regionally, seasonally, and across the whole domain. We found that a secondary production covariate representing high density *Calanus finmarchicus* aggregations reduced uncertainty the most for the full-domain model, followed by modeled net primary productivity covariates. As a component of our validation process, we used a retrospective forecasting approach to determine how well the inclusion of primary or secondary production would have predicted the 2010 regime shift in the Gulf of Maine.

A management-focused population viability analysis for North Atlantic right whales

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The North Atlantic right whale (*Eubalaena glacialis*) is among the most endangered whale species in the world and has been in decline since 2010. Considerable effort is directed toward its recovery by striving to remove threats. In this report, we describe the development of a population viability analysis for right whales that is designed to assess the current status, evaluate the contributions of various threats, and explore the management interventions needed to achieve recovery. The individual-based model that underlies this analysis accounts for age- and stage-specific survival and reproductive rates, the effects of severe injury from entanglement or vessel strike, and future changes in prey availability and accessibility. Several new or updated empirical analyses supplied parameter estimates; and parametric uncertainty was carefully incorporated into the model results.

This model and the results it produced are meant to represent an assessment of the current status of North Atlantic right whales, using the best available scientific and commercial data, and state-of-the-art analytical tools. Our knowledge of the future of the right whale population, however, has limitations. We have endeavored to fully incorporate uncertainty into this model, but there are many areas for continued improvement. We view this model as a living tool that can be improved, adapted, and extended as new data, new methods, and new questions arise.

An international collaboration to produce transboundary models of occurrence and absolute density of North Atlantic right whales

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As the climate changes, North Atlantic right whales (NARW) are shifting their habitat use patterns within U.S. and Canadian waters. Understanding where NARW are distributed throughout their habitat is a critical and difficult transboundary conservation problem. To address this challenge, scientists from Duke University, Fisheries and Oceans Canada (DFO), the U.S. National Marine Fisheries Service, and a variety of other organizations met in Montréal, Québec in December 2022 to discuss a potential collaboration to develop transboundary models for North Atlantic right whales.

With support from the US Navy, NOAA and many other partners, scientists from Duke have created a NARW density model for U.S. waters, using aerial and shipboard surveys contributed by U.S.-based collaborators. Using data collected in Canadian waters over the past five years, DFO is currently developing an occurrence model for NARW in Canadian waters. Neither country's models can account for the entire population, making it difficult to evaluate model performance or confidently estimate how many whales are in each country at a given time of year. A transboundary model that spans the entire North American range of the species is needed, yet scientists in each country have used different analytical techniques. Simply merging predictions is insufficient.

The Montreal meeting resulted in agreement to form a transboundary collaboration and the establishment of a steering committee tasked with coordinating the development of two transboundary models, one using the U.S. density modeling methods and one using the Canadian probability of occurrence modeling methods. Over the course of the next 18 months, the organizations will work collaboratively on data sharing and modeling method development. The resulting methods will help refine our knowledge of NARW habitat use, and offer updated scientific information to resource managers, on both sides of the border, to inform management efforts.

Assessing North Atlantic right whale abundance: A novel data fusion

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Monitoring marine mammal abundances and distributions can enable assessment of factors influencing individuals and populations, but such assessments are difficult to achieve using a single observation modality. Myriad data collection methods exist, yet relatively few statistical methods take advantage of multiple spatial modalities simultaneously. Each method of observation has its own strengths and weaknesses, and fusing more of these data sources together represents an opportunity to improve our inference on abundance.

This study is focused on North Atlantic right whales (NARW) in Cape Cod Bay where aerial survey and passive acoustic data were collected during the 2005-2018 winter-spring seasons. Each survey method provides only a partial evaluation of whale abundance and distribution in the Bay, but the combination of data via the two modalities offers the opportunity to better quantify abundance and distribution and their levels of uncertainty.

