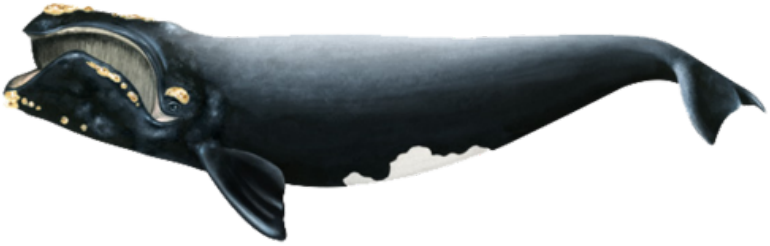

Evaluating Effectiveness of U.S. Management Measures:

Summary of the North Atlantic Right Whale Technical Expert Working Group on Evaluating Effectiveness of U.S. Management Measures, 21-23 May 2018, Woods Hole, Massachusetts

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OVERVIEW AND PURPOSE

NOAA's National Marine Fisheries Service (NMFS) convened an expert working group at the Northeast Fisheries Science Center (NEFSC) in Woods Hole, Massachusetts, May 21-23, 2018, to gather input on how NMFS should evaluate the effectiveness of U.S. management measures for reducing ship strikes and entanglements of North Atlantic right whales.

The primary purpose of the meeting was to: (1) review available data sets and analyses (for both the U.S. and Canada) on the rates and types of entanglements and vessel strikes with right whales to better understand their potential impact on population dynamics, and (2) identify potential methods/analytical tools (and associated pros/cons) available to address the key questions.

Specific key questions:

- Have there been changes in the effects of human-caused mortality and injury on right whale population dynamics during the last 10 years as a result of U.S. management measures?
- How are threats outside U.S. waters influencing population dynamics?
- What are the best analytical tools (and the data needed to inform such tools) to evaluate potential future management efforts?

See **Appendix B** for the workshop agenda.

WORKING GROUP ORGANIZATION

To prepare for the working group, NMFS convened a steering committee to help shape the structure and agenda, identify candidate participants, and develop materials for use during the workshop. The steering committee members included: Kristy Long (Office of Protected Resources), Sean Hayes (NEFSC), Mike Asaro (Greater Atlantic Regional Office), Lance Garrison (Southeast Fisheries Science Center), and Barb Zoodsma (Southeast Regional Office).

PARTICIPANTS

The working group was composed of eight participants from within and outside of NMFS who have expertise in quantitative methods used for such analyses as well as those who have great familiarity of existing data for North Atlantic right whales. Those participants included: Amy Knowlton (New England Aquarium), André Punt (University of Washington), Matthew Hardy (Fisheries and Oceans Canada), Angelia Vanderlaan (Fisheries and Oceans Canada), Ed Trippel (Fisheries and Oceans Canada), Richard Pace (NEFSC), Jason Baker (NMFS Pacific Islands Fisheries Science Center), Steve Lindley (NMFS Southwest Fisheries Science Center), Jeff Moore (NMFS Southwest Fisheries Science Center), and Jim Carretta (NMFS Southwest Fisheries Science Center). In addition to the Steering Committee, other NMFS staff included Donna Wieting (Office of Protected Resources), Shannon Bettridge (Office of Protected Resources), Diane Borggaard (Greater Atlantic Regional Office), and Nick Sisson (Office of Protected Resources).

WORKSHOP SUMMARY

The workshop began with a welcome from Donna Wieting, Director of the NMFS Office of Protected Resources. D. Wieting noted that NMFS has taken substantial actions for right whale conservation, but not enough, and this working group will help NMFS assess which measures are working and which ones are not, and how to approach the questions being asked. She also noted that NMFS and Fisheries and Oceans Canada (DFO) need to support each other in efforts going forward.

Following the welcome, the morning of day one began with a presentation by L. Garrison on how the working group should consider "effectiveness" throughout the three-day workshop. A discussion ensured, with several panel members suggesting that to evaluate effectiveness a baseline should be described and quantified, prior to or in the absence of management to use as a benchmark.

The remainder of day one was devoted to discussing the analyses (e.g., spatio-temporal overlap) that have been conducted by both the U.S. and Canada to evaluate the effectiveness of the ship strike reduction measures, including ship speed requirements and changes to shipping routes. The panel members did not identify additional data beyond what is currently available to inform the analyses. Discussion primarily focused on updating the existing analyses, with several identified options for refinements and new analyses.

Day two was focused on evaluating entanglement risk and assessing measures to reduce that risk. Presentations centered around the current available data to evaluate the effectiveness of fishing gear requirements and subsequent limited analyses conducted in both the U.S. and Canada. Panel members noted that the lack of data on fishing effort substantially limits our ability to assess effectiveness of mitigation measures. Despite the lack of data, the panel members identified several additional analyses that could be conducted to inform effectiveness.

On day three the panel members further discussed and provided input on existing analyses and identified future analyses to evaluate effectiveness of ship strike and entanglement mitigation measures. This generated substantial discussion, with multiple ideas identified for both topics.

