North Atlantic Right Whale Monitoring and Surveillance: Report and Recommendations of the National Marine Fisheries Service's Expert Working Group

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List of Acronyms

BOEM – Bureau of Ocean Energy Management
CCB – Cape Cod Bay (CCB)
CCS – Provincetown Center for Coastal Studies (CCS),
DFO – Department of Fisheries and Oceans Canada
GOM – Gulf of Maine
GoSL – Gulf of St. Lawrence
GSC – Great South Channel
LIMPET – Low Impact Minimally Percutaneous Electronic Transmitter
NARW – North Atlantic right whale
NEAq – the New England Aquarium
NEFSC – Northeast Fisheries Science Center
NMFS – National Marine Fisheries Service
NOAA – National Oceanic and Atmospheric Administration
PAM – Passive Acoustic Monitoring
RNA – Ribonucleic Acid
SEFSC – Southeast Fisheries Science Center
SERO – Southeast Regional Office
SEUS – Southeastern United States
U.S. – United States
UAS – Unmanned Aerial Systems
VHR – Very High Resolution

EXECUTIVE SUMMARY

The National Marine Fisheries Service (NMFS) North Atlantic right whale (NARW) Steering Committee convened an expert Working Group to address two objectives related to monitoring NARWs: (1) improving our understanding of population status by identifying and tracking essential population metrics, and (2) improving our understanding of distribution and habitat use. The Working Group consisted of five NMFS researchers (the authors of this report) with expertise in marine mammal monitoring, but not directly involved in current NARW monitoring efforts. The Working Group was convened during a three-day workshop (held at NMFS Southwest Fisheries Science Center in La Jolla, California, from October 22-24, 2019, with remote participants on Day 1), and on a series of follow up conference calls. This report provides a brief summary of the information provided to the Working Group, including historic and current NARW monitoring efforts conducted by NMFS and partner institutions, information on the status and trends of NARWs, and analyses conducted during the workshop or at the Working Group's request. Moreover, the report primarily presents the Working Group's recommendations for a comprehensive monitoring strategy to guide future analyses and data collection on (1) NARW demographics and population status, (2) distribution shifts and habitat use range-wide, and (3) the health of individuals and the population. The Working Group's recommendations are intended to improve NMFS' overall monitoring strategy for NARW, with recognition of the significant contribution to NARW research and monitoring carried out by NMFS and partner institutions and agencies.

The Working Group's recommendations address several overarching themes. These include (1) identifying the essential population and individual metrics to be monitored, (2) characterizing analyses that may be conducted with existing data that are critical to fine-tuning and efficiently executing an effective monitoring plan, (3) expanding the NARW species distribution model through data standardization and coordination, (4) establishing an integrated visual and passive acoustic monitoring (PAM) scheme, and (5) evaluating the utility of other research tools including satellite imagery and telemetry tagging for NARWs.

The Working Group agreed that the most important population and individual metrics to be monitored include adult survival, calf to subadult survival, abundance, calf production, population age-sex structure, number or reproductive females, and the visual health index. At present, adult survival, abundance, and calf survival are estimated with high precision and low bias through the intensive aerial photo-identification efforts of NMFS and its partners. In contrast, calf to subadult survival is estimated with low precision owing to small sample size, and the number of reproductive females is not estimated annually. The age-sex structure of NARWs has not been estimated, though given the extensive data available on individual whales, could be generated and would provide valuable insight into the current demographics of the population and its future trajectory. Finally, a visual health assessment has been developed that provides information on individual health and body condition. A 2019 workshop on NARW

health assessment provided insights into expanding and improving this assessment. The Working Group recommends that once the utility of those metrics has been established, their estimation should be considered for integration in the monitoring program.

The NARW data that have been amassed to date are an invaluable resource that could be further analyzed to inform a future, more optimized monitoring plan. The Working Group identified and described 11 retrospective analyses within four overarching objectives: (1) optimizing aerial and vessel-based survey effort to ensure high precision and low bias in the estimation of population and individual metrics identified above, (2) maintaining sufficient effort to detect entangled, injured, and dead NARWs, (3) improving characterization of the overall risk seascape, and (4) improving understanding of the relative detection by visual versus passive acoustic platforms. Many of the analyses identified will be critically important to designing and executing an efficient monitoring plan.

The current NARW habitat model is a valuable resource for examining habitat hotspots and historical distribution shifts. A robust quantitative habitat-based density model requires specific data inputs, and the variability in data collection approaches across all NARW partners has slowed progress toward the next generation model. Increased standardization in the collection of a small subset of survey effort metrics and sighting parameters would facilitate much broader integration of the vast network of spatial data collected on NARWs and, together with cooperation with Canadian modeling efforts, provide a more robust model for future predictions of habitat shifts and risk assessments.

Based on review of past and current NMFS and partner survey efforts, the relative contribution of unique photographic identifications from various regions and contributors, and the ongoing PAM work along the U.S. and Canadian east coasts, the Working Group provides specific recommendations for developing an integrated visual (aerial and vessel-based) and PAM plan that attempts to maintain appropriate survey effort to estimate essential population demographic metrics, track individual health status, and capture habitat hotspots and shifts, in an efficient and cost-effective manner while reducing cost and risk to humans of significant and sustained use of survey aircraft. This plan envisions:

- Establishing a network of 16 long-term passive acoustic listening stations to monitor distribution and habitat use
- Conducting targeted aerial surveys (i.e., at aggregations of whales) to collect photo-identifications of ~90% of the population within a given year
- Coordinating efficient, and timely identification of individuals across all data collectors within a survey year
- Conducting periodic broad-scale systematic aerial surveys of the entire Gulf of Maine and Southern New England area, alternating with a systematic rotation through all historical NARW hotspots

- Maintaining or increasing vessel survey effort to collect individual health data and replace aerial surveys for collecting individual identification photos whenever possible

The Working Group puts forward these recommendations acknowledging the significant efforts of NMFS and its partners over several decades. The recommendations in this report are intended to capture the best and most effective elements of those past and ongoing efforts and provide a roadmap for a systematic, efficient, and effective monitoring strategy for the future.

I. WORKSHOP OBJECTIVES

The National Marine Fisheries Service (NMFS) North Atlantic right whale (NARW) Steering Committee convened an expert Working Group to address two broad objectives related to monitoring NARWs: (1) improving our understanding of population status by identifying and tracking essential population metrics, and (2) improving our understanding of distribution and habitat use. The expert Working Group consisted of five staff with expertise in marine mammal monitoring and quantitative assessments, but not directly involved with current NARW monitoring efforts, who were asked to develop options for a comprehensive strategy to:

1. Monitor population status, including estimates of abundance, trends, survival and birth rates, and other demographic metrics
2. Monitor distribution shifts and habitat use range-wide
3. Assess health of individuals and the population (e.g., identify causation/threats, assess sublethal effects) through biological sampling

The Working Group's specific tasks were to provide expert guidance to the Steering Committee on how best to achieve the following more specific objectives:

Population Status

- Identify the essential population demographic metrics (e.g., survival rate, birth rate, age at calving, calving rate, age structure, life span) the agency should use to track recovery of this species, including a description of why each metric is essential for monitoring the population status.
- Develop a monitoring/surveillance plan for each essential population metric identified above, including options for:
    - Sampling methods
    - Data types
    - Sampling locations (e.g., region and/or range-wide)
    - Monitoring/survey frequencies

Distribution and Habitat

- Determine approach for identifying:
    - Distribution, occurrence, and habitat use in the mid-Atlantic region (i.e., west of 72° 30' West, south of 40° 00' North through 35° 30' North (North Carolina))
    - Migratory corridor and associated physical and biological features in the mid-Atlantic
    - The unobserved portion of the population in time/space (i.e., "missing whales" not detected during aerial surveys in northeast and southeast)
    - Where animals die

- Determine best methods for quantifying changes in occurrence and distribution (e.g., relative to a changing climate)
- Determine whether, and if so how, historic and current visual sightings data can be combined with passive acoustic detection data to assess past and current occurrence and distribution, and decadal-scale changes in distribution

Health Status

- Determine approach for identifying cause(s) or contributing factors for dead, injured, entangled animals and poor reproduction and poor health
- Determine approach for collecting:
    - Health assessment data, such as body condition and skin condition including scarring
    - Hormones for assessing reproductive state, stress, metabolism/energetics, nutritional state
    - Injury state (e.g., wounds, entanglements, skin lesions, etc.)

The Working Group met October 22-24, 2019 at the NMFS Southwest Fisheries Science Center in La Jolla, California (see Appendix II). The group received presentations on management needs for monitoring data, using mark-recapture analysis to estimate abundance and evaluate trends, current monitoring efforts in the U.S. and Canada using planes, vessels, and passive acoustics, and current funding levels (see Appendix III). The following report describes recommended options for comprehensively monitoring the NARW population throughout its range using various platforms and the rationale associated with each element.

II. Description of Current Efforts

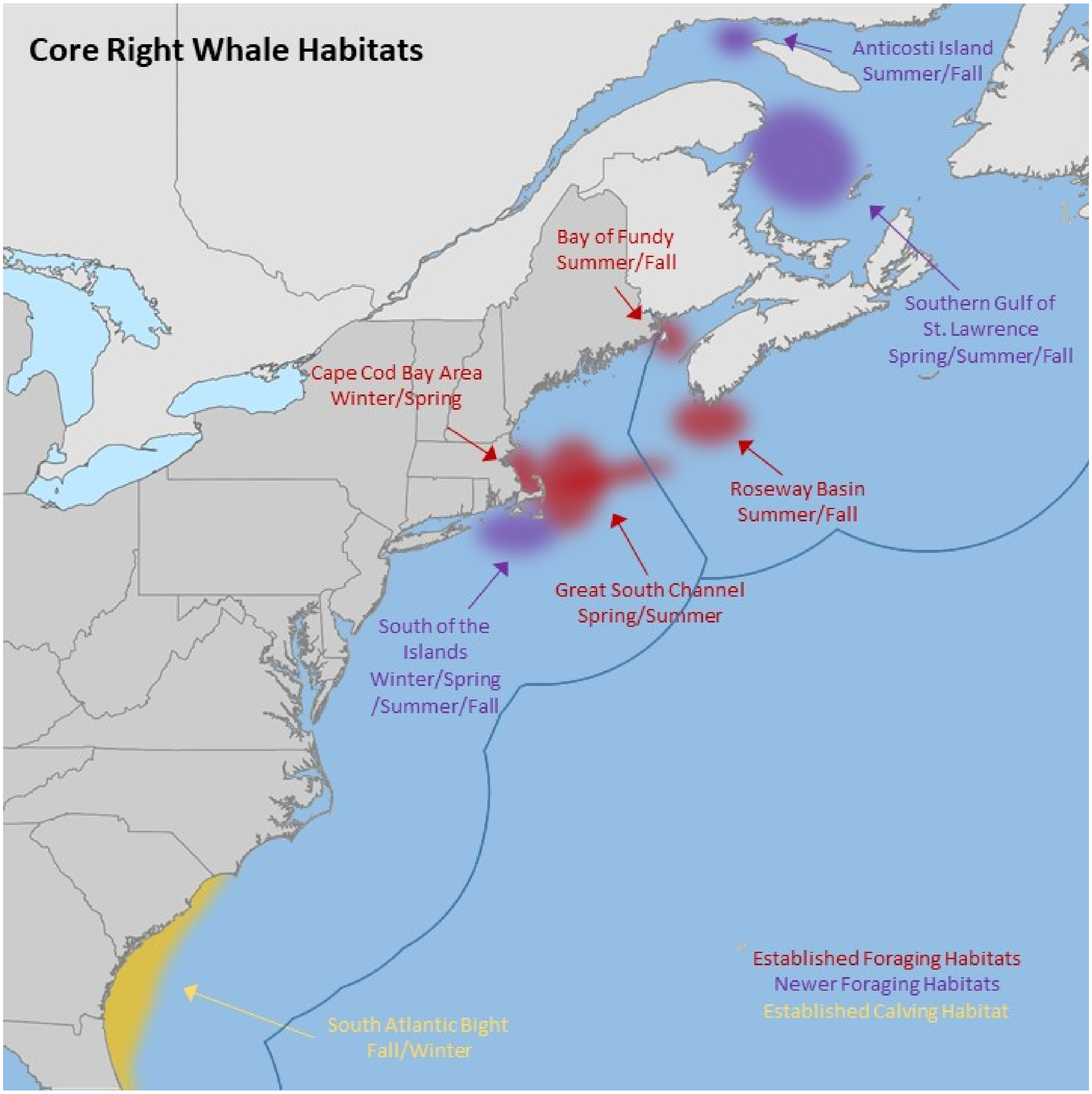

Figure 1. Known primary North Atlantic right whale habitats.