We present a novel approach referred to as "thinned point pattern data fusion." We apply this approach to demonstrate consequentially improved inference regarding NARW abundance and distribution using a combination of visual and acoustic data compared with data from a single modality. Our approach adopts an unknown true intensity which generates a realization of all right whale locations along with two partially observed data sources informing about this realization. We demonstrate model performance through simulation and by using aerial and acoustic data collected in April 2009. Via simulation, we can show that using the two types of data affords us better estimates of both abundance and uncertainty. With actual data, we show how the latent intensity and daily estimates of abundance change across days. Our method takes advantage from the combination of the existing data sources for NARW, and should better reveal their distribution and abundance both within Cape Cod Bay and elsewhere throughout their range.

An analysis of North Atlantic right whale/human interactions in the Southeast US calving grounds relative to the northern foraging grounds

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Seasonal migration of the critically endangered North Atlantic right whale (NARW), *Eubalaena glacialis*, exposes it to areas with high anthropogenic activity as it migrates between the Southeast US calving grounds and the Northern foraging grounds. Fundamental differences in vessel traffic, fishery type, and NARW behavior in the Southeast US calving grounds, the Northern foraging grounds and the Mid-Atlantic migration corridor creates a different risk environment for the NARW in each habitat. Given that the most vulnerable NARW demographic — breeding females and calves — are primarily found in the Southeast calving grounds, we examine the spatial and temporal patterns in anthropogenic threats in the Southeast calving grounds relative to the Northern foraging grounds and the migration corridor. NARW injury and sighting data (1980-2020) from the North Atlantic Right Whale Consortium (NARWC) are analyzed by examining variations in the number of unique injury events per NARW and injury event type, the ratio of detected vessel strike injuries to sightings within a region, and interannual variability in vessel strike injuries within each region, taking into account the fact that detected injuries may not be indicative of the location where the injury occurred. Although reduced prey availability in the 2010s has been linked to reduced NARW use of the Southeast US calving grounds, overall, higher vessel strike injury ratios were seen for the calving grounds in the 2010s relative to the 2000s which may be due to a lack of regulations for vessels under 65 feet and poor compliance to the vessel speed rule in the calving grounds. This work has implications for tailoring management practices to the specific risk environment present in any particular NARW habitat, thereby increasing the efficacy of protective policies.

A Decision Support Tool for assisting multi-interest stakeholders in assessing the entanglement risk of large whales in commercial fishing gear

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The Atlantic Large Whale Take Reduction Team (the TRT), formed in the United States under the Marine Mammal Protection Act in 1996, recommends measures to reduce mortalities and serious injuries of North Atlantic right whales (*Eubalaena glacialis*), humpback whales (*Megaptera novaeangliae*), and fin whales (*Balaenoptera physalus*) due to entanglement in commercial fixed gear (trap/pot and gillnet) fisheries along the US east coast. We developed a Decision Support Tool (the DST) to assist the TRT in their decision-making process. The DST estimates the relative risk and severity of whale entanglement based on the spatial overlap of whales and fishing gear and the relative lethality of different gear types. The spatial distribution of large whales is incorporated through habitat density models developed by Roberts *et al.* (2016) while the spatial distribution of vertical lines from fixed gear fisheries utilizes a variety of state and federal fishery-dependent data sources. The relative lethality index, used to compare the differences in risk attributed to different fishing gear configurations, is derived from the discrepancy between observed and predicted gear configurations observed on severely-entangled large whales. The DST can be configured and run quickly for simple scenarios, allowing stakeholders to rapidly evaluate various potential management actions but is also capable of running multiple complex, interacting scenarios. We describe the DST as an analytical model and stakeholder negotiation facilitator, discuss its present application, and explore pathways for future development and expansion.