PRESENTATION SUMMARIES

Defining Effectiveness

Presentation - Setting the Stage: Defining Effectiveness

L. Garrison began by defining effectiveness, noting that it is defined by outcomes - were the goals of the policy achieved? Realistic goals can be hard to define, and gradients of effectiveness can occur. Four aspects of effectiveness were discussed:

- Did the target behavior change? Specifically, did ships slow down and did fisheries adopt intended practices?
- Was the relative risk reduced compared to the baseline?
- Did interaction rate decrease and the survival rate increase?
- Were conservation goals achieved? Or, were actions sufficient to reduce the risk of extinction?

The presentation ended with a question to the group, can we build upon recent improvements in characterizing right whale population status to develop better quantitative frameworks for assessing effectiveness?

Summary of Discussion

A robust discussion followed L. Garrison's presentation on effectiveness, with several panel members noting that a baseline should be described and quantified, prior to or in the absence of management to use as a benchmark. It was noted that the baseline for North Atlantic right whales is relatively short and Southern right whales could be used as a proxy or for comparison.

Several panel members provided input on analyses for evaluating effectiveness. The panel discussed using absolute risk versus relative risk in these types of analyses and noted various scenarios where one may be more appropriate than the other. One panel member described two components related to evaluating effectiveness: (1) did you detect it if it happened and (2) could you detect it in principle. Recognizing the difference between evaluating compliance and evaluating effectiveness, one panel member outlined a three-stage process:

- Evaluate compliance and the associated behavioral changes by shipping/fishing industry,
- Determine whether the measure(s) reduced the impact to the population (effectiveness),
- Determine whether the measure(s) achieved the conservation goal (e.g., increase in female survival rate).

The group further discussed the importance of using projection models for these types of effectiveness analyses.

Ship Strikes

Presentation - Frameworks for Evaluating Ship Strike Risks

L. Garrison provided an overview of the frameworks available for evaluating ship strike risks. He began with approaches to assessing risk, noting that risk has been defined by degree of spatial and temporal overlap between vessels and whales. There is also a relative risk metric used to assess where and when a high degree of overlap will occur. He used the routing strategies in the southeast U.S. as a case study, showing the associated data employed that supported the process and how the final routes were chosen. L. Garrison also noted that these approaches were used to develop the ship speed rule (50 CFR 224.105), as well as other routing strategies. He also provided information on updated models (Roberts *et al.* 2016, in prep.) and the available data (e.g., coast-wide Automatic Identification System (AIS) for some vessels), as well as on approaches to explicitly quantify the risk of mortality by modeling the probability of whale-ship collisions and estimating the likelihood of mortality due to a collision as a function of factors such as vessel size and speed. Issues with scale were first discussed, with L. Garrison noting that the resolution of whale density models may influence risk estimation (broad-scale models are 10x10km). The panel identified options for improving our ability to quantitatively estimate encounter and mortality risk, through integrating the following into available models:

- Relative whale and vessel size,
- Whale speed and potential avoidance behavior,
- Whale dive-surface behavior, and
- Probability of mortality given contact between whale and vessel (function of vessel speed).

Presentation - Known Unknowns: Estimating the Fraction of Coastal Bottlenose Dolphin Carcasses That Are Documented Ashore

J. Carretta provided a review of approaches for using stranding data to develop correction factors for mortality and serious injury (M/SI) estimates. He described that human-caused mortality is underestimated but determining by how much is difficult. There are many reasons for non-detection of carcasses: carcass sinks, drifts away, strands on remote beaches. J. Carretta described an example using *Tursiops sp.* as these animals live close to shore and have a well-known distribution and abundance. In order to determine how many carcasses are theoretically available for recovery, J. Carretta *et al*. conducted Monte Carlo simulations using the estimated U.S. population size for *Tursiops sp.* and annual mortality rates for calves and adults. Simulations showed that 22 adult carcasses would be expected for recovery, with J. Carretta noting that they estimate that ~24% of available carcasses are recovered. According to Kraus *et al.* 2005, 17% of right whale carcasses are estimated to be recovered/documented, which is higher than many other cetaceans.

Presentation - Quantifying Mortality and Vessel Strike Reductions

L. Garrison provided a detailed explanation on efforts to quantify mortality and vessel strike reductions. He began by describing the quantification of ship strikes and effectiveness, noting

that ship strike mortality documentation is dependent on carcass recovery and complete necropsies. AIS data are needed to document compliance, as well as compare carcass recovery rates before and after the implementation of mitigation measures. L. Garrison noted that there have been patterns with compliance identified in the literature; Lagueux *et al.* 2011 and Silber *et al.* 2014 showed that compliance with ship speed regulations and routing measures increased over time, resulting in a 72% decrease in vessel strike mortality in the southeast U.S. The topic of effectiveness was further described using the Laist *et al.* 2014 analysis that examined carcass recovery rates before and after implementation of the ship speed rule. Results showed that Seasonal Management Areas (SMAs) drastically reduced the number of recovered ship struck right whales in those areas. L. Garrison ended his presentation describing the challenges in quantifying ship strike effectiveness. The metrics used to quantify effectiveness are highly dependent on carcass recovery and changes in survey patterns/effort and shifts in right whale distribution may result in changes in recovery rates. He noted that conducting necropsies and determining cause of death are critical; associated analyses must be updated regularly to evaluate any changes in risk.