Primary Data Collection Efforts in Support of Population Assessment

The primary data collected for monitoring population status (population size, trends in abundance, survival rates, and recruitment) come from the photo-identification studies in known NARW habitats (Figure 1) conducted from multiple platforms (aircraft and surface vessels) by multiple governmental and non-governmental programs. Most of the current data are provided by the Provincetown Center for Coastal Studies (CCS), NMFS Northeast Fisheries Science Center (NEFSC), Department of Fisheries and Oceans (DFO) Canada and Transport Canada, the

New England Aquarium (NEAq), and combined efforts of the NMFS Southeast Fisheries Science Center (SEFSC), NMFS Southeast Regional Office (SERO), and the states of Florida and Georgia, as well as a variety of other contributors. Major funders of this data collection include NMFS, the Bureau of Ocean Energy Management (BOEM), U.S. Navy, Transport Canada, DFO and the State of Massachusetts. All sighting and survey effort records are submitted to the NARW Consortium Database maintained by the University of Rhode Island for inclusion in the sightings database and those with photographs are also submitted to the NEAq for integration into a unified photo-identification catalog[1]. Most field research teams match their photographs to this catalog during their field efforts.

The number of NARW identifications collected by each cooperating institution and platform (aerial or vessel) has varied from 2001 to 2017 (Appendix I, Tables 1 and 2), with contributions from Canada increasing dramatically in recent years as the distribution of NARWs has shifted and the efforts of Canadian Government agencies have increased. Similarly, the number of NARW identifications has varied by region from 2001 to 2017 (Appendix I, Tables 3 and 4), most notably with recent increases in sampling in the Gulf of St. Lawrence. Many individual NARWs are seen by multiple institutions and in multiple areas within a single year, such that the number of NARWs seen uniquely by a single institution/platform (Appendix I, Table 2) or in a single area (Appendix I, Table 4) is typically less than ⅓ of the total number of NARWs seen in a year. Each year, surface vessels provide a few identifications that are not obtained from any other source (Appendix I, Table 2), but the majority of identifications now come from aircraft (Appendix I, Table 1).

Photo-Identification Data Contributed by Partners

1. Provincetown Center for Coastal Studies aerial surveys in Cape Cod Bay[2]

CCS flies a fixed survey grid over the entirety of Cape Cod Bay and the eastern Cape several days per month during winter and early spring until NARWs leave this foraging ground for other regions. These surveys provide a large number of photo identifications (Appendix I, Tables 1 and 3), including a large proportion of the unique identifications provided to the catalog each year (Appendix I, Tables 2 and 4). CCS also conducts small boat habitat surveys along predetermined tracklines to visit 8-9 sampling stations, as well as foraging surveys directed by aerial sightings of NARWs, both of which may provide additional photo identifications.

[1] http://rwcatalog.neaq.org/Terms.aspx
[2] https://coastalstudies.org/right-whale-research/population-monitoring/

2. DFO Canada[3] and Transport Canada[4] aerial surveys in the Gulf of St. Lawrence

In response to apparent recent increases in NARW abundance and observed deaths in the Gulf of St. Lawrence, DFO and Transport Canada now conduct substantial aerial survey effort from spring through fall to locate NARWs. The survey effort has been focused primarily on the main shipping routes within the Gulf of St. Lawrence, as well as over primary fishing regions, but includes some flights into other regions of likely NARW habitat. Oblique identification photographs are collected from the planes, though information on regions with large aggregations of whales is generally passed to NMFS to conduct flights for additional photo-identification efforts. DFO survey efforts account for most of the unique identifications in Canada (Appendix I, Tables 2 and 4).

3. New England Aquarium[5] small boat surveys in the Bay of Fundy, Roseway Basin/Scotian Shelf, and Gulf of St. Lawrence

The NEAq began annual small boat surveys in the Bay of Fundy in 1980 and in the Roseway Basin/Scotia Shelf regions more recently. Traditionally, both surveys provided a reasonable number of unique identifications (Appendix I, Table 2), but the number of NARWs using these areas has declined in recent years. The NEAq has recently been conducting small boat surveys in the Gulf of St. Lawrence in response to an increase in NARW sightings in that region. Many of the NEAq photo-identification efforts are focused on collecting data for individual whale health assessments, requiring more detailed photographs from a variety of angles to provide a robust examination of current health status (e.g., Pettis et al. 2004). The NEAq has been conducting aerial surveys in the offshore waters south of Nantucket and Martha's Vineyard since 2011, though the steering committee did not have access to these data so they are not discussed specifically in this report.

4. Southeastern U.S. (SEUS) small boat surveys

The states of Georgia and Florida conduct small boat surveys of the winter calving areas, directed by NARW detections from the aerial surveys. This effort serves primarily to collect biopsy samples of calves for genotyping and later identification.

[3] https://www.dfo-mpo.gc.ca/species-especes/mammals-mammiferes/narightwhale-baleinenoirean/alert-alerte/index-eng.html
[4] https://www.tc.gc.ca/en/services/marine/navigation-marine-conditions/protecting-north-atlantic-right-whales-collisions-ships-gulf-st-lawrence.html
[5] https://www.andersoncabotcenterforoceanlife.org/category/right-whale-research/

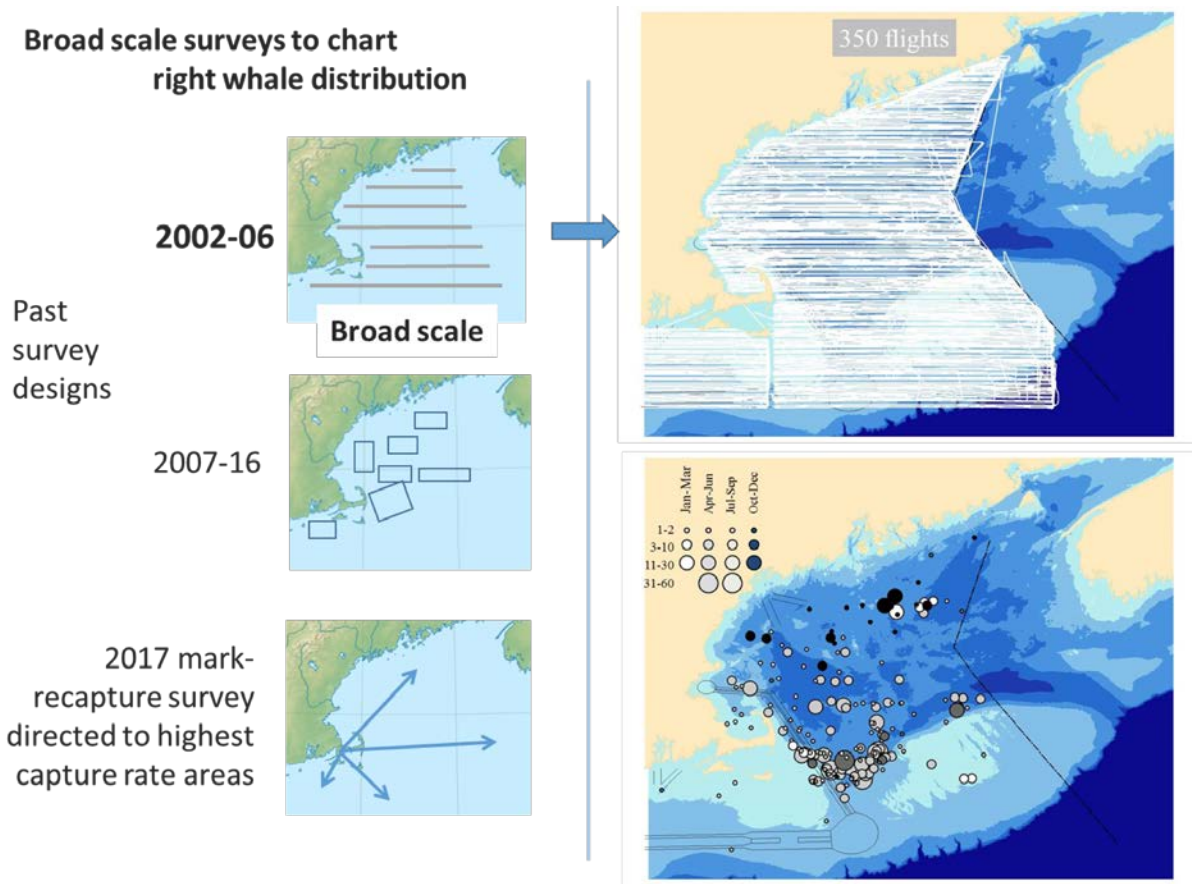

Figure 2. Summary of NEFSC aerial survey approaches since 2002 (left panels), and overall survey effort and combined NARW sightings resulting from broad-scale surveys form 2002-2006 (right panel). Provided to Working Group by NEFSC.

Photo-Identification Data Collected by NMFS Aerial Surveys

The NEFSC conducts aerial surveys in a National Oceanic and Atmospheric Administration (NOAA) Twin Otter for much of the year. These include surveys of designated geographic areas as well as other Gulf of Maine sites in spring, summer, and fall, South of the Islands (i.e., Nantucket and Martha's Vineyard) in fall, winter, and spring, and most recently in the Gulf of St. Lawrence in spring, summer, and fall. Much of the survey effort in the Gulf of St. Lawrence is dedicated to areas of NARW concentration identified from DFO surveys and also to locate dead or entangled NARWs for recovery efforts.

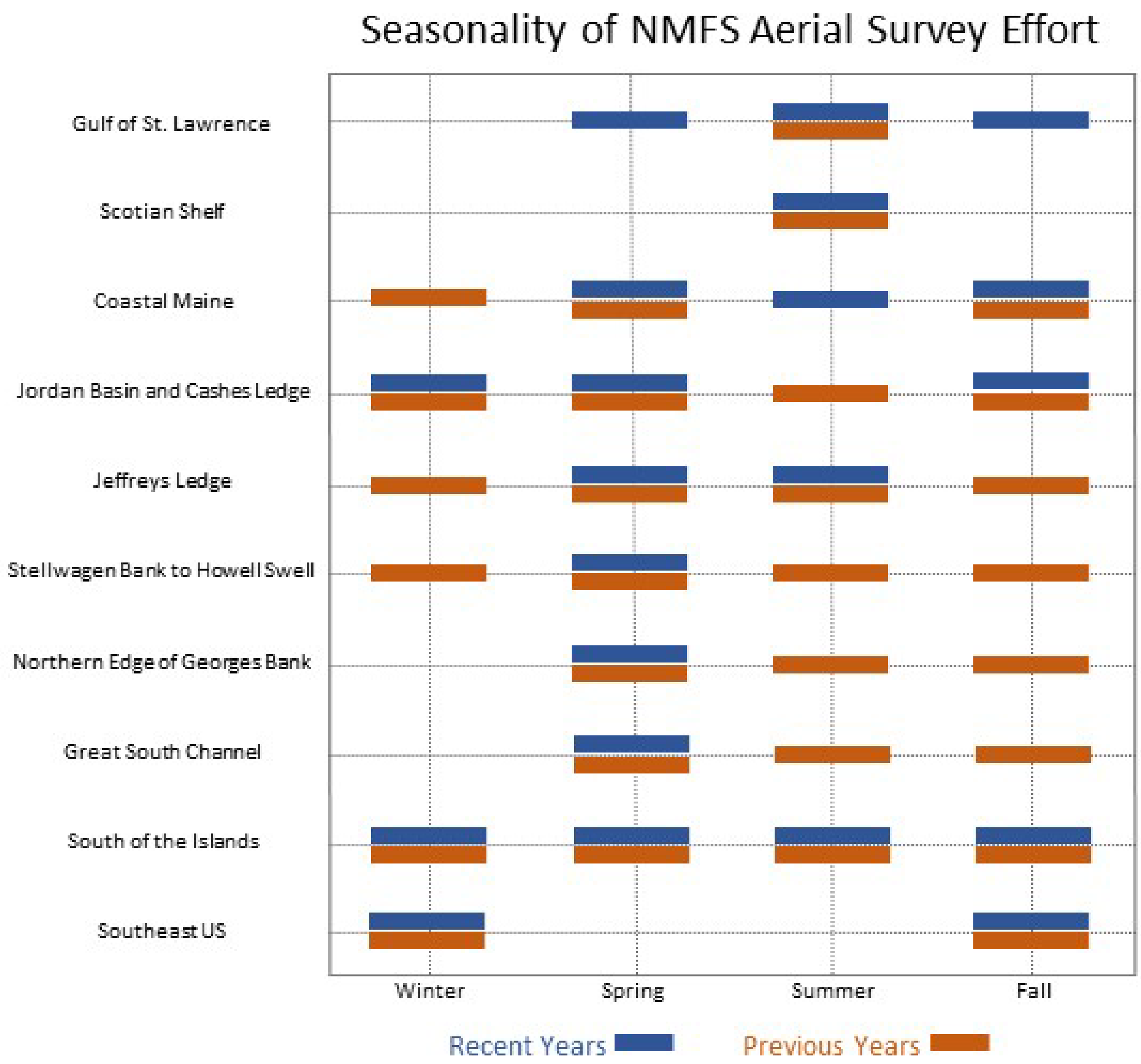

Figure 3. Seasonal distribution of NMFS aerial survey effort in recent years (2016-2019), and previous years (2010 through 2015). Actual effort may vary considerably between locations.