Calvin's life history - a short film

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Twenty years ago the Calvineers picked Calvin, the right whale, for a mascot and a mentor. Calvin is now 31 years old and has experienced every joy and every trauma that right whales endure in an urban ocean. Calvin has been sighted by research teams 340 times and each time her behaviors have been recorded. The Calvineers have learned about right whales by studying Calvin's behavioral life history and they have produced PowerPoints that feature Calvin's experiences. Every aspect of the Endangered North Atlantic right whale is illuminated by Calvin's life. The Calvineers requested behavioral data from the Right Whale Consortium so they could make a display timeline of Calvin's life. While working on the timeline they had the idea that the story unfolding would make a great film. The Calvineers hired a filmmaker and a drama coach. They collectively wrote the script, filmed, directed and acted for the film. But Calvin is not the only right whale with an extensive sighting history. All of the more than 700 known right whales have a similar sighting and behavioral history. So, this film is dedicated to the scientists who collect, analyze and report the overwhelming amount of data about North Atlantic right whales. It is hoped that people will come to understand the wealth of science that exists about right whales through this film. Perhaps skeptics, who say the science is not good enough, will realize that there is solid scientific evidence available to make sound decisions about saving the North Atlantic right whales from extinction. When all the data is considered there is no denying that new rules have to be authorized immediately or right whales in the North Atlantic are doomed.

Speeding towards extinction: Vessel strikes threaten North Atlantic right whales

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Collisions with vessels are driving North Atlantic right whales toward extinction. Research suggests that if vessels slow down to 10 knots or less, they can reduce the risk of death by vessel strikes by 80 to 90 percent. The U.S. government has established mandatory and voluntary slow zones to protect North Atlantic right whales. Using self-reported data by vessels through Automated Identification System (AIS) transmissions compiled through the Global Fishing Watch (GFW) mapping platform, Oceana analyzed the behavior of speeding vessels to determine compliance and cooperation in mandatory Seasonal Management Areas (SMAs) and voluntary Dynamic Management Areas (DMAs), respectively. Compliance and cooperation through both mandatory and voluntary slow zones were poor, with an average of 84.32% non-compliance in SMAs and 82.06% non-cooperation in DMAs across the research period. This analysis suggests that current measures are not sufficient to slow vessel traffic and reduce the risk of vessel strikes to North Atlantic right whales, and significant revisions to current safeguards are necessary.

Abundance and energy density of subsurface layers of *Calanus* spp. in the southern Gulf of St. Lawrence in spring 2022

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A substantial proportion of the population of the North Atlantic right whale (NARW), *Eubalaena glacialis*, has visited the southern Gulf of St. Lawrence (sGSL) each year since the late 2010s. In this region, copepods (*Calanus* spp.) are an important component of the NARW diet; however, direct measurements of prey abundance (ind m^{-3}) and estimates of energy density (kJ m^{-3}) at fine scales that are relevant to NARW feeding are scarce. We quantified vertical distribution of *Calanus* spp. (3-m resolution) using a Video Plankton Recorder (VPR) and the species-stage composition of *Calanus* spp. in 40-m depth bins using depth-stratified plankton nets at 48 station occupations during 24 May-9 June, 2022. In each VPR profile, we converted the maximum abundance of *Calanus* spp. to energy density using copepod energy content ind $^{-1}$ obtained from a subset of stations (n = 15). Maximum abundances of *Calanus* spp. typically occurred in a layer 10-20 m above the bottom at depths ranging between 50-90 m. The bottom 40-m depth strata was generally dominated by stage CIV of *Calanus hyperboreus*, characterized by a mean energy content of 13.4 J ind^{-1}. Maximum abundances and energy densities were ca. 1500 ind m^{-3} and 20 kJ m^{-3}, respectively. The observed prey energy densities are consistent with minimum energy demands of a resting female NARW reported in a recent analysis of NARW bioenergetics; however, the NARW may be capable of locating higher-density prey layers than we observed. Our results highlight the potentially important contribution of near-bottom aggregations of *C. hyperboreus* to the NARW diet in the sGSL in spring.