Presentation - Vessel-Strike Risk to North Atlantic Right Whales in Canadian Waters: Historical Perspectives, Data Review, Mitigation Measures

A. Vanderlaan provided an overview of historical perspectives, available data, and current mitigation measures related to ship strike risk in Canada. Between 1993-1999, Canada implemented a Mariner Awareness Program with four goals aimed at educating the public about ship strike risk. These four goals included designating right whale conservation areas in the Bay of Fundy and Roseway Basin; publishing information on right whales, the conservation areas, and precautionary guidelines for vessel operations; publishing pamphlet, "Caution Mariners: Please avoid collisions with right whales;" and including the right whale conservation areas and an information box on two nautical charts. Education alone did not solve the problem. Effectiveness in reducing vessel strikes appeared limited due to ability and (or) willingness of mariners to follow precautionary advice. As a result, Canada implemented two conservation initiatives: vessel rerouting and speed restrictions. Risk analyses of Canadian measures showed that there was an 82% reduction in relative risk in Areas to be Avoided (ATBA). Simulation studies to assess absolute risk using correlated random walks were also conducted to examine the effects of the initiatives on changes in whale distribution and vessel traffic. Measures were put in place in the Bay of Fundy, Roseway Basin, and Gulf of St. Lawrence, though reductions in risk were achieved with minimal effects on industry, she noted that these initiatives will not completely eliminate ship strikes.

Summary of Discussion

Panel members did not identify additional data beyond what is currently available to inform analyses to assess the effectiveness of ship speed requirements and changes to shipping routes. It was noted that there may be a disconnect between the ship speed rule and effectiveness and conservation outcomes - SMAs are effective, but whales are being struck outside of SMAs. Much of the initial discussion centered on the data used in the risk assessment for ship strikes, specifically about using predictive models versus actual sightings-per-unit-effort (SPUE).

With respect to absolute risk of mortality versus relative risk, when an absolute estimate is known, a comparison can be made with what is actually observed. To determine a baseline for ship strike mortality, a cause of death analysis was again identified as critical because it increases the power of the analysis and allows for predicting mortality in the absence of mitigation measures (e.g., vessel speed regulations). It is estimated that ½ to ⅔ of carcasses are detected. However, detection rates differ spatially. Also related to carcass recovery, vessel size and associated impacts on right whales were discussed. A whale that dies from blunt force trauma may not show any visual evidence and unless the animal is retrieved and a full necropsy is performed, cause of death would be unknown. On the other hand, a whale that dies from a propeller cut is more likely to be observed visually via survey and cause of death (or serious injury) could be speculated without performing a full necropsy. It is presumed that larger, heavier vessels could cause blunt force trauma deaths whereas smaller lighter vessels would likely not cause blunt force trauma but could cause lethal propeller cuts. Panel members identified vessel size as a possible additional variable to consider in ship strike analyses.

The group discussed the possibility of conducting an analysis similar to Rockwood *et. al* (2017) for blue and fin whales off California using a novel application of a naval encounter model. One panel member noted that there may have been more data available for the Rockwood *et al.* analysis and NMFS may consider whether we have the necessary data for right whales to conduct a similar analysis.

Canadian risk assessment analyses were also briefly discussed. Panel members felt that there are benefits to integrating the Canadian approach of using observed distributions of whales to inform simulations with the U.S. approach of using environmental predictions. Both risk assessments could be used to validate each other given the approaches are complementary.

Once panel members became familiar with the methodology for assessing risk from ship strikes, the discussion shifted towards whether the methods currently being used in the U.S. are adequate for evaluating the current regulations. The panel had some difficulty disentangling the effectiveness of the regulations from the overall decline of the population. An important point was made by one panel member, asking if the effect size (size of the difference between regulation effectiveness and population decline) is large enough to detect. Though the difference is likely small, it may have an effect at the demographic level and thus is an important aspect to consider in determining effectiveness success. However, some panel members noted that existing analyses should be updated and identified several specific refinements for NMFS to consider undertaking (see **Appendix A**).

Entanglements

Presentation - Overview of the North Atlantic Right Whale Stock Assessment Report
S. Hayes began day two with an overview of the abundance trends of right whales and entanglement history. He explained that a shift in habitat used by the whales occurred around

2011, with whales inhabiting areas historically not known to have high right whale abundance. As well as a distributional shift, the threat of entanglement has surpassed ship strikes as the dominant threat. Starting in 1990, commercial lobster landings have grown exponentially; prior to that landings were steady. Though the volume of gear according to trap tags is the same, effort in the lobster fishery has moved offshore possibly causing the gear to be in the water longer with an increased threat of heavier gear that whales may encounter due to trap configurations and line diameter.

Presentation - Current Statistical Methods Used to Determine Abundance and Cause-Specific Mortality

R. Pace provided a discussion of modeling efforts to estimate right whale population size and cause-specific mortality. He explained that the motivation for this work was primarily due to the decline in annual resighting rates, which previously was >80% between 1995-2011. He provided an introduction to the first use of the multi-state hierarchical mark-resight/recapture mode to estimate abundance. This flexible framework allows for varying mean annual capture rates and individual capture heterogeneity and can accommodate several biologically-plausible aspects of right whale demography. Resultant estimates from this analysis points to a population that is in decline.

R. Pace went on to explain the second function of the hierarchical Bayesian, state-space model, to estimate mortality (latent and observed) and attempt to apportion it between entanglement and 'other/unknown.' Findings from this analysis show that there has been a relatively constant, substantial anthropogenic mortality source influencing right whale demography. By adding entanglement-related mortality to other sources, the population will continue to decline if current fecundity rates continue.