Photo-identification surveys conducted by the NEFSC have evolved substantially over time. These surveys initially flew over the Great South Channel (1998-2001), and then evolved to broad-scale systematic surveys (2002-2006) throughout U.S. waters in the Gulf of Maine and Southern New England (Figure 2 and Figure 3). The results of those broad-scale surveys led to more targeted surveys in designated “boxes” from 2007-2016 in order to maximize survey effort in locations that consistently contained aggregations of NARWs. This was modified starting in 2017 to direct survey efforts to areas with the highest capture rates, to maximize detections of unique individuals. Surveys are flown repeatedly to the same area until the discovery curve for new individuals levels off and few or no new individuals are detected.

SERO, in collaboration with the states of Georgia and Florida, conduct aerial surveys of the winter calving areas. These have been very successful, and not long ago were providing as many as 120 unique identifications per year. However, NARWs' usage of the area has dramatically declined, and as few as seven NARWs, including accompanied calves, have been identified in recent years.

Analysis Efforts to Assess Population Status

The primary tool for integrating and interpreting the photo-identification data into population assessments is the Bayesian integrated population model developed by Pace et al. (2017). Analyses of data collected through 2018 presented at the workshop show relatively constant non-calf (ages 5+) survival rates of ~0.98 and 0.97 (for males and females, respectively) from 1990 to 2014 and a decrease to ~0.96 and 0.95 (respectively) for 2015-2016. Survival rates of calves (0-5 years) were about 2% less than for females ages 5+, and changes in both adult and calf survival rates over time are constrained in the model to follow an identical trend (i.e., the age-sex class effect is additive on the logit scale). Survival rate estimates of NARWs younger than adults have low precision, owing to small sample sizes. Consequently, it remains uncertain whether juvenile survival has changed in recent years. The model estimates an increasing population trend from ~260 in 1990 to a maximum of ~483 in 2011 followed by a decrease to ~410 in 2018.

A calf production index (the proportion of calves in the population) can be estimated from the number of calves observed in a given year and the model-based estimates of population size. Results show that calf production has been very low since 2010 (compared to values in 2001-2009) and is below the level required for replacement of adults. It appears that this recent decline in calf production is largely responsible for the observed decline in population size in recent years. The potential contribution of reduced survival of both young and adult NARWs to the population trend remains uncertain.

The estimated proportion of the population sampled by photo-identification each year (capture probability) has been very high, roughly 90% in the years 2000 to 2010. Capture probabilities began to drop starting in 2011 likely because of changes in NARW distributions (Davis et al. 2017), reaching levels of approximately 50-60% in 2014. With subsequent changes in survey effort, values for the most recent years (2016-17) are again approaching 90%. A high capture probability not only reduces the variance in estimated parameters, it also reduces the likelihood of bias caused by violations in model assumptions.

The higher male survival rate than female survival rate will result in a population with an increasingly biased sex ratio in older individuals, which reduces the reproductive potential for a given total population size. In the published model of NARW population dynamics, Pace et al. (2017) estimate that the ratio of females to males increased from 1:1.15 in 1990 to 1:1.46 in 2015. If this apparent pattern continues, there is concern that population productivity may continue to decrease.

Efforts to Describe Distribution and Habitat

There have been many efforts to describe NARW foraging and mating habitat, drivers of habitat preferences, and habitat quality and variability. The same aerial and vessel surveys that provide identification photographs also provide much of the data used to study distribution and habitat. Opportunistic sightings also provide new insights in areas that are not covered by existing survey effort. Quantitative descriptions of NARW habitat typically require design-based surveys and data from targeted surveys cannot be used for these analyses. Diverse PAM efforts have also been ongoing for almost two decades and collectively provide a rich dataset for examining distribution. However, most passive acoustic recorder deployments have been short-term or funded by partners interested in specific questions or regions, requiring researchers to piece together datasets that do not overlap in time, do not consistently sample the same sites, and may not be recording in optimal seasons or locations.

Several decades of research have shown that NARWs use discrete habitats at specific times of the year (Figure 1), and researchers have taken advantage of this to target data collection. Well documented NARW foraging habitats include Cape Cod Bay, the Great South Channel and edge of Georges Bank, an area to the south of Martha's Vineyard and Nantucket, the waters around the Bay of Fundy, Roseway Basin, the southern Gulf of St. Lawrence and the western end of Anticosti Island (Davies et al. 2019; Davis et al. 2017; Durette-Morin et al. 2019; Leiter et al. 2017; Mayo et al. 2018; Simard et al. 2019). Additionally, the whales' only known calving ground extends along the coast of the South Atlantic Bight (Gowan and Ortega-Ortiz 2014; Keller et al. 2012). NARWs respond to environmental changes and may use habitat intermittently over time. The whales have been known to nearly abandon a frequently used foraging habitat only to come back in future years in large numbers. In recent years, the whales have demonstrated actual shifts in distribution, frequenting previously unrecognized foraging habitats. However, sightings data indicate that NARWs may investigate a previously preferred habitat, but not stay if the prey resource is insufficient, so some habitats previously used no longer have high densities of NARWs (Davies et al. 2019; Davis et al. 2017).

A recent effort to aggregate all available and appropriate survey data resulted in monthly predictive habitat models along the U.S. east coast for NARWs and several other cetacean species (Roberts et al. 2016). These habitat-informed density models offer the most comprehensive evaluation of NARW density along the east coast to date and include relevant data through 2016. The Duke University team is currently funded under a cooperative agreement with NMFS to update the models using 2017 and 2018 data as well as create separate models for the periods before and after 2010 when NARW distribution began to shift. It is worth noting that not all NARW surveys or datasets are appropriate for use in this type of quantitative model. This density modeling effort requires survey data collected using line-transect survey protocols. The Roberts et al. models are not able to incorporate opportunistic NARW sightings, non-line transect survey data, or data from directed survey efforts (i.e., those directed at known aggregations of NARWs).

There have been many PAM efforts throughout the northwest Atlantic over the past decade, including efforts by NEFSC to maintain collaborative long-term monitoring of species occurrence from the northern Gulf of Maine south through the New York Bight as part of the Northeast Passive Acoustic sensing Network (Van Parijs et al. 2015). Acoustic data provide insights into the occurrence of NARWs at times of the year when poor weather and lack of light make visual surveys highly restricted (i.e., late fall to early spring). A recent analysis of NARW seasonal and annual occurrence throughout the Northwest Atlantic using a diverse set of PAM data collected by a large number of collaborators resulted in an impressive assessment of changes in NARW distribution over 11 geographic regions from 2004 through 2014 (Davis et al. 2017). Although the aggregated dataset provides great insights into NARW occurrence and changes in distribution over the decade, the lack of concurrent and continuous monitoring at many locations hinders detailed examination of the movements of NARWs between regions and the changes in distribution over time (see Figure 4).

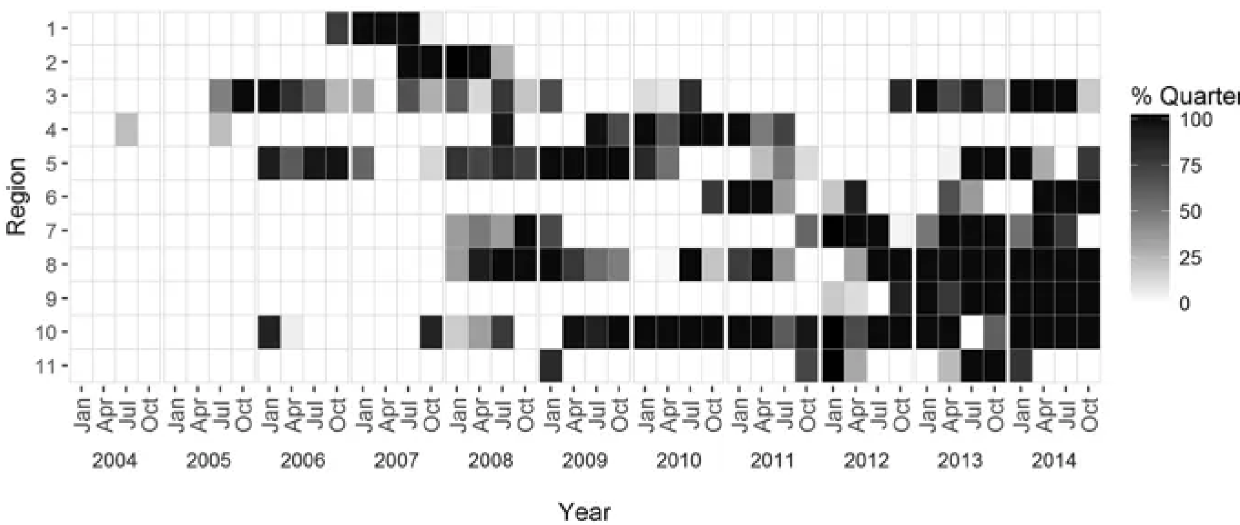

Figure 4. (Reprinted from Davis et al. 2017, Figure 5). The proportion of year with available passive acoustic recordings in each monitored region (see Davis et al. 2017, Fig. 1). Years are split into quarters from January 2004 to December 2014. Black indicates at least one recorder present for the entire quarter year for that region, lighter gray indicates a portion of that time period with recordings, and white indicates no available acoustic data for that region and time period.

Recent NARW sightings and acoustic detections in the Northeast Atlantic, coupled with historic records of NARW presence, are intriguing and suggest monitoring efforts should expand to targeted surveys in these more eastern areas, at least on a sporadic basis. For example, within the last decade one NARW has been sighted and detected in Icelandic waters during the summer months. Historic whaling records also indicate NARWs used this area in the summer.

Efforts to Assess Population Health

Health status has largely been assessed using photographs from the aerial and vessel surveys using a well-established NEAq protocol. These visual health assessments have been shown to be correlated with survival and birth rates for NARWs (Pettis et al. 2004). Additional biological samples taken during small boat efforts also contribute information on hormone levels and other metrics. Photogrammetric measurements of NARWs have been made from unmanned aerial systems (UAS) deployed from surface vessels and may also contribute useful information on health status. To date, only the visual health assessments are routinely done and other efforts are largely in the research and development phase. Additional research is needed to determine whether other metrics are correlated with survival and birth rates.

In June of 2019, NMFS convened a workshop related to assessing NARW health. The goals of the workshop were to (1) assess current NARW health information data, including associated data gaps, and (2) identify appropriate available and needed tools and techniques for collecting standardized health data that can be used to understand health effects of environmental and human impacts (e.g., entanglement), and inform fecundity and survivorship models to ultimately guide population recovery. A forthcoming report further details this workshop and efforts to assess NARW population health. An important result of the workshop was the recognition that the vast majority of data used to assess NARW health are collected during vessel surveys. Accordingly, in developing recommendations for vessel surveys, the Working Group considered health assessment data needs.

III. Data Gaps and Limits to Inference

Need for Spatially-Temporally Standardized Survey Design

As NARW distribution has varied over time, so has the spatial distribution of survey effort, as ‘following’ larger aggregations of animals maximizes collection of photo identifications and other datasets. Indeed, the collection of identification photographs of NARWs has been spectacularly successful, providing for precise estimates of population size and survival rate by year (Pace et al. 2017).