Abundance estimates of North Atlantic right whales in eastern Canada from aerial line-transect surveys between 2017 and 2022

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Since 2017, the Department of Fisheries and Oceans (DFO) Canada monitors the distribution of North Atlantic Right Whales (NARW) in Canadian waters through aerial surveys. These visual line-transect surveys follow a systematic design over the Gulf of St. Lawrence (GSL), Bay of Fundy, Scotian shelf, and Grand Banks. Using 201 NARW sightings obtained in passing mode during surveys from 2017 to 2022, strata-specific abundance indices were

derived using distance sampling models. Across years, 94% of the NARW sightings occurred in the southern GSL region, especially in the western stratum of this region. Preliminary analyses show that surface abundance indices of NARW varied among and within years in the southern GSL, with the highest abundance observed at 71 individuals (SE=38) in June of 2018. In 2022 specifically, abundance indices in the southwestern GSL stratum varied over time from null abundances at the beginning (April) and end (November) of the aerial survey season, to peaks in abundance reaching 39 individuals in early June and in late July (SE=24 and 23, respectively).

Visual line-transect surveys of cetaceans are subject to biases resulting in surface indices underestimating abundance due to 1) whales being present in the region surveyed but unavailable to observers while diving (availability bias), and 2) whales available but missed by observers (perception bias). Availability bias correction factors are being developed based on tagging data and closing procedures carried out during surveys. Double-observer methods were implemented during surveys to allow mark-recapture distance-sampling analyses to estimate perception bias. Preliminary analyses suggest a perception bias of 0.62 (SE=0.07) for primary observers, equivalent to increasing surface abundance indices by a factor of 1.61. Once fully corrected, these abundance estimates will provide key information on seasonal and interannual variations in the abundance and distribution of NARW in Canadian waters over the past six years.

Near real time prediction of the North Atlantic right whales' distribution in the Gulf of St. Lawrence

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The abrupt shift in the North Atlantic right whale foraging area that has been observed since the mid-2010s rapidly came to a head in 2017, when at least 15 individuals (out of a little more than 350 individuals) have been found dead in Canadian waters they came to rely on more and more. Most of the deaths have been attributed to unfortunate ship strikes and entanglement with fishing gears.

As a result, the Canadian government has taken mitigation measures in areas where whale encounters are likely, yet an efficient implementation of this policy requires a more accurate knowledge of the right whale distribution and ecology. Since the area of study is large and the whales are few, surveys by ships and plane, passive acoustic sensor arrays and citizen reports are all useful, but they are not sufficient yet to improve the situation significantly if they are not integrated coherently. To support these efforts, the SIMBA project (Système Intégré de Modélisation de la Baleine noire de l'Atlantique) aims at predicting right whales' distribution on the Northwest Atlantic shelf by using the most recent satellite imagery and sightings data to predict the probability of presence of North Atlantic Right Whales individuals at a fine spatio-temporal scale in the Gulf of St. Lawrence. Here we present preliminary results from ensemble models of the right whale distribution, based on both statistical and machine learning approaches. This aims at helping decision-makers and mariners to make more efficient recommendations regarding possible restrictions to human activities in areas likely to shelter right whales.

What's in a biopsy: maximizing the use of skin and blubber for North Atlantic right whale health assessment research

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North Atlantic right whales are exposed to a myriad of anthropogenic and natural stressors that impact individual and population health. A transboundary necropsy collaboration between the U.S. and Canada is improving our assessment of cause of death and diseases in stranded individuals. A better

understanding of the sublethal or cumulative impacts of stressors on right whale health and reproduction in the wild is essential for improving population management and supporting recovery. Investigating health in wild cetacean populations is a unique challenge given the limited availability of sample types typically used for health assessment. Newer tools and technologies that use remote biopsies composed of skin and blubber offer promising insight into the physiological health and life history in wild marine mammals. Currently, research partners have individualized sample collection needs specific to discreet projects with limited scope. As part of our efforts to build a community of practice for right whale health assessment, we are developing new sample collection and processing protocols that aim to extend and maximize the use of samples for long-term, integrated health assessment research, including the use of epigenetics, transcriptomics, lipidomics, and hormone analyses. When combined, the broad application of tools like these have the potential to provide a deeper understanding of the link between stressor exposure and quantifiable impacts to individual and population health, including reproductive success. Coordination and collaboration between partners in the U.S. and Canada, as well as with the southern hemisphere right whale community, could further strengthen health assessment research on this critically endangered species.