Presentation - Historical Overview of the North Atlantic Right Whale Entanglements and Their Impacts

A. Knowlton provided an historical overview of right whale entanglements and their impacts. She began by describing the efforts of the New England Aquarium (NEAQ) to create a database of scar coding, entanglement risk, and visual health assessment case studies for all right whales entangled in gear. Through this analysis, NEAQ has concluded that 85% of right whales show evidence of entanglement, and moderate and severe injuries have become more prevalent in the past decade. Detrimental health impacts due to chronic entanglements have been noted, with further research being conducted on gender-specific impacts. A. Knowlton noted that the entanglement problem has become more pronounced likely as a result of stronger ropes, increased density, and expanded range of fishing effort coupled with the distributional shift of right whales. Through the NEAQ's monitoring efforts, changes in entanglement rates can now be detected on a near real-time basis.

A. Knowlton continued her presentation with a discussion on the NEAQ's efforts to assess the strains put on ropes during fishing operations to inform whether fishermen could fish with weaker ropes. Partnering with commercial fishermen to conduct field testing, NEAQ has

measured the strain put on ropes with various lobster gear configurations, and have developed and tested "whale release" ropes. She explained that testing has shown that weaker or sleeved ropes could be used in some but not all fisheries. Configuration of gear (e.g., number of pots) and water depth are a significant factor in the amount of load on the gear in the water column. Heavier configurations or deeper water would preclude the use of weaker or sleeved ropes.

Presentation - Existing Frameworks and Data on Right Whale Entanglements

M. Asaro described the existing frameworks for quantifying entanglement risk. He began with a description of the data and analysis supporting the Atlantic Large Whale Take Reduction Plan "co-occurrence model." The initial goals of the modeling efforts were to provide members of the Atlantic Large Whale Take Reduction Team an understanding of the seasonal distribution of fishing gear and whales and to provide analytical support for policy development. However, co-occurrence scores have many limitations due to shortcomings of the underlying data and provide an imperfect basis for characterizing the potential of whale-gear encounters. M. Asaro mentioned the model has been criticized by the Team because of these limitations. Efforts are currently being made to update the platform and underlying data to improve the applicability of the model.

M. Asaro continued the presentation with a brief discussion on fisheries data reporting requirements. Coast-wide there are many different reporting requirements, with little federal reporting requirements for inshore lobster fisheries. At present, Vessel Trip Reports (VTR) are only required for vessels permitted for another, non-lobster fishery, with many of those vessels fishing in Lobster Management Area 3 offshore. He noted that the Atlantic States Marine Fisheries Commission plans to introduce new VTR in additional fisheries

The presentation finished up with an overview of the ongoing analysis of fishing gear recovered from entangled whales. Recovered gear is catalogued at a gear warehouse where it is photographed and measured. Through this process, M. Asaro noted that out of 117 documented right whale entanglements, 29 cases had positive gear identifications. Of those 29, 13 cases were identified to gear type and location where the gear was set.

Presentation - North Atlantic Right Whale: Evaluating Effectiveness of Measures

M. Hardy provided an overview of DFO efforts to evaluate effectiveness of Canadian measures. He began by describing the perspective from the Gulf of St. Lawrence where few right whale sightings were recorded before 2015, but surveillance effort was also low, whereas in 2017 over 100 individual right whales were observed. He explained that this trend may be due to total *Calanus sp.* biomass, the primary prey of right whales, which has been lower than average in areas where right whales were historically observed (Gulf of Maine and Scotian Shelf) and more variable in the Gulf of St. Lawrence. It was also noted that there is a high entanglement risk in the Gulf of St. Lawrence with intense fishing efforts over a short period, but also mandatory effort reporting in the snow crab fishery.

In response to the 12 confirmed mortalities in 2017 in Canada, DFO released a comprehensive incident report (Daoust *et al.* 2017), increased surveillance efforts through aerial and boat

surveys and passive acoustic monitoring, and implemented fisheries regulations aimed at gear changes and trap reductions. M. Hardy explained that SMAs are already in place and a Dynamic Management Area (DMA) was recently enacted in response to the sighting of two right whales in the Gulf of St. Lawrence.

M. Hardy concluded with a discussion of the data gaps and challenges that Canada still faces. He explained that though significant efforts have been made in the past year, evaluation of which measures yielded the best results need to occur as well as gaining an overall better understanding of right whale distribution. Preliminary Management Strategy Evaluations have already shown a "fence effect" of fishing effort around the SMAs.

Summary of Discussion

Overall, panel members had difficulty identifying options for assessing the effectiveness of U.S. measures to reduce entanglements due to large data gaps. Effort data for the U.S. lobster fishery was identified as critically important to inform analyses. One panel member noted that data show entanglement of right whales is a systemic issue with 85% of the population showing evidence of entanglement, but asked how do we define that scientifically. Panel members discussed that trends in entanglement severity have been getting progressively worse since 1990s, but that survival/mortality rates apparently have not reflected that in current models (i.e., through 2016 data). The working group discussed whether a potential lag effect could exist. One participant noted that entanglement severity and mortality has been increasing over the last decade, and the population may not be as resilient as it has been. Another panel member noted that there has been a reduction in reproductive rate due to at least two causes: chronic entanglement and prey limitations. It would be useful to partition the contribution of these causes to changes in fecundity. The panel member further identified one option for refining the modelling to estimate the degree to which the increased inter-birth interval due to entanglement (based on available energetic analyses or observational data) contributes to reduced reproduction, while perhaps assuming the remainder is due to the environment.