However, there are trade-offs to this adaptive sampling approach. As noted above, such opportunistic (in contrast with design-based) datasets are less amenable to spatial habitat and density-surface modeling. They also make it difficult to assess longitudinal changes in population distributions because the locations of animals are confounded with the locations of effort and new aggregation sites can be difficult to detect (e.g., if NARWs start using un-surveyed areas). In addition, the estimation of certain demographic metrics can be prone to bias under this adaptive sampling approach. In particular, obtaining an unbiased estimate of population size requires that all animals in the population are available to be sampled, meaning that all individuals are at least occasionally present in areas where photo-identification efforts are occurring. If a segment of the population is, or becomes, unavailable to the survey efforts (by permanently moving to new areas), the population size will be under-estimated. Less obviously, estimates may also be biased if capture heterogeneity (across years or individuals) is extreme. Extreme heterogeneity can occur if, for example, some animals temporarily (for a period of years) emigrate to un-sampled areas, or if individuals are site-faithful to areas sampled more- or less-often. Heterogeneity can be modeled with random effect parameters, but this does not provide a guarantee of eliminating bias (e.g., if heterogeneity is not logit-normal distributed) and does not improve precision. These issues can affect survival-rate estimation as well, although survival estimation is more robust to capture heterogeneity than is abundance estimation. Finally, this adaptive sampling approach means that only a fraction of the population's distribution is known, with the remainder of the population being distributed in un-surveyed areas. A potential concern is that these 'missing' animals could be incurring mortality risk (e.g., from vessel strike or gear entanglement) that is not being managed or assessed. Systematic annual survey area throughout the NARW range, including new areas that may have a relatively high likelihood of being occupied, would provide a more complete picture of whether the population is incurring risks throughout the year.

A coordinated range-wide monitoring plan should achieve a balance between maximizing photo-identification data collection (i.e., targeted effort on aggregations) and obtaining broad-scale, spatially and temporally representative distribution data throughout the range that allows for valid spatial modeling and detecting changes in animal use and movement patterns. There should be continuous monitoring in potential high-risk areas should NARWs start using those areas (e.g., in areas of high fishing vertical line density or vessel traffic), as well as periodic monitoring of some sort (acoustic or visual survey) in areas of potential but previously undocumented use, so that potential colonization of these areas is detectable. Areas of potential use could be identified, for example, by spatial density or occupancy modeling efforts, fit to visual survey or PAM data (cf., Monsarrat et al. 2015; Roberts et al. 2016). The viability of using satellite image data to identify new aggregation areas could also be explored.

Collection of Consistent Data Elements by All Data Contributors

There are many researchers and institutions contributing to NARW research and recovery efforts. Many of these institutions have been conducting NARW research for decades and use their own established protocols for various types of data collection. The NARW Consortium has done a tremendous job of aggregating the various data sources to make all data maximally usable to the collective; however, some quantitative analysis efforts have been hindered by differences in data collection approach among data contributors. In particular, NARW spatial density models require standard measures of search effort and perpendicular detection distance, which have not been readily available from all surveys. Although there have been significant post-hoc efforts to standardize data for analyses, this has been a large task that could be mitigated through developing standards for collecting a common data subset across the various data contributors.

Leveraging Existing Data to Address Key Management Questions

The impressive photo-identification catalog and analyses of these data have generated precise inferences about trends in population size, survival, and reproductive rates. However, the full potential of the catalog in addressing additional management questions has yet to be fully explored. Additional, key management questions such as those related to quantifying unobserved human-caused mortality and understanding anthropogenic influences on survival and reproduction may be addressed through additional analyses of the catalog, modifying or extending existing models, and in some cases, through modifying survey efforts to obtain additional necessary data. Below, the Working Group makes several related recommendations on this point.

IV. Recommendations

Essential Population and Individual Metrics

Several key demographic metrics and individual-level metrics have been and continue to be estimated for this population. Some of these, including adult survival and abundance, are estimated with high precision and apparently with little bias. It would be informative to improve estimates of some other metrics and population metrics that are currently either estimated with low precision or not available. Below, the Working Group provides a list of high priority metrics and recommendations regarding their relative need for improvement.

Adult Survival

Adult survival is currently estimated annually with sufficient precision and low bias. This should be continued. The Working Group suggests that survival modeling be further investigated to evaluate support for any change in the disparity between adult male and female survival rates over time. The estimated survival rates in Pace et al. (2017) and updated output shared at the workshop were based on a model with an additive survival effect, which constrains the sex difference to be constant over time. A model with a *sex x time* interaction might indicate whether adult female survival has become relatively lower than male survival in recent years. The initial sex state of individuals of unknown sex (assumed to be at parity) may also affect the change in sex ratio in the model. The Working Group also recommends exploration of alternative assumptions on initial sex ratios.

Calf to Subadult Survival (Roughly Ages 0 to 5 Years)

Calf to subadult survival is currently estimated annually but with relatively low precision owing to low sample sizes. The Working Group recommends exploring alternative capture-recapture model formulations to determine whether any change in survival of young animals has occurred in recent years. One such potential formulation might allow young NARW survival to be estimated independently from adults (i.e., an interaction rather than additive age effect) and with years grouped appropriately (i.e., before and after some potential change-point year) for young animals in order to increase the precision of estimates for this age class. A proportion of young NARWs are of uncertain age. Precision in age-specific estimates of young NARW survival could be improved by increased effort to determine their ages through genetic sampling and matching with biopsy samples obtained from neonates.

Abundance

Population size is estimated annually and with high precision and low bias. This should be continued.

Calf Production

The number of calves born annually is determined through total enumeration during intensive aerial surveys in the calving area. It is rare to find a new calf on the foraging grounds not previously identified on the southeast calving grounds. Calf production combined with other relevant information can be used to derive other reproductive metrics of interest, including gross reproductive rate (calves per mature female), calves per female (without regard to age), a calving index (calves divided by total abundance), and inter-birth interval. Estimation of calf production should continue, with effort adjusted appropriately to achieve total enumeration without excessive expenditure of survey resources.

Population Age-Sex Structure

The age-sex structure of the NARW population is not currently available. The age-sex structure is a product of the annual survival and reproductive output of a population for a generation. As such, it is a convenient graphical integration of a population's history. Gaps in one or more ages reflect either a deficit in births or high historic mortality. Furthermore, future population trends are determined by both prevailing vital rates (survival and reproductive rates) and current age-sex structure. If an age-sex structure is significantly perturbed relative to the theoretical stable age distribution associated with the lifetable (matrix of survival and reproductive rates), the future realized population trend may be dominated by the age-sex structure. Currently, the NARW age-sex structure is not estimated, but it could be based on the known individuals in the population and information on their known, estimated, or minimum ages. There will be error in the estimated age-sex structure owing to uncertainty in observed individuals' ages and sexes, as well as uncertainty in the estimated unobserved portion of the population in a given year. However, given the wealth of data available for this population, it is anticipated that the uncertainty in the age-sex structure will be relatively low. A variety of statistical approaches could be used to incorporate uncertainty in age and sex into the estimated structure. Again, additional effort to biopsy young animals and match them via genetic analysis to already sampled neonates would reduce uncertainty in the calf to subadult ages.

Number of Reproductive Females

This metric is easy to understand and conveys the current dire status of the NARW. It has been estimated in the past but apparently is not updated regularly. This could be readily achieved using reproductive histories of individual females combined with the female population age structure.

Visual Health Index (and Potentially Other Health Metrics)

The preceding metrics are all population-level metrics in that they apply to demographic groups of animals or the entire population. Here the Working Group highlights the priority to measure relevant health metrics at the *individual* level. An existing visual health assessment index is derived from photographs and incorporates information on qualitative body condition, skin condition, rake marks, cyamid loads, and lesions. These body and skin condition metrics have proven to be a significant predictor of individuals' survival. A suite of additional individual health associated metrics was identified during the 2019 NARW Health Workshop as potentially informative for health status, future survival, and future reproductive performance. Once the utility of such metrics has been established, their estimation should be considered for integration in the monitoring program.

Interrogating Existing Data to Inform Future Monitoring Schemes

The NARW data that have been amassed to date are an invaluable resource that could be further analyzed to inform a future, more optimized monitoring plan. The Working Group was provided an extensive overview of the data collection and monitoring efforts that have been ongoing by NMFS and other organizations; however, the Working Group did not have an opportunity to analyze existing data to inform monitoring plan recommendations. Although the Working Group presents a monitoring plan below, it acknowledges that aspects of this proposed plan may be refined through additional analyses of existing datasets. **The Working Group recommends several analyses of the photo-identification, survey, and other data prior to finalizing a monitoring plan**. Below the Working Group outlines desired objectives and a suite of analyses that could be conducted on existing data to help achieve those objectives through the design of an improved monitoring plan.

Objective 1. Optimize Aerial and Vessel Survey Effort to Ensure High Precision and Minimize Bias in Estimates of Survival, New Entrants, and Abundance in an Efficient Manner

Achieving this objective depends upon maintaining high (approximately ≥ 0.90) annual capture probabilities for all age and sex classes, minimizing heterogeneity in capture probabilities among individuals, and re-distributing effort in such a way as to reduce oversampling or undersampling of certain areas (and thereby certain segments of the population).

Proposed retrospective analyses:

A. Enumerate and track number of overall and unique identifications by source, platform, and region. During the workshop, the number of individuals documented per year by platform and organization (Appendix I, Table 1) and geographic area (Appendix I, Table 3) was provided for review, together with the number of individual NARWs seen only by a single platform or source (Appendix I, Table 2) and in a single area (Appendix I, Table 4). This information is extremely informative for determining where effort may be adjusted to maximize the number of individuals identified each year. The 2018-2019 data could not yet be evaluated in this way, but should be added when it becomes available to reflect the most current information for planning future survey effort. Further, while the Working Group aimed to identify the most significant data contributors based on the provided presentations, some significant sources may have been omitted such that the organizations and platforms should be reviewed for completeness.

B. Investigate drivers of individual capture heterogeneity. Heterogeneity can be attributed to both sampling methods and intrinsic biology of animals. It may be possible to discern from existing capture histories if the variability in re-sightability among individuals is mostly due to distribution of survey effort in space and time, variability in animal behavior affecting detection and identification, or variability in mark distinctiveness among individuals. Such information could be used to adjust survey design to reduce heterogeneity.

C. Related to (B), investigate temporal and spatial patterns of occurrence for those NARWs seen only once per year, or which go undetected for one or more years. These NARWs, by definition, have relatively low sighting probabilities. This analysis may suggest strategies for increasing the probability of detecting these NARWs, thereby reducing potential bias in estimates of survival and abundance.

D. Subsample existing sightings histories to simulate how reduced effort (temporally/spatially) might affect the precision and bias of the metrics used to monitor population status. This will help inform whether reducing effort in specific areas, times, or from specific platforms will result in undue bias or unacceptable uncertainty. This will also help evaluate whether the overall capture probability goal could be reduced to less than 90% of the population per year.

E. Determine level of effort required to identify new calves. With the reduced number of calves seen in the southeast area in recent years, a post-hoc re-sampling analysis could be used to determine the level of aerial effort that is needed to find and photograph all calves born in a given year (recognizing that this effort is likely to change as the number of births changes). In addition, the integrated mark-recapture model provides estimates of calf production. These estimates should be compared to independent estimates of calf production (e.g., from the southeast surveys). If the model approach indeed provides good estimates of calf production, this could potentially reduce the need to collect as much winter survey data from the southeast region.

Objective 2. Maintain Sufficient Effort to Detect Entangled, Injured, and Dead North Atlantic Right Whales

Achieving this objective is critical for assessing threats, assigning cause of death, designing mitigation strategies, and evaluating the efficacy of those strategies. Between 2010 and 2017, approximately 50% of the estimated NARWs that were killed or seriously injured were detected. Live, entangled NARWs may be disentangled and thereby relieved of suffering, injury, and death. Any adjustment in surveillance for optimizing estimation of demographic metric must be balanced with potential degradation in the likelihood of detecting entangled, injured, and dead NARWs.

Proposed retrospective analyses:

A. Map when, where, and by what platform entangled, injured and dead NARWs have been first detected to date.

B. Subsample existing sightings data to simulate how dead, injured, and entangled NARW detections would have been affected by reduced effort. Determine the level of aerial survey effort needed to detect dead, injured, or entangled NARWs.

C. Estimate unobserved human-caused mortality. Integrating information on human-caused injury and mortality (e.g., entanglements, vessel strikes) into the mark-recapture model may help build on previous efforts to estimate unobserved human-caused mortality (Pace et al. in prep.). For example, for entanglements this would take the form of a multi-state model, where sighting information is used to classify individuals as entangled or not, and this information is used to estimate the probability of transitioning from an un-entangled to an entangled state (taking resight probability into account) and the associated mortality rate. It would also provide estimates of the annual likelihood of animals becoming entangled in a year. Surveys designed to maximize detection of entangled, injured, or dead NARWs, and to identify the location of entanglement, injury, and mortality, would provide more robust data to inform this effort.

Objective 3. Improve Characterization of Risk Seascape

Understanding the spatial and temporal distribution of threats is key to designing mitigation measures.