Measuring weak breaking strength gear modifications before and after use in Atlantic Canadian fixed-gear fisheries

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In 2022, weak breaking strength gear requirements, believed to alleviate the severity of entanglements for critically endangered North Atlantic right whales, were implemented in US fixed-gear fisheries. To meet comparability standards under the Marine Mammal Protection Act, Fisheries and Oceans Canada plans to implement similar requirements in non-tended fixed-gear fisheries in 2024. As of July 2023, DFO has not confirmed how they will approve and regulate gear requirements for this measure. Our study aimed to identify gear modifications on the market that would meet expected standards for weak breaking strength gear (i.e., 1700 lbf + 10%) and to evaluate their change in breaking strength after use in Canadian commercial fisheries. This was informed with information from the Northeast Fisheries Science Center, which currently approves gear modifications for use in US fisheries and from international and North American standards for testing fiber rope. Control samples consisted of 20 types of sleeves, links, rope, and other contrivances marketed as weak breaking strength gear modifications or as having a load threshold of 1700 lbf or less. These samples were tested in new condition to determine if they meet this standard based on their average breaking strength. Of these 20 controls, 10 types were tested after use in simulated fishing trials (≤ 13 hauls) and 5 types after use by harvesters for one fishing season (50-60 hauls). When new, 7 of these 20 types had breaking strengths above 1700 lbf + 10% (i.e., 65% passing rate). Notably, the breaking strengths of the weak ropes that were tested following use were all reduced, many to well-below safe working load limits. These findings have implications for the implementation of weak breaking strength gear modifications in Atlantic Canadian fisheries, specifically regarding their safe-use and seasonal replacement rates.

Fisheries and Oceans Canada: An update on research and monitoring activities for North Atlantic right whales (*Eubalaena glacialis*)

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Fisheries and Oceans Canada (DFO) continues to conduct research on the critically endangered North Atlantic right whale (NARW, *Eubalaena glacialis*) with initiatives including monitoring through systemic aerial surveys and passive acoustics, and habitat, prey, threat, and satellite-tagging studies. Systematic aerial surveys to document the spatiotemporal distribution of NARWs in Canadian waters started in mid-April, with multiple passes of the southern Gulf of St. Lawrence (GSL) supporting the development of species distribution models. Additional surveys were undertaken in the northern GSL, Cabot Strait, and waters off Newfoundland and Labrador. Passive acoustic monitoring (PAM) for NARWs continues with nine near real time buoys in the GSL and the first operational year of the Whale Acoustic Slocum Program. Archival PAM continues at a number of sites including the GSL, the NARW critical habitats, across the Cabot Strait, sites along the edge of the Scotian Shelf, the Laurentian Channel, Placentia Bay, and the Grand Banks. In addition to field testing a pop-up PAM system, whale call propagation studies via playbacks were conducted in nearshore and offshore Newfoundland waters. Prey studies incorporating field observations of *Calanus spp*. spatial distributions in the southern GSL and bio-physical *Calanus hyperboreus* modelling are in progress to characterize processes influencing foraging habitat. Transboundary species distribution model development for NARW prey, and analysis of *Calanus* size and energy content as proxies for prey quality are also underway. Satellite tagging documenting NARW diving behaviour in relation to prey distribution and abundance was pursued in July 2023 to help estimate collision and entanglement risks. DFO continues to curate the NARW imagery submitted to and collected by the Government of Canada, and a site fidelity study is underway to examine decadal changes in Canadian habitat use and occupancy based on photo-identified NARWs. This presentation summarizes the NARW research undertaken by DFO and its collaborators.