Much of the entanglement discussion focused on the one effectiveness analysis of requirements for U.S. commercial fisheries that has been conducted using data through 2009 (Pace *et al*. 2014). Many panel members noted the need to determine the statistical power needed to detect a change in the right whale population based on entanglement mitigation measures. Without understanding statistical power, some panel members thought that it was difficult to gauge the proportion of population decline that could be attributed to entanglement versus the environment. A discussion ensued on what may be affecting fecundity and finding a covariate to explain it. One panel member noted that the right whale population is below carrying capacity, but it seems there are resource limitations affecting the species. In order to disentangle the impact of entanglement on fecundity, data on how entanglement affects individual fecundity over time and how frequently animals become entangled is needed. If it can be determined how much decline in fecundity is related to entanglement, it might be possible to assess how much of the decline can be controlled through mitigation.

Panel members discussed how the mechanics of whale entanglement and behavior (i.e., the actual process of whales becoming entangled, the perception and behavior of whales around lines, how often they encounter them, etc.) are poorly understood. Models that have whales moving randomly may or may not be realistic. Mitigation measures might be informed by better characterizing the mechanics of entanglement and whale behavior. Panel members identified options for exploring this area of research (see **Appendix A**, Data Needs).

Throughout the thoughtful discussion, panel members identified many options for evaluating the effectiveness of U.S. measures to reduce entanglements (see **Appendix A**).

LITERATURE CITED

Daoust, P.-Y., Couture, E.L., Wimmer, T., and Bourque, L. 2017. Incident Report: North Atlantic Right Whale Mortality Event in the Gulf of St. Lawrence, 2017. Collaborative Report Produced by: Canadian Wildlife Health Cooperative, Marine Animal Response Society, and Fisheries and Oceans Canada. 224 pp. http://publications.gc.ca/collections/collection_2018/mpo-dfo/Fs149-10-2017-1-eng.pdf

Harting, A.L., Johanos, T.C. and Littnan, C.L., 2014. Benefits derived from opportunistic survival-enhancing interventions for the Hawaiian monk seal: the silver BB paradigm. *Endangered Species Research*, *25*(1), pp.89-96. https://www.int-res.com/articles/esr2014/25/n025p089.pdf

Kraus, S.D., Brown, M.W., Caswell, H., Clark, C.W., Fujiwara, M., Hamilton, P.K., Kenney, R.D., Knowlton, A.R., Landry, S., Mayo, C.A. and McLellan, W.A., 2005. North Atlantic right whales in crisis. *Science*, *309*(5734), pp.561-562. http://science.sciencemag.org/content/309/5734/561/tab-pdf

Lagueux, K.M., Zani, M.A., Knowlton, A.R. and Kraus, S.D., 2011. Response by vessel operators to protection measures for right whales Eubalaena glacialis in the southeast US calving ground. *Endangered Species Research*, *14*(1), pp.69-77. https://www.int-res.com/articles/esr_oa/n014p069.pdf

Laist, D.W., Knowlton, A.R. and Pendleton, D., 2014. Effectiveness of mandatory vessel speed limits for protecting North Atlantic right whales. *Endangered Species Research*, *23*(2), pp.133-147. https://www.int-res.com/articles/esr_oa/n023p133.pdf

Martin, J., Sabatier, Q., Gowan, T.A., Giraud, C., Gurarie, E., Calleson, C.S., Ortega-Ortiz, J.G., Deutsch, C.J., Rycyk, A. and Koslovsky, S.M., 2016. A quantitative framework for investigating risk of deadly collisions between marine wildlife and boats. *Methods in Ecology and Evolution*, *7*(1), pp.42-50. https://besjournals.onlinelibrary.wiley.com/doi/epdf/10.1111/2041-210X.12447

Pace III, R.M., Cole, T.V. and Henry, A.G., 2014. Incremental fishing gear modifications fail to significantly reduce large whale serious injury rates. *Endangered Species Research*, *26*(2), pp.115-126. https://www.int-res.com/articles/esr2015/26/n026p115.pdf

Roberts, J.J., Best, B.D., Mannocci, L., Fujioka, E., Halpin, P.N., Palka, D.L., Garrison, L.P., Mullin, K.D., Cole, T.V., Khan, C.B. and McLellan, W.A., 2016. Habitat-based cetacean density models for the US Atlantic and Gulf of Mexico. *Scientific reports*, *6*, p.22615. https://www.nature.com/articles/srep22615.pdf

Rockwood, R.C., Calambokidis, J. and Jahncke, J., 2017. High mortality of blue, humpback and fin whales from modeling of vessel collisions on the US West Coast suggests population impacts and insufficient protection. *PloS one*, *12*(8), p.e0183052.

http://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0183052&type=printable

Silber, G.K., Adams, J.D. and Fonnesbeck, C.J., 2014. Compliance with vessel speed restrictions to protect North Atlantic right whales. *PeerJ*, *2*, p.e399.
https://peerj.com/articles/399.pdf