Proposed retrospective analyses:

A. The Working Group recommends increased modeling effort to better understand drivers of variation in calf production, the correlation between calf production and survival (for various age classes), and the relative contribution of environmental versus anthropogenic impacts to survival and reproduction. An effort should be made to investigate correlates of survival and reproduction in sighting histories (cf., Wade and Clapham 2000) to determine whether individuals' distribution patterns have been predictive of subsequent survival, health status, reproductive success, or observation as injured or entangled. Calf production may be reduced by nutritional stress, injury-related stress (vessel strike or entanglement), or the additive or synergistic effect of these. An analysis of an individual's reproductive success and sighting histories as they relate to these factors may help to tease apart the influence of these factors on calf production.

As with calf production, adult survival may similarly be reduced by nutritional stress and human-caused factors (entanglements and vessel strikes). In general, adult survival is expected to be more robust to environmental conditions than reproduction, but whether the environment is playing a role in reducing adult survival may be detectable by correlation with calf production, annual oceanographic or prey metrics that should relate to the individual's ability to meet energetic needs, and independent population-health assessment data. Inferences from this effort would better inform risk assessments and the extent to which current population dynamics are within management control vs. driven by environmental conditions.

B. Some risks have been more or less well described for the areas and times where NARWs have traditionally been present. In recent years, NARWS have redistributed in ways that were not predicted nor are even yet well characterized. Given this uncertainty, formally characterizing threats (e.g., vessels/fishing) in areas where NARWs *may* be spending more time in recent years (e.g., Mid-Atlantic, Canada outside Gulf of St. Lawrence, Iceland, others) could help prioritize survey effort (including acoustic recorders) to characterize NARW use of the highest perceived risk areas.

Objective 4. Improve Understanding of Relative Detection by Acoustics Versus Visual Survey

Acoustic and visual (aerial and vessel) surveillance are used to detect presence of NARW and a future monitoring plan will continue to employ both methods. Both methods fail to detect some NARWs that are present. In particular, behavioral state and acoustic propagation conditions may have significant impact on the ability of acoustic monitoring devices to detect NARWs known to be in a given area. Understanding these factors and predicting when each method will provide the greatest surveillance pay-off is key to a cost-effective monitoring plan.

<u>Proposed retrospective analyses:</u>

A. Evaluate situations where acoustic recorders were present in the same times and places as aerial or boat surveys. Identify instances where acoustic monitoring indicated NARWs were present but they were not detected visually, and vice versa. This may inform strategies for deploying surveillance resources, especially in currently under-surveyed locations of interest.

Improving the North Atlantic Right Whale Habitat Model

NARW spatial density models have been developed at Duke University (e.g., Roberts et al. 2016). There have been a number of challenges associated with expanding the geographic scale of the models and the types of data that can be used to inform the density predictions. For example, it seems that some data contributors do not distinguish between periods of 'on-effort' vs. 'off-effort' survey or note the distance to sighted groups. Many of our other recommendations already address some of these challenges (need for systematic effort, need for common data types, etc.). However, the existence of a broad spatial-scale predictive modeling tool would have many uses in facilitating efficient monitoring for NARWs within and between years. Extrapolation of models using environmental covariates to presently un-surveyed areas could provide clues for targeting regions for PAM or focusing aerial surveys in the future.

Further, the Working Group was presented an overview of ongoing work by DFO with regard to developing NARW habitat-prediction models. To the extent feasible, **the Working Group recommends a coordinated and unified modeling approach to provide distribution and density predictions across the range of NARW habitat.** Such a model would require considerable collaboration among U.S. and Canadian researchers to ensure consistent data inputs, but would provide a powerful tool for examining possible distribution shifts based on future conditions or for identifying locations where future focused effort may be most efficient or effective.

Although NMFS conducts a large share of overall aerial survey efforts, there are several other research groups that regularly or intermittently conduct aerial surveys, including collection of identification photographs. Attempts to integrate and use these data are slowed by the need to standardize the data to a common framework (identifying periods of survey effort versus periods off the transect line for other purposes, measurement perpendicular sighting distance, etc.). Working with contributing research groups, **the Working Group recommends developing standards for collecting a common data subset (e.g., effort and perpendicular sighting distance) instituted by all aerial survey efforts to facilitate maximal use of collected encounter and photo-identification data.** The identification and collection of a common data subset isn't meant to replace data collection protocols long used by various survey groups, but rather to ensure that a standard set of data required for quantitative analyses is collected in the same way by all partners, maximizing the utility for all datasets. At minimum, all teams should record whether the survey (or portion of the survey) was systematic, opportunistic, or directed at known aggregations, and for those portions that represent systematic survey effort, indicate when the plane is "on-effort" surveying along the transect line, and the distance to sighted groups.

An Integrated Passive Acoustic and Visual Survey Monitoring Plan

The Working Group thinks that a well-designed, long-term coordinated visual and PAM effort may yield the greatest benefit by providing consistent input datasets for examining occupancy, predicting (or at least retrospectively identifying) distribution shifts, and supporting abundance analyses and estimation of other vital demographic rates for this population. Passive acoustic recorders can provide continuous monitoring year-round, providing valuable information on occurrence, even in times of year with poor weather conditions. Visual surveys provide opportunity to collect identification photographs, critical for quantitative assessment. Aerial platforms also provide broad geographic sampling, better for spatial modeling of habitat use, compared to fixed-site PAM efforts.

The complementary strengths of these data collection platforms allow for efficient and cost-effective data collection across a broad area. Monitoring of high risk areas (e.g., shipping lanes, high density vertical line fishing areas) with low densities of NARWs is probably best accomplished with acoustic recorders, whereas monitoring and data collection in high density hotspots is achieved with visual survey platforms where critical identification photographs can be taken, and other biological samples can be collected. While specific regions or periods may be best suited to either passive acoustic or visual survey effort, there are several cases where the combination of monitoring approaches may provide for the greatest and most consistent data collection opportunity. For example, acoustic monitoring data may reveal the presence of NARWs in an area, allowing subsequent targeted visual surveys to that area. In specific regions, deploying near real-time auto-detection buoys may provide opportunity to rapidly deploy visual survey resources when NARWs are detected, allowing for data collection from NARWs that may not be commonly seen in core foraging areas. Conversely, if visual sighting rates fall in an area where NARWs used to occur at higher density, a switch to acoustic monitoring of the area allows for continued monitoring of the region in the event that the NARWs return as conditions change and NARW distribution shifts.

Therefore**, the Working Group recommends that NARW passive acoustic and visual surveys become more systematic**. There are many areas that should be monitored each year (continuously or seasonally as appropriate) in a similar way, and on a standard cycle. Such monitoring may be acoustic or visual depending on the density of NARWs likely to be in that area, and may switch between visual and acoustic monitoring over time, but consistent monitoring in those spaces should be maintained through some sampling platform. Some areas should continue to be sampled every year. Other areas can be sampled on a less frequent basis, but without abandoning periodic sampling altogether, despite the apparent distribution of NARWs. This will reduce the number of assumptions being made about where the NARWs are, and will let data inform the analyses of NARW distribution, and its change through time. Specific passive acoustic and visual survey recommendations addressing this need for systematic survey efforts are described in more detail in the sections below.

Acoustic Monitoring to Examine Distribution and Habitat Use

Although NARWs are not highly vocal when transiting and mom-calf pairs are often quiet, presumably to prevent detection by predators, PAM efforts have clearly identified occurrence in regions that were not otherwise being monitored. While the detection probability may vary seasonally and by behavioral state, PAM is a low cost monitoring tool, particularly when using archival recorders and analyzing data with highly efficient and accurate automatic detectors and call classifiers.

While visual surveys, both aerial and vessel-based, have been common for decades, PAM efforts specifically designed for monitoring NARW distribution and habitat shifts have not been broadly or sustainably supported. Several PAM efforts have been undertaken by a large variety of institutions, though many were not specifically designed to assess NARW distribution or occurrence. An impressive effort to consolidate these disparate data to assess NARW trends and distribution over time has resulted in valuable insights (Davis et al. 2017); however, the lack of systematic long-term sampling designs hinder the ability to derive strong conclusions from these data. **The Working Group recommends that NMFS establish and analyze long-term permanent passive acoustic stations** where recorders will be regularly maintained to ensure long-term records of NARW occurrence at those sites. Analysis of passive acoustic data from specific monitoring locations will allow for identifying shifts in distribution over time and habitat use changes. Some of our recommended monitoring locations occur in Canadian waters. The Canadian Government and some academic researchers have plans for an impressive array of PAM stations in the Gulf of St. Lawrence and surrounding waters. Effort need not be duplicated, but the long-term effort should be sustained independent of the funding streams of these individual researchers.

The Working Group recommends a large number of permanent continuous long-term monitoring sites, augmented by a smaller number of established stations that could be monitored every 2-4 years, or in response to other information such as from visual surveys. There should be a commitment to fund all stations consistently through time and all sites should be monitored with calibrated and standardized equipment to allow for robust quantitative comparisons among sites. Although the location of specific monitoring sites may need to be adjusted over time for various reasons, possible monitoring sites should be well considered in advance to allow for the greatest consistency without additional confounding variables (including differences in site-specific physical features and detection range) that may reduce the value of some datasets for various quantitative or qualitative examination of space use, population trends, or other metrics. Reductions in overall monitoring effort should be carefully considered based on proven redundancy in the results of passive acoustic efforts at neighboring monitoring stations, and the ability to monitor that region with other approaches.

The location of the permanent acoustic stations should be based on a combination of several factors, including:

- Hotspots of historical and/or current NARW distribution
- Shipping lanes where risk of vessel strike is highest
- Areas with high density of fishing gear with vertical lines
- Areas through which migration is thought to occur

- Calving areas

The Working Group recommends long-term (multi-year) continuous acoustic monitoring in the regions listed below (Figure 5). The rationale for choosing various locations is noted in parentheses. Some locations may require more than one acoustic monitoring site to adequately monitor the region. Acoustic monitoring has been conducted in several of these locations. If appropriate, use of the same monitoring sites should be considered.

1. Northern Gulf of St. Lawrence near Anacosti Island (current foraging area, high density of fishing gear)
2. Southern Gulf of St. Lawrence near Prince Edward Island (current foraging area, high density of fishing gear)
3. Roseway Basin/Scotia Shelf (historical foraging area)
4. Coast of Maine (high density of fishing gear)
5. Jordan Basin (historical foraging area, seasonally increasing density of fishing gear)
6. Boston Harbor shipping lane (exposure to vessel traffic)
7. Georges Bank (historical forging area, offshore pot fishery)
8. North of Great South Channel (current foraging area, exposure to vessel traffic)
9. Great South Channel (current foraging area, exposure to vessel traffic)
10. South of Islands (e.g., Martha's Vineyard and Nantucket) (current foraging area)
11. New York Bight (current foraging area, exposure to vessel traffic)
12. Mouth of Delaware Bay (migratory route, historical winter aggregations, exposure to vessel traffic)
13. Mouth of Chesapeake Bay (migratory route, historical winter aggregations, exposure to vessel traffic)
14. Cape Hatteras (migration pinch point)
15. Charleston Inlet (migratory route, exposure to vessel traffic)
16. Southeast US calving ground (calving area, exposure to vessel traffic)

The Bay of Fundy was identified as a high priority area for passive acoustic monitoring; however, strong tidal currents may prevent successful monitoring of this region so it is not listed above. If appropriate and cost-effective mooring options become available, monitoring in this region should be considered. Alternative approaches to monitoring the Bay of Fundy may be needed in the meantime.

In addition to the permanent monitoring areas identified above, the Working Group recommends additional year-round monitoring occur on a periodic basis (every 2-4 years) in the following regions:

- Jeffreys Ledge (historical foraging area)
- Wilkinson Basin, Gulf of Maine (historical foraging area)
- Savannah Inlet (migratory route, exposure to vessel traffic)

Finally, exploratory short-term monitoring should be carried out to investigate the occurrence of NARWs in potential foraging areas that are not being surveyed by other means. Such areas may include regions with infrequent sightings of NARWs, or regions to the northeast where foraging habitat is predicted by various modeling efforts (including that of Monsarrat et al. 2015). This list is not exhaustive, but rather provides suggestions based on the above rationale. Some regions may be better assessed with underwater gliders outfitted with PAM devices. The choice of acoustic monitoring platform can be determined based on hardware available, the size of the possible monitoring region, and the need to monitor for extended duration. After examination of the results in Monsarrat et al. (2015), the Working Group specifically recommends exploratory short-term monitoring in the following areas that have three features: (1) identified as predicted habitat from the model results, (2) historical (pre-1950) records of NARWs, and (3) post-1950 sightings of NARWs:

- Off of southeast Labrador (possible summer/fall foraging area). Labrador is approximately the same distance from the Gulf of Maine as is the foraging area in the Gulf of St. Lawrence, suggesting easy travel to this area if it becomes a productive foraging area.
- Off of southeast Greenland (possible summer/fall foraging area). Although farther, this area could be utilized once NARWs leave Cape Cod Bay after the spring.
- Off the east and west coasts of Iceland (possible summer/fall foraging area). Iceland is more distant than other proposed monitoring areas; however, at least one NARW has been seen recently in local waters.