A new statistical method for estimating the population size of the North Atlantic right whale

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We estimate the population size of the North Atlantic right whale using a novel Bayesian statistical framework. Two challenges in estimating population size are (1) some whales that have been sighted are now dead, and (2) some living whales may never have been sighted. We account for the first issue by estimating the probability that each sighted whale is currently alive, given its sighting record in the NARWC database. These probabilities are then adjusted using additional information about each whale, such as whether it has been entangled or struck by a vessel. Based on the adjusted probabilities, we randomly simulate a dataset consisting of whales thought to be alive. We then apply to this dataset a method from statistical ecology for estimating the number of never-sighted individuals. This estimate is added to the number of whales thought to be alive to arrive at an estimate of population size. We then repeat this process, arriving at a posterior distribution of estimated population sizes that accounts for uncertainty in both the current status of sighted whales, and the number of never-sighted whales. Our estimates of current population size are consistent with estimates from the Pace et al (2017) model, confirming the urgent need for conserving this species.

Are New York Bight copepods abundant and energy-rich enough to be prey for North Atlantic right whales?

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North Atlantic right whales regularly travel through the waters of the New York Bight during their seasonal coastal migrations, however it is not known whether they forage in this area. Vertical net tow samples (25 m depth to the surface) from Long Island out to the shelf break were collected during seasonal surveys from 2019 to 2021. Abundance (# / m^3) of *C. finmarchicus* and other common copepod species varied greatly both within and among cruises with peak densities of > 4,000 *C. finmarchicus* / m^3 in spring 2019. Lipid content of *C. finmarchicus* was calculated using literature values of energy density and imaging techniques to measure lipid volume in individual animals. These data provide a way to assess volumetric energy density (Joules / m^3) of the copepod preyfield in this region, a metric relevant to copepod predators. In addition to *C. finmarchicus*, we assessed the energetic contributions of two smaller, but also abundant copepods (*Centropages typicus, Temora longicornis*) which occasionally were more important than *C. finmarchicus* to the overall copepod biovolume or volumetric energy density. The results from the New York Bight were compared with samples from two regions (Cape Cod Bay, Gulf of Maine) which historically have been copepod-rich areas and important feeding grounds for NARWs.

Current NARW passive acoustic monitoring project updates from the NEFSC

Wilder, J.[1]; Baumgartner, M.[2]; Davis, G.[3]; Koilpillai, H.[1]; Tennant, S.[1]; Transue, L.[1]; Walker, J.[1,4], Van Parijs, S.[3]

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The Passive Acoustic Research Group at the Northeast Fisheries Science Center continues to expand its passive acoustic monitoring (PAM) program and develop new approaches for using PAM data to address science and management needs. In collaboration with partners, PAM recorders are deployed in U.S. waters along the Northwestern Atlantic, focused on areas including the Gulf of Maine, the Massachusetts/Rhode Island wind energy lease areas, National Marine Sanctuaries, and the Mid-Atlantic. In 2023, 45 recorders have been deployed (expanding from the 15 continuous archival bottom-mounted recording sites starting in 2020), in addition to over 20 real-time gliders and moored surface buoys. Results on NARW detections will be presented. Additionally, we released the Passive Acoustic Cetacean Map (PACM), a public online web application that displays species detections from our PAM data and that of a wide number of collaborators for a complete look at PAM work in the western North Atlantic. Passive Acoustic Reporting System Templates are available online to submit PAM detection data for all species to be displayed on PACM. We encourage any collaborators to contact us and contribute your detection data to provide a more comprehensive dataset. We are nearing completion of an acoustic database where detection data can be requested and accessed similarly to current North Atlantic Right Whale Consortium datasets. We have also worked with partners to facilitate a proposed PAM grid network (from Van Parijs et al. 2021) to collaborate on where acoustic effort occurs, avoiding duplicate effort and conducting wider PAM coverage as a whole. Updates will be provided for all of these innovative, collaborative ways that we use to display,

process, and serve up passive acoustic data, allowing for improved data exploration and understanding.