APPENDIX A. ACTIONS IDENTIFIED BY INDIVIDUAL PANEL MEMBERS

Overarching

- Develop a projection model to evaluate the impact of ship strikes and entanglements on the current population status (pre- and post-rule).
- Continue to recover carcasses and determine cause of death
    - Evaluate carcass recovery (e.g., Laist *et al.* paper) in proximity to SMAs, and express as per capita rates.
    - Consider changes in right whale abundance over time in analyses.
    - Use expert elicitation to aid in cause of death determinations in dead right whales where cause of death is short of definitive (to assign an estimated probability of ship strike versus entanglement versus other sources of mortality for model inputs).
    - Develop proxies for carcass detection rate (e.g., flight hours, # photos submitted to the catalogue, etc.) given this is different from the mark-recapture rate.
- Create a table of current tools, and data available to populate these tools, as well as which questions about the population and threats need to be answered.
- Calculate a time series of reproductive rate, number of calves per female or per mature female as opposed to the API (calves divided by total population size).

Effectiveness

- Describe and quantify baseline prior to or in the absence of management to use as a benchmark.
- Conduct an analysis similar to Harting *et al.* 2014, which translated interventions to save individual Hawaiian monk seals into effects on population growth and overall size of the population assuming there are enough data on right whale individuals to perform this analysis.
- Assess compliance (ship speed rule and fishing gear requirements), and associated industry behavior changes to understand effects of regulations going forward.
    - Create a table of current regulations and compliance and data collection needs.

Mark Recapture Model

- Update and continue to develop mark recapture (MRC) model to include recruitment process and account for sublethal effects.
- Formally include the mortality-based-on-source per capita graph in the right whale SAR.
- Adopt/modify the MRC model to partition mortality between entanglement and other (ship strike) sources.
    - Determine whether proportion of "other" from total M/SI has remained the same or declined with ship strike measure implementation (e.g., by formally testing as a covariate).
- Determine how to address "other" unknown sources.
- As with ship strike, use the MRC model to test whether the probability of becoming entangled is different pre- and post-mitigation measures. Consider 5-year increments as annual changes may not be detectable.

- In addition to a model fit with pre- and post-rule entanglements, fit a model with fully time-varying probability of becoming entangled to evaluate whether there are any notable trends unrelated to management (i.e., evaluate post-hoc correlations with potential covariates such as whale distribution, fishery effort distribution, increased use of stronger ropes, etc.). Also, consider whether the probability of detecting entanglements is lower for young animals than adults given young ones might disappear faster in heavier gear. Attempt to fit a model with age/class specific detection probabilities.
- Include humpback data to increase sample sizes for some of the parameters in models.

Ship Strikes

- Compare change in rate of ship strike cases in SMAs where ship speed rule is in place. Rate means number of whales per year per whale present in the SMAs during time when speed rules in place.
    - Explore whether this can be evaluated for individual or regionally- combined SMAs as well as all areas combined, which may indicate whether certain areas were more effective than others. Spatially and temporally explicit to account for changes in distribution. (Parallel to the Laist and Knowlton 2014 analysis).
    - Change recovery rates to per unit time per whale in SMA.
- Update AIS data analysis to evaluate compliance rates for 2008-2017 for ship speed and recommended routes and include Canadian data as well as to evaluate Great South Channel ATBA compliance (and compare to Canadian ATBA).
- Update spatial risk analysis evaluating vessel traffic overlaid with whale distribution based on Roberts *et al*. 2016 (and in prep) and for example, generate predicted distribution for some time frame in 5-year increments and include Canadian data where appropriate.
- Create encounter rate model similar to Rockwood *et al*. 2017 to evaluate mortality risk as a function of vessel speed and routing measures (spatial overlap). Compare data from Rockwood *et al*. 2017 to analogous data available for right whales.
- Consider using cause of death analysis to determine an upper bound of the maximum effect of ship strikes on the population to help prioritize management actions.
- Assess changes in the rate of vessel strike mortalities of right whales from 2008-2017.
- Consider using the Canadian approach of observed distributions of whales versus the U.S. approach of environmental predictions to validate each other given they're complimentary. Both have strengths and weaknesses.
    - Evaluate the two approaches ("sophisticated" random walk and "simpler" spatial overlay) to compare outcomes/results.
    - Integrate speed of vessels into the U.S. analysis for simulations.
- Determine how small vessels contribute to ship strike risk. For example, continue studies to assess propeller cuts and sublethal/lethal impacts.

Entanglements

- Update Pace *et al*. 2014 with data 2010-2017, plus add in covariates to use as predictors (e.g., population size/trend, measures of effort for detecting carcasses, etc.), to determine whether M/SI rate has changed.
- Partition the contribution of entanglement and environmental change to changes in fecundity.