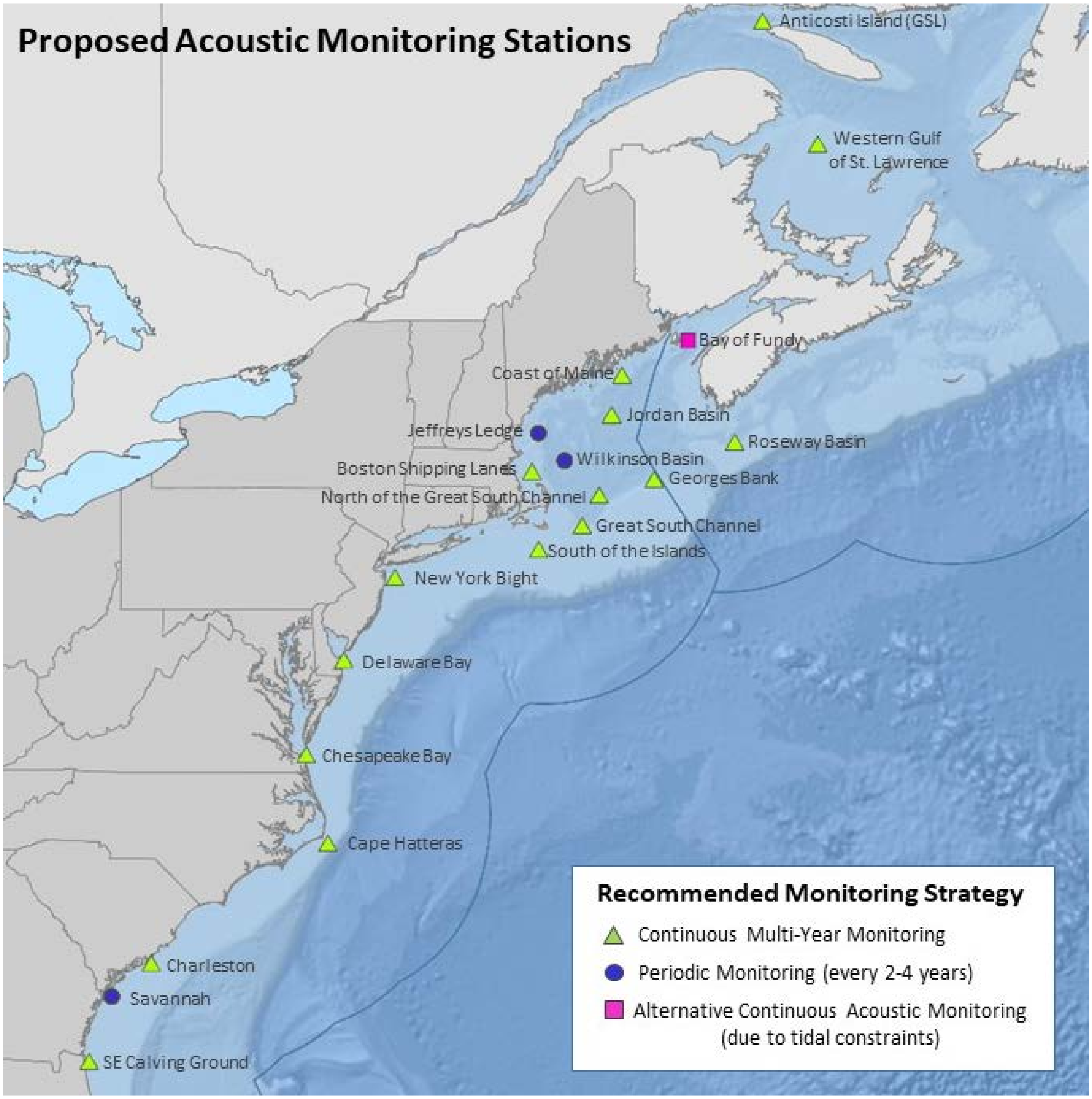

Figure 5. Proposed acoustic monitoring stations in the U.S. and Canada. Continuous year-round monitoring is recommended at the green sites and periodic monitoring (every 2-4 years) at purple sites. The red site (Bay of Fundy) is considered a priority for continuous monitoring but may require an alternate plan due to strong tidal forces. The locations are approximate and do not represent a specific monitoring site.

In addition to archival long-term monitoring, real-time acoustic monitoring in the mid-Atlantic area and in currently sparsely used foraging areas may provide opportunity for response to intermittent and infrequent aggregations of NARWs in these areas. Auto-buoys provide for near real-time detections of NARW calls that visual survey teams can then respond to for collection of identification photographs or biological samples. Real-time monitoring efforts must be well coordinated to ensure visual teams are available to respond to relatively rare detection events. If such coordination is not feasible, the cost of real-time efforts may not be worth the investment.

PAM is a powerful and efficient method for monitoring NARW distribution, though its capacity to provide insights is limited by several biological and physical factors that must be considered when designing a PAM network for the species. Calling rates vary among demographic groups and during different behaviors (Parks et al. 2014), such as quieter mother-calf pairs, which may result in lower detection probability in calving regions and along northbound migration routes. Detection probability also varies with different acoustic habitats, bathymetry, and recorders (e.g., Rice et al. 2014; Risch et al. 2014), highlighting the need to use consistent calibrated hardware and quantify detection range seasonally if aiming to use the data in quantitative analyses of NARW distribution, and especially if attempting to estimate NARW abundance using these data.

Aerial Surveys and Collection of Identification Photographs

Photo-identification studies are conducted by a number of groups independent of NMFS, including CCS, DFO, and the NEAq. These groups have consistently provided 50% or more of all photo identifications, and their efforts are essential to maintaining a high quality monitoring program for this population. Below, the Working Group provides a strawman survey plan based on the information provided to the Working Group (not informed by the analyses outlined above).

Specifically, the plan assumes continuation of the following efforts by NMFS partners:

- Vessel-based surveys in the Bay of Fundy, Roseway Basin, and in the Gulf of St. Lawrence by the NEAq
- Aerial surveys in Cape Cod Bay and areas adjacent to Cape Cod by CCS
- Aerial surveys in the Gulf of St. Lawrence by Canada DFO and Transport Canada

The evolution of the NEFSC survey effort- from broad-scale surveys, to specific survey boxes, to directed effort in areas of high capture rates- was sensible and highly successful at maximizing the collection of identification photographs. The NEFSC aerial surveys in recent years have often resulted in more than 200 identifications in a year (Appendix I, Table 1), but there is considerable overlap in identifications with other survey efforts, such as with CCS effort in Cape Cod Bay, and in 2017-2018 with DFO efforts in the Gulf of St. Lawrence (Appendix I, Table 4). The proportion of unique identifications attributable to NEFSC aerial surveys averages about 32% per year since 2002, though this identification rate has fallen by about 10% compared to the period of broad-scale surveys (~41%). There are many factors that may confound the rate of capturing unique identifications in recent years, including extent and distribution of survey effort and NARW distribution, and while the Working Group commends the significant NEFSC aerial efforts to collect identification photos, it recommends returning to broader scale surveys that would allow for identifying habitats being used by NARWs for the first time, return to historically used habitats, and presence of NARWs in high risk areas.

Underlying all of our survey recommendations is the premise that **photo-identification efforts should be designed and maintained to achieve a capture probability of approximately 90%.** A metric for measuring progress towards meeting this objective is the number of unique individuals sampled in a given year. The NEFSC endeavors to maximize the number of animals identified in a year for a given level of sampling effort by targeted sampling of high-density areas. In this way, roughly the same number of unique animals can be detected with significantly fewer flight hours. The Working Group supports this approach, though also recommends that sampling be designed to achieve a wide range of sample locations to reduce potential bias associated with geographic heterogeneity in capture probability among individuals.

The Working Group also recognizes that aerial photo-identification efforts represent a risk to survey personnel. The geographic coverage provided by aerial surveys should be weighed against the high value of data that may be collected using alternative platforms, such as surveys by surface vessels and the use of UAS launched from surface vessels. In particular, the use of UAS for collecting photographs may allow for reducing aerial survey effort for photo-identification. Mindful of the danger of aerial surveys, **the Working Group specifically does not recommend increasing aerial survey effort to achieve a higher than 90% capture probability** to monitor population abundance, trends, and vital rates. Effort reductions may be achieved by reducing the number of days allocated to return to high-density hotspots, and terminating effort there before a full plateau in the discovery curve. From discovery curves presented to the Working Group, it appears that ~1/3 to 1/4 of the survey effort in those locations results in obtaining only a few additional identifications. Of course, one cannot know when the discovery curve will plateau until it is observed. However, sufficient experience in the last few years exists to be able to make some predictions of how many days should be spent returning to a high-density area, in order to reduce the total number of flight days.

The Working Group considers this 90% metric to be cumulative across all data contributors and platforms, such that **the Working Group recommends additional efforts to coordinate identification of individuals across all data collectors** operating along the east coast throughout the survey year. This could be accomplished if survey teams were to determine NARW identities as soon as possible after detection by vessel or aerial surveys. These would ideally be entered into a shared near real-time updated list of unique NARWs identified by any survey platform during the year. When the collective effort from all surveys identifies a number of unique NARWs greater than 90% of the NARW abundance estimated for the previous year, aerial survey efforts should be reduced, or redirected to other tasks, including identifying and tracking dead or injured NARWs.

NARW distribution is likely to continue to vary in the future, and it is important that systematic surveys be conducted to recognize those changes when they occur. The Working Group approves of the current design, whereby key areas of known NARW aggregation are targeted (i.e., boxes in Figure 2) and survey effort is dynamically allocated in those areas until most or all the unique NARWs within them have been identified. However, **the Working Group recommends that this approach should be balanced by repeating broad-scale systematic surveys of the entire Gulf of Maine/Southern New England on a regular schedule**. The Working Group also notes that some boxes are no longer surveyed in some years, apparently because they have recently contained few or no NARWs (e.g., Jordan Basin in the middle of northern Gulf of Maine). The Working Group recommends that some effort continue in these areas, on an annual basis if possible. This could be accomplished by a lower density of aerial track lines or by a shift to passive acoustic recorders to, at least retrospectively, identify a return of NARWs to that habitat.

The following is an example of an aerial survey plan that accords with our recommendations.

(I) Conduct a broad-scale survey covering the Gulf of Maine and Southern New England every 3rd year.

The Working Group recommends that a broad-scale survey should be conducted every 3rd year. This timing balances detecting distributional shifts in a timely fashion with maintaining higher efficiency in obtaining NARW identifications in other years by focusing effort on high NARW density areas. The survey would be designed to provide data that could be used for modeling the spatial distribution of NARWs, by providing systematic uniform coverage of the survey area. These data would help identify and analyze major changes in NARW distribution and habitat use. This would ensure that emerging habitat hotspots have a high probability of being discovered relatively quickly so they can be included in future photo-identification surveys, and that emerging use of areas with high risk from vessel traffic or high density of fishing gear vertical lines would also be identified. At least two complete surveys should be completed, one in spring, and one in late summer/fall (September/October) to ensure surveys are not missing important areas being used by NARWs. The goal should not be to detect every single NARW in the survey area, rather to achieve a high probability of detecting areas being used by an appreciable number of NARWs.

The Working Group recognizes that conducting such broad-scale surveys could potentially consume all or a large percentage of available flight time in a year. To balance the need for information on broad-scale distribution with collecting identification photographs, a stratified design may be appropriate, where specific strata could be designated to have higher sampling intensity (e.g., more transect lines). Strata with higher sampling would be guided by those areas currently known to contain higher densities of NARWs, such as South of the Islands. The Working Group is aware that the NEAq is currently conducting aerial surveys south of Nantucket and Martha’s Vineyard, and that this effort is not captured in the present enumeration of unique identification photos by platform or area. That effort need not be replicated by NMFS to the extent that the NEAq continues to fly in that region and collect the data needed to assess overall distribution and abundance (i.e., identification photographs and effort information).

(II) In the two other years of a 3-year period, continue targeted photo-identification surveys, with modification to ensure some systematic components are maintained through time.