- Estimate the degree to which the increased inter-birth interval due to entanglement contributes to reduced reproduction, while assuming the remainder is environmental; this could help inform how much change in the population could be affected by reducing entanglements.
- Determine encounter rate for stationary fishing gear using swim speed and residence time similar to the Martin *et al*. 2016.
- Unify the abundance and mortality state-space models.
- Use all data to estimate survival for known sex animals, this might lower error.
- Compare demographic rates with other right whale species, particularly adult female survival. Calculate each year that contributes to intrinsic growth rate (lambda).
- Compare location/gear configuration of gear taken off entangled whales to a random sample from the co-occurrence model.
- Continue to rectify NMFS SAR and NEAQ M/SI classifications to feed in MRC model.
- Create state space model that accounts for entanglement history of individuals.
- Examine the specifics of entanglements that have occurred and whether there are any notable differences compared to co-occurrence model.
- Compare increased Canadian data collection and subsequent fine scale analysis to standard U.S. data collection and analysis. Canadian effort is focused Gulf of St. Lawrence-wide, rather than mark-recapture focus of U.S. methods
- Develop a hypothesis as to why whales get entangled. Scenarios to consider: traveling in groups versus foraging versus migrating.
- To assess Take Reduction Plan efficacy, model line strength as a covariate (on a year basis), line strength based on unit of time.

Data Needs

- Fishing effort data, particularly offshore, are essential for evaluating impacts of fishing mitigation measures.
- Scarring information (for both entanglement and ship strikes).
- Right whale distribution data to evaluate shifts. For both continued population assessment and to evaluate potential threats, better characterize changes in distribution, perhaps using tracking studies or broader survey effort.
- Mark alternative gear (i.e., weak rope) differently than standard gear to differentiate and inform effectiveness.
- Evaluate compliance using fishery observer and enforcement data and articulate gaps in data to assess compliance.
- Determine whale residence time in various habitats.
- Deploy video camera tags on whales moving in areas where threats (especially vertical lines) are present given Ari Friedlaender *et al*.'s work with such tags on blue and humpback whales demonstrates the potential of this approach. Models of entanglement risk based on simulated whale movement and fishing effort are not informed by actual data on how whales perceive, react to and move around vertical lines.
- Given ship strike mortality includes more than blunt force (e.g., there have been a few cases of healed broken bones) and whales in poor health could be vessel strike victims, ask Michael Moore and Bill McLellan to whether the frequency of bone breaks documented in animals is changing over time.

APPENDIX B. WORKSHOP AGENDA

DAY ONE: MONDAY, MAY 21

8:30 – 8:45 AM **ARRIVALS AND GREETINGS**

8:45 – 9:00 AM **WELCOME AND INTRODUCTIONS**

9:00 – 9:30 AM **WHAT DO WE MEAN BY "EFFECTIVENESS"?** (L. GARRISON)

9:30 – 10:30 AM **SHIP STRIKES: REVIEW CURRENT FRAMEWORKS FOR QUANTIFYING SHIP STRIKE RISK** (L. GARRISON)

- Describe existing frameworks and data available to populate those models (vessel strike events, including locations, timing, vessel types/speed/transit)
- Clarifying Questions and Discussion
  - Are there alternative conceptual frameworks that should be considered to better quantify ship strike risk? Are current metrics of risk appropriate?
  - What are the key information gaps in the current conceptual framework? How could those gaps be addressed?
  - Is it important to quantify absolute risk of mortality or is an assessment of relative risk sufficient?

SHIP STRIKES: REVIEW ANALYSES ON EFFECTIVENESS OF U.S. MITIGATION MEASURES (L. GARRISON)

- Analyses for quantifying ship strikes mortalities
- Effectiveness of U.S. vessel strike reduction measures
  - Speed reductions – regulatory and voluntary
  - Routing measures
  - Mandatory Ship Reporting (MSR) System

10:30 – 10:45 AM ***BREAK***

10:45 –12:30 PM **SHIP STRIKES: REVIEW ANALYSES ON EFFECTIVENESS OF U.S. MITIGATION MEASURES – CONTINUED** (L. GARRISON)

- Review approach for using stranding data to develop correction factors for M/SI estimates (10 minutes - J. Carretta)
- Clarifying Questions and Discussion
  - Are there analyses other than those that have been done to date to evaluate effectiveness that NMFS should consider undertaking?

- Are the metrics of effectiveness appropriate and quantifiable?
- Are there tools available to determine whether we could increase effectiveness based on modifications (i.e., in time/space) to existing measures?
- Can the analyses to date be used to determine whether U.S. measures have decreased the number/rate of right whale mortalities/serious injuries?

12:30 – 1:30 PM ***LUNCH***

1:30 – 3:00 PM **SHIP STRIKES: REVIEW DATA, ANALYSES, AND MITIGATION MEASURES IN CANADA** (A. VANDERLAAN)

- Description of Canadian data and analyses related to quantifying risk
- Clarifying Questions and Discussion
  - Should NMFS consider undertaking parallel analyses?
  - How can the U.S. and Canada integrate data into analyses to get overall context of ship strike risk and effectiveness of mitigation measures?

3:00 – 3:15 PM ***BREAK***

3:15 – 5:00 PM **SHIP STRIKES: DISCUSSION (NOTE THIS WILL CONTINUE ON DAY 3)**

- Are current approaches to quantifying the risk of whale-vessel interactions sufficient? What are the key data gaps that could be addressed?
- Are current tools sufficient to determine whether U.S. ship speed measures have significantly altered the rate of right whale mortalities due to vessel strikes?
- Can additional information be gained from studies focusing on carcass recovery or the observation and evaluation of injuries (e.g., propeller scars)?
- Are there additional effects other than mortality (e.g., disturbance, non-serious injuries, etc.) that should be considered further? What models or data are appropriate for evaluating these effects?