The Working Group is impressed by the efforts to increase the collection of identification photographs of NARWs from the NEFSC aerial surveys. It is clear that photographs from some locations are only collected from that platform, and every year these contain identifications of NARWs only seen in those areas. This especially includes the Great South Channel, the area north of the Great South Channel, north of Cape Cod Bay, the northern edge of Georges Bank, and the area South of the Islands. The Working Group encourages continuation of this work, and commend the NEFSC aerial survey team for their efforts.

The establishment (after the 2002-2006 broad-scale surveys) of designated survey boxes around hotspots was an excellent idea. The Working Group recommends maintaining consistent survey boxes through time to provide another source of long-term data to assess habitat use and NARW movements. It appears from examination of past survey efforts that the geographic boundaries of some surveyed boxes occasionally changes seasonally or annually. The Working Group recommends fixing the boundaries of the survey boxes and maintaining a single design of specified survey boxes. In particular, the Working Group recommends establishing a permanent survey box South of the Islands (Nantucket and Martha's Vineyard), to the south of Block Island, and in the New York shipping lane. This could include a partitioning into an eastern (south of Block Island) box and a western (south of Nantucket) box. The Working Group also notes that a large number of NARWs were seen in spring well to the south of the area typically surveyed (i.e., Nantucket shoal, or south of Block Island), close to the edge of the shelf break. The Working Group realizes this may be a newly discovered extension of this area, such that the 'permanent' box to be surveyed in the future may need to encompass this area, as well.

Further, as shown in Figure 3, there are several locations in the Gulf of Maine that are no longer surveyed in summer or fall because NARWs are no longer commonly seen there. The recommended broad-scale surveys will provide information from this area; however, additional effort in this historical hotspot would be worthwhile given the significant fishing effort there. Therefore, **the Working Group further recommends establishing a regular systematic rotation through all historical hotspots** and in all seasons previously detected. This could be accomplished by rotating among historical hotspots over the two years of targeted surveys between broad-scale surveys.

Finally, reiterating our recommendation related to improving the NARW habitat model, **the Working Group recommends working with all data contributors to develop standards for**

collecting a common data subset that may be instituted by all aerial survey efforts to facilitate maximal use of collected encounter and photo-identification data. Many aerial survey efforts provide identification photos that contribute to examining population demographics and distribution. With relatively little additional data recording effort, periods of survey efforts that are either systematic, opportunistic, or targeted may be identified, and the effort within each state tracked to allow for use of a border set of survey data within a robust quantitative habitat-modeling framework.

Data Collected on Vessel-Based Surveys

As much as possible, **the Working Group recommends substituting vessel-based effort for aerial effort**. The Working Group makes this recommendation for several reasons. First, for the safety of researchers, as cumulative time spent flying adds to cumulative risk. Second, genetic, some health assessment, and other biological sample data can only be collected from NARWs on the water. A monitoring plan that aims to provide appropriate data for monitoring individual and population health must include vessel-based survey and data collection efforts. Such efforts provide the only opportunity to collect biopsy samples for genetic and other tissue-based analyses, to fly UAS platforms for photogrammetry or blow sampling, and to allow for collection of fecal samples. **The Working Group recommends that vessel-based survey efforts be maintained at least at current levels, or increased to replace aerial survey effort, across all data contributors**. Expansion of boat-based UAS surveillance may be a viable replacement for some aerial survey effort though will require investment in vessel support. Vessel-based survey efforts are currently undertaken primarily by NMFS' partners. If partners are not able to continue vessel-based survey and data collection efforts, such efforts may need to be augmented by or funded by NMFS.

Work by Pettis et al. (2004) has shown that photo-identification images can be used for monitoring the health of individuals. There are also many powerful new techniques and methodologies that have become available in recent years. These include analyses of hormones, various 'Omics- including ribonucleic acid (RNA) transcriptomics for gene expression such as immune response and photogrammetry for examining body condition and identifying pregnant females. Although many of these analyses are not yet being undertaken on NARWs, every effort should be taken to accommodate the greatest range of future analytical approaches possible. **To that end, the Working Group recommends that biopsy samples be placed into small liquid nitrogen dry shippers immediately on collection**, to provide high quality genetic material that can be used for cutting edge methods such as RNA transcriptomics, but also archived for methods that have not yet been developed. Further, efforts to obtain biopsy samples from older calves should be prioritized so they can be genetically matched to samples from neonates in order to reduce age and sex uncertainty in assessment models.

At present, the majority of health assessments linked to survival are almost entirely based on photographs collected during vessel-based surveys. Through development and testing of various proxies, it may be feasible to determine overall health condition through use of aerial imagery, collected by airplane or UAS. As such, **the Working Group recommends a set of feasibility studies using imagery collected by UAS**. Lateral imagery taken from the vessel paired with aerial imagery collected by UAS for the same whale may provide for development of proxies measured from the aerial photographs for health metrics that are currently only derived from vessel-based photos. In particular, health assessments based on length and girth measurements made from aerial photographs would provide additional health data for a larger sample of NARWs than can currently be achieved by vessel-based photographs alone.

The Working Group members do not consider themselves experts in health assessment, and largely defer to input provided at the June 2019 Health Assessment Workshop. Beyond recommendations for maintaining vessel-based survey effort, the Working Group outlines two research projects it feels should be carried out to further health assessment studies on NARWs.

1. Examine whether body condition or skin condition assessments may provide an early indication of calf production. It is possible that years of low calf production would be preceded by periods of poor body of skin condition.
2. Determine appropriate and efficient biological sampling for establishing pregnancy rates.

Other Research Recommendations

In addition to the monitoring plan recommendations provided above, the Working Group identified several other research tools that could be used to assess NARW distribution and abundance.

Examination of Acoustic Records from the Northeast Atlantic and Adjacent Seas

Many researchers along the west coast of Europe and in the Mediterranean have deployed passive acoustic sensors to study a variety of cetacean and fish taxa. In addition, NARWs have been observed off the coast of France and the west coast of Europe and a portion of adjacent seas have been identified as regions of probable NARW habitat by Monsarrat et al. (2015). Although none of these sensors were deployed specifically to look for NARW calls, **the use of efficient and reliable automatic detectors could make such “needle in a haystack” analysis a relatively quick and possibly highly valuable task**.

Satellite Imagery

Recent progress has been made in using very high resolution (VHR) satellite imagery to study large whales in remote areas (e.g., Cubaynes et al. 2019) This approach could be useful for identifying new or previously undetected aggregation areas, particularly if any exist to the north of where current survey efforts exist. Spatially extrapolated areas of predicted occurrence would be a logical first area to explore with VHR imagery. **Satellite image data should be explored as a potential option for identifying NARWs and documenting distribution shifts**.

Tagging

It is clear that long-term location satellite tags could help provide valuable data about NARW habitat use, including discovery of unknown foraging areas, return to previously used forarging areas, and other shifts in distribution that might occur. It could also help estimate time spent by NARWs in high-risk areas, and could help further define important migration corridors. However, tag durations are still too short to provide the needed information without deploying deep implantation tags that embed in muscle tissue. Information presented to the Working Group indicated that Low Impact Minimally Percutaneous Electronic Transmitter (LIMPET) tags had fairly short durations and that the newly developed 'Blubber' tags, although better, in a test on eight Southern right whales, had a median duration of only 16 days, with a mean of 21 days (A. Zerbini. pers. comm.). The developers of the 'Blubber' tag are continuing research and modifications with a goal of trying to extend the median duration to 30 days.

Assuming a travel rate of ~75 nautical miles per day, it would take a NARW leaving Cape Cod Bay ~10 days to reach the Gulf of St Lawrence or southeast of Labrador, but about ~22 days to reach possible foraging areas southeast of Greenland, and even longer to reach Iceland. Migration from South of the Islands to Georgia would take ~11 days. Many of these movements cannot yet be fully documented via existing non-deep-implant tag technology. Documenting shorter distance movements, though potentially feasible, would require deployment of the tag within several days of departure to have a reasonable chance of documenting the journey, a logistical challenge for most research teams.

Given concerns about risk to these critically endangered whales from deep implantation tags, it seems reasonable to wait to evaluate whether the retention time can be increased for novel, less invasive tagging technologies (e.g., LIMPET tags, 'Blubber' tags, or other technologies) to the point where they can be used to answer the most pressing questions about NARW movement. **The Working Group recommends evaluating the results from Southern right whale tagging efforts before additional tagging of NARWs.**

V. CONCLUSIONS AND ACKNOWLEDGEMENTS

The Working Group assembled by the NARW Steering Committee consisted of NMFS researchers with expertise in marine mammal monitoring and quantitative assessments, but not directly involved in current NARW monitoring efforts. The intent of assembling such a group was to provide a knowledgeable, but independent review of the past and current research efforts by NMFS and its partners, and from that, develop a comprehensive monitoring plan that was not influenced by a direct interest in the long-standing research efforts. The Working Group endeavored to consider the full range of monitoring options, while understanding funding and logistic constraints, the rationale for various research approaches, and the evolution of NARW research in the region. The Working Group did not attempt to conduct independent analyses or assessments of the vast wealth of NARW data available. The Working Group did its best to be as detailed as possible with recommendations in hopes that they will be helpful as NMFS considers how to move forward with NARW monitoring over the coming years.

The Working Group could not have accomplished their task without the direct input of several NMFS researchers from the NEFSC (Tim Cole, Lisa Conger, Richard Pace, Sofie Van Parijs), managers from NMFS' Greater Atlantic Regional Office (Diane Borggaard), NMFS Office of Protected Resources (Caroline Good), and DFO (Simon Nadeau) the NARW Steering Committee (Mike Asaro, Lance Garrison, Sean Hayes, Kristy Long, Eric Patterson, Barb Zoodsma, and see Appendix II) and other independent institutions and agencies dedicated to NARW research and conservation. NMFS and other research institutions and agencies have been working to understand many aspects of NARW biology, ecology, and the threats to the species for decades. The large and impressive collective effort and the cooperation among research groups should be applauded. It is the summary of this impressive effort and large dataset that provided the Working Group with a rich understanding of the rationale for past and current efforts, where efforts could be shifted while maintaining the high quality demographic dataset, and where new approaches or new analyses of existing data may provide new insights.

The Working Group has developed a set of recommendations that include retrospective analyses of existing datasets, expansion of the NARW habitat model, and specific recommendations for the design and execution of an integrated visual and PAM plan. Ideally, these recommendations will contribute to efficient and effective monitoring of important NARW population metrics, while also making those research efforts safer for the dedicated researchers who conduct them every year.

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APPENDIX I. TABLES

Table 1. Total number of NARWs identified by each contributing survey platform and institution from 2001 to 2017 (resights across contributors have not been removed, but resights of individuals within an institution have)[6]. Abbreviations are given in Section II. Information provided by Richard M. Pace based on data collected by many individuals and institutions (see acknowledgements in Pace et al. 2017).

Year	NEFSC Aerial	NEFSC Vessel	CCS Aerial	SEUS Aerial	NEAq Vessel	DFO Aerial	All
2001	31	52	106	83	142	7	282
2002	206	89	96	58	115	20	303
2003	175	152	93	84	91	6	314
2004	118	21	91	76	154	1	286
2005	258	44	93	179	243	6	353
2006	188	0	121	135	225	6	347
2007	295	0	191	137	144	1	379
2008	288	115	200	188	176	0	389
2009	262	0	214	237	218	0	422
2010	267	111	182	225	102	1	422
2011	257	46	329	152	190	3	437
2012	183	169	236	59	86	8	374
2013	23	73	241	50	117	4	297
2014	134	62	262	49	83	21	371
2015	103	50	144	39	6	20	267
2016	140	31	195	30	97	49	323
2017	211	128	254	5	38	105	363

[6] The data used to generate these tables were preliminary working datasets. The tables should be updated prior to use in future planning. Also see recommendations in *Objective 1. Optimize Aerial and Vessel Survey Effort to Ensure High Precision and Minimize Bias in Estimates of Survival, New Entrants, and Abundance in an Efficient Manner*, Proposed retrospective analyses: A.

Table 2. Number of NARWs uniquely identified by only one survey platform and institution from 2001 to 2017 (NARWs sighted by more than one institution have been removed)[7]. Abbreviations are given in Section II. Information provided by Richard M. Pace based on data collected by many individuals and institutions (see acknowledgements in Pace et al. 2017).