5:00 PM ***ADJOURN***

DAY TWO: TUESDAY, MAY 22

8:30 – 8:45 AM **ARRIVALS AND GREETINGS**

8:45 – 10:05 AM **ENTANGLEMENTS: REVIEW EXISTING FRAMEWORKS FOR QUANTIFYING ENTANGLEMENT RISK**

- Overview of the North Atlantic right whale SAR (20 minutes - S. Hayes)
- Describe existing frameworks and available data to populate models (entanglement events, M/SI rate, gear density, and disentanglement) (30 minutes - M. Asaro)
- Sublethal effects as informed by scarification analyses, entanglement trends (including increasing severity), and bioenergetics (30 minutes - A. Knowlton)

10:05 – 10:20 AM ***BREAK***

10:20 – 12:00 PM **ENTANGLEMENTS: DISCUSS EXISTING FRAMEWORKS FOR QUANTIFYING ENTANGLEMENT RISK - CONTINUED** (M. ASARO AND S. HAYES)

- Clarifying Questions and Discussion
  - How should NMFS:
    - Estimate M/SI (e.g., correction factor)
    - Prorate unknown/unidentified gear by fishery/country
    - Characterize health and productivity impacts from entanglement events and incorporate sublethal effects in analyses
    - Quantify the relative contribution of disentangled animals to the population abundance and trajectory

12:00 – 1:00 PM ***LUNCH***

1:00 – 2:30 PM **ENTANGLEMENTS: REVIEW DATA, ANALYSES, AND MITIGATION MEASURES IN CANADA** (M. HARDY)

- Description of data available for Canadian fisheries and gear types as well as Canadian mitigation measures
- Clarifying Questions and Discussion
  - How can these data be incorporated into U.S. frameworks to better estimate mortality?
  - How can these data be incorporated into U.S. frameworks to forecast an expected risk reduction of potential mitigation measures?

2:30 – 2:45 PM ***BREAK***

2:45 – 4:00 PM **ENTANGLEMENTS: REVIEW ANALYSES ON EFFECTIVENESS OF U.S. MITIGATION MEASURES**

- Effectiveness of U.S. ALWTRP regulations (30 minutes - R. Pace)
  - Gear mods – sinking groundline, vertical line reduction
  - Time/area closures
- Clarifying questions and discussion
  - How can this approach be updated to address more recent mitigation measures?
  - Are there other approaches to consider?
  - What are the limitations of the current approaches and options to address any such limitations?

4:00 – 5:00 PM **ENTANGLEMENTS: DISCUSSION (NOTE THIS WILL CONTINUE ON DAY 3)**

- Are we collecting the appropriate data to evaluate effectiveness?
- Are there additional data that would be useful?
- Can we identify any efficiencies for collecting data?
- What data are needed to update and improve information on impacts from entanglements relative to right whale spatial distribution?

5:00 PM **ADJOURN**

DAY THREE: WEDNESDAY, MAY 23

8:00 – 8:15 AM **ARRIVALS AND GREETINGS**

8:15 AM – 1:00 PM **WRAP-UP DISCUSSION: PROVIDE INPUT ON EXISTING ANALYSES AND IDENTIFY OPTIONS FOR FUTURE ANALYSES**
(Including break)

- Can we evaluate effectiveness of U.S. measures?
  - Consider there are multiple metrics of "effectiveness", such as:
    - Frequency of documented M/SI
    - Reducing entanglement rate
    - Reducing scarification rate
    - Reducing severity of entanglements
    - Increasing population (size and/or trend)
    - Decline in reproductive success/rate
    - U.S. and. Canadian components- determining regional threats and impacts
    - Probability of quasi-extinction is less than x% in 100 years……..based on recovery plan
- Which of these metrics are most meaningful and what should NMFS focus on tracking? How? Can we put it in the context of

management measures that we have implemented (e.g., ALWTRP and ship speed regulations)?
- Can we characterize impact of individual management measures? In terms of number of whales "saved" from taking action?

SHIP STRIKES

- Can we determine whether ship strike reduction regulations have impacted population growth rate? If so, how?
- What data are needed to update and improve information on the population impacts from ship strikes?
- Should NMFS modify its conceptual approach to quantifying mortality and impacts from vessel strikes and effectiveness analyses?
- Should additional effort be made to quantify risks from smaller vessels or non-regulated vessels?

ENTANGLEMENTS

- Can we determine whether ALWTRP regulations have impacted population growth rate? If so, how?
- What data are needed to update and improve information on fisheries spatial distribution?
- What data are needed to improve assigning M/SI to fishery (e.g., gear marking)?
- How should NMFS:
  - Estimate M/SI (e.g., correction factor)?
  - Pro-rate unknown gear/fishery/country?
  - Characterize health and productivity impacts from entanglement events?
  - Quantify the relative contribution of disentangled animals to the population abundance and trajectory?

ALL HUMAN-CAUSED MORTALITY

- What are options for determining areas of greatest risk given current understanding of whale distribution and fishing/shipping distribution, such as:
  - Spatial risk analysis, co-occurrence models
  - Spatial density models to predict current whale distribution based on recent environmental conditions (e.g., Roberts *et al*. models).
  - Which model frameworks (e.g., PCOD, PVA, etc.) could be used to evaluate the relative contribution of mortality sources to population dynamics, considering population level impacts due to mortality sources?

1:00 PM **ADJOURN**