Year	NEFSC Aerial	NEFSC Vessel	CCS Aerial	SEUS Aerial	NEAq Vessel	DFO Aerial	All
2001	2	2	8	8	4	0	24
2002	40	11	5	4	6	0	66
2003	22	28	18	14	0	0	82
2004	28	5	14	16	21	1	85
2005	40	1	7	6	12	1	67
2006	38	0	9	15	22	0	84
2007	41	0	13	8	1	1	64
2008	56	3	17	5	6	0	87
2009	34	0	20	17	5	0	76
2010	43	5	10	24	2	0	84
2011	36	0	31	11	2	1	81
2012	44	19	43	5	5	1	117
2013	4	1	78	9	3	2	97
2014	27	1	74	11	1	5	119
2015	44	4	37	10	2	6	103
2016	35	0	39	5	11	14	104
2017	23	1	27	0	2	25	78

[7] The data used to generate these tables were preliminary working datasets. The tables should be updated prior to use in future planning. Also see recommendations in *Objective 1. Optimize Aerial and Vessel Survey Effort to Ensure High Precision and Minimize Bias in Estimates of Survival, New Entrants, and Abundance in an Efficient Manner*, Proposed retrospective analyses: A.

Table 3. Total number of NARWs identified in each survey location from 2001 to 2017 (resights across locations have not been removed, but resights of individuals within a location have)[8]. Abbreviations are for the Bay of Fundy (Fundy), Cape Cod Bay (CCB), the great south Channel (GSC), the Gulf of St. Lawrence (GoSL), the Gulf of Maine (GOM), and the southeastern United States (SEUS). Information provided by Richard M. Pace based on data collected by many individuals and institutions (see acknowledgements in Pace et al. 2017).

Year	Fundy	CCB	GSC	GoSL	GOM	SEUS	All
2001	151	78	210	9	82	83	282
2002	145	20	207	20	98	58	303
2003	116	36	217	6	111	84	314
2004	108	61	160	1	76	76	286
2005	192	45	282	6	70	179	353
2006	113	66	99	6	190	135	347
2007	162	127	287	1	210	137	379
2008	183	180	227	0	193	188	389
2009	186	205	142	0	209	237	422
2010	86	136	178	1	243	225	422
2011	178	283	155	3	286	152	437
2012	53	192	98	8	230	59	374
2013	15	216	67	4	82	50	297
2014	108	247	111	21	98	49	371
2015	29	124	42	50	97	39	267
2016	120	180	110	50	98	30	323
2017	35	252	98	131	95	5	363

[8] The data used to generate these tables were preliminary working datasets. The tables should be updated prior to use in future planning. Also see recommendations in *Objective 1. Optimize Aerial and Vessel Survey Effort to Ensure High Precision and Minimize Bias in Estimates of Survival, New Entrants, and Abundance in an Efficient Manner*, Proposed retrospective analyses: A.

Table 4. Number of NARWs uniquely identified in only one survey location from 2001 to 2017 (NARWs sighted in multiple locations have been removed)[9]. Abbreviations are for the Bay of Fundy (Fundy), Cape Cod Bay (CCB), the great south Channel (GSC), the Gulf of St. Lawrence (GoSL), the Gulf of Maine (GOM), and the southeastern US (SEUS). Information provided by Richard M. Pace based on data collected by many individuals and institutions (see acknowledgements in Pace et al. 2017).

Year	Fundy	CCB	GSC	GoSL	GOM	SEUS	All
2001	13	2	55	1	5	8	84
2002	24	2	51	6	8	4	95
2003	7	4	71	3	21	14	120
2004	19	7	42	0	8	16	92
2005	10	3	44	1	8	6	72
2006	9	3	7	2	33	15	69
2007	8	1	42	0	14	8	73
2008	12	11	21	0	28	5	77
2009	4	20	11	0	23	17	75
2010	4	6	17	0	25	24	76
2011	5	19	8	0	25	11	68
2012	8	29	15	3	52	5	112
2013	3	83	16	2	9	9	122
2014	14	63	23	5	3	11	119
2015	7	33	18	17	15	10	100
2016	38	49	30	8	10	5	140
2017	2	52	7	16	1	0	78

[9] The data used to generate these tables were preliminary working datasets. The tables should be updated prior to use in future planning. Also see recommendations in *Objective 1. Optimize Aerial and Vessel Survey Effort to Ensure High Precision and Minimize Bias in Estimates of Survival, New Entrants, and Abundance in an Efficient Manner,* Proposed retrospective analyses: A.

APPENDIX II. WORKSHOP PARTICIPANTS AND CONTRIBUTORS

Table 5. List of workshop participants, contributors, affiliations, and role and contributions.

First	Last	Affiliation	Role and Contributions
Jason	Baker	Pacific Islands Fisheries Science Center	Working Group
Jay	Barlow	Southwest Fisheries Science Center	Working Group
Jeff	Moore	Southwest Fisheries Science Center	Working Group
Erin	Oleson	Pacific Island Fisheries Science Center	Working Group
Paul	Wade	Alaska Fisheries Science Center	Working Group
Mike	Asaro	Greater Atlantic Regional Fisheries Office	NARW Steering Committee, Workshop Organizer
Lance	Garrison	Southeast Fisheries Science Center	NARW Steering Committee, Workshop Organizer, Presenter, Participant, Report Editor
Sean	Hayes	Northeast Fisheries Science Center	NARW Steering Committee, Workshop Organizer, Presenter, Participant, Report Editor
Kristy	Long	Office of Protected Resources	NARW Steering Committee, Lead Workshop Organizer, Presenter, Participant, Report Editor
Eric	Patterson	Office of Protected Resources	NARW Steering Committee, Workshop Organizer, Report Editor
Barb	Zoodsma	Southeast Regional Office	NARW Steering Committee, Workshop Organizer, Participant, Report Editor
Diane	Borggaard	Greater Atlantic Regional Fisheries Office	Participant
Tim	Cole	Northeast Fisheries Science Center	Presenter
Lisa	Conger	Northeast Fisheries Science Center	Presenter
Caroline	Good	Office of Protected Resources	Presenter, Participant, Report Editor
Simon	Nadeau	Fisheries and Oceans Canada	Presenter
Richard	Pace	Northeast Fisheries Science Center	Presenter, Participant, Analytical Support
Sofie	Van Parijs	Northeast Fisheries Science Center	Presenter

APPENDIX III. WORKSHOP AGENDA

North Atlantic Right Whale Expert Working Group: Monitoring and Surveillance

October 22-24, 2019

Meeting Location:
NMFS Southwest Fisheries Science Center, Pacific Conf. Rm.
La Jolla, California

AGENDA

Meeting Goals

The primary goals of this meeting are to develop options for a comprehensive strategy to:

1. Monitor population status
    a. Estimate abundance
    b. Evaluate trends
    c. Estimate survival rates, birth rates, and other demographic parameters
2. Monitor distribution shifts and habitat use range-wide
3. Assess health of individuals and the population (e.g., identify causation/threats, assess sub-lethal effects) through biological sampling

The options should range from a minimally-acceptable effort (i.e., reduced precision) to the ideal, best case effort, while simultaneously considering cost effectiveness.

Objectives

The Working Group's specific tasks are to provide expert guidance to the North Atlantic Right Whale Steering Committee on how best to achieve the objectives below.

Population Status

- Identify the essential population demographic metrics (e.g., survival rate, birth rate, age at calving, calving rate, life span) the agency should use to track recovery of this species, including a description of why each metric is essential for monitoring the population status.
- Develop a monitoring/surveillance plan for each essential population metric identified above, including options for:

- Sampling methods,
- Data types,
- Sampling locations (e.g., region and/or range-wide), and
- Monitoring/survey frequencies.

Distribution and Habitat

- Determine approach for identifying:
  - Distribution, occurrence, habitat use in the mid-Atlantic region (i.e., west of 72° 30’ West, south of 40° 00’ North through 35° 30’ North (North Carolina))
  - Migratory corridor and associated physical and biological features in the mid-Atlantic
  - The unobserved portion of the population in time/space (i.e., “missing whales” not detected during aerial surveys in the northeast and southeast)
  - Where animals die
- Determine best methods for quantifying changes in occurrence and distribution (e.g., relative to a changing climate)
- Determine whether, and if so how, historic and current visual sightings data can be combined with passive acoustic detection data to assess past and current occurrence and distribution, and decadal-scale changes in distribution

Health Status

- Determine approach for identifying cause(s) or contributing factors for dead, injured, entangled animals and poor reproduction and poor health
- Determine approach for collecting:
  - Health assessment data, such as body condition and skin condition including scarring
  - Hormones for assessing reproductive state, stress, metabolism/energetics, nutritional state
  - Injury state (e.g., wounds, entanglements, skin lesions, etc.)

DAY ONE: TUESDAY, OCTOBER 22

8:30 AM **ARRIVALS AND GREETINGS**

8:45 AM **WELCOME AND INTRODUCTIONS**

9:00 AM **DESCRIBE MANAGEMENT NEEDS AND ASSOCIATED MEETING GOALS AND OBJECTIVES** (KRISTY LONG, OFFICE OF PROTECTED RESOURCES (OPR))

9:30 AM **EVALUATE POPULATION STATUS**

USING MARK RECAPTURE PHOTO-IDENTIFICATION DATA TO MONITOR ABUNDANCE AND EVALUATE TRENDS (RICHARD PACE, NEFSC) (15 MINUTES)

NORTHEAST - AERIAL & VESSEL SURVEYS (TIM COLE, NEFSC) (45 MINUTES)

- Describe all surveys (NMFS and partners) and purposes (e.g., mark recapture, entanglement status)
- Describe assets, methods, and data collected
- Describe projected Fiscal Year 2020 plans
- Clarifying questions and discussion

10:30 AM **BREAK**

10:45 AM **SOUTHEAST & MID-ATLANTIC - AERIAL SURVEYS AND VESSEL-BASED EFFORTS** (LANCE GARRISON, SEFSC) (20 MINUTES)

- Describe surveys and purposes (e.g., calf production, biopsy efforts via vessels)
- Describe assets, methods, and data collected
- Describe projected Fiscal Year 2020 plans
- Clarifying questions and discussion

INITIAL THOUGHTS AND REFLECTIONS (10 MINUTES)

11:15 AM **ASSESSING HEALTH THROUGH BIOLOGICAL SAMPLING**

VESSEL SURVEYS – NMFS AND PARTNERS (LISA CONGER, NEFSC) (45 MINUTES)

- Describe health-related data collection (e.g., photogrammetry, biopsies, scarring rates, etc.)
- Describe assets, methods, and data collected
- Describe projected Fiscal Year 2020 plans
- Clarifying Questions and Discussion

12:00 pm **LUNCH (ORDER IN - CHEESE SHOP)**

1:00 PM **CANADIAN MONITORING AND SURVEILLANCE EFFORTS** (SIMON NADEAU, DFO)

1:45 PM **DISTRIBUTION AND MONITORING**

PASSIVE ACOUSTIC MONITORING OVERVIEW (SOFIE VAN PARIJS, NEFSC) (45 MINUTES)

- Describe projects and purposes
- Describe assets, methods, and data collected
- Describe projected Fiscal Year 2020 plans
- Clarifying Questions and Discussion

OVERVIEW OF TAGGING EFFORTS (SEAN HAYES, NEFSC) (30 MINUTES)

3:00 PM **BREAK**

3:15 PM **OVERVIEW OF RECENT MONITORING AND SURVEILLANCE EFFORTS** (CAROLINE GOOD, OPR)

3:45 PM **OVERVIEW OF CURRENT FUNDING AND CAPACITY** (KRISTY LONG, OPR)

4:15 PM **DISCUSS APPROACH FOR DEVELOPING COMPREHENSIVE MONITORING AND SURVEILLANCE PLAN(S)**

5:15 PM **ADJOURN**

6:30 PM **SOCIAL GATHERING** (HOSTED BY JAY BARLOW)

DAY TWO: WEDNESDAY, OCTOBER 23

8:30 AM **ARRIVALS AND GREETINGS**

8:45 AM **REVIEW DAY 1 AND PREVIEW DAY 2**

9:00 AM **GROUP DISCUSSION AND DRAFTING (INCLUDING BREAK)**

12:00 PM **LUNCH**

1:00 PM **GROUP DISCUSSION AND DRAFTING (INCLUDING BREAK)**

5:00 PM **REVIEW PROGRESS FROM DAY 2 AND PREVIEW DAY 3**

5:30 PM **ADJOURN**

DAY THREE: THURSDAY, OCTOBER 24

8:30 AM **ARRIVALS AND GREETINGS**

8:45 AM **GROUP DISCUSSION AND DRAFTING (INCLUDING BREAK)**

12:00 PM **LUNCH**

1:00 PM **REVIEW PROGRESS AND FINALIZE STRATEGY**

4:00 PM **WRAP-UP AND NEXT STEPS**

5:00 PM **ADJOURN**