North Atlantic Right Whale (*Eubalaena glacialis*) Scenario Planning Summary Report

Diane L. Borggaard, Dorothy M. Dick, Jonathan Star, Barbara Zoodsma, Michael A. Alexander, Michael J. Asaro, Lynne Barre, Shannon Bettridge, Peter Burns, Julie Crocker, Quay Dortch, Lance Garrison, Frances Gulland, Ben Haskell, Sean Hayes, Allison Henry, Kimberly Hyde, Henry Milliken, John Quinlan, Teri Rowles, Vincent Saba, Michelle Staudinger, and Harvey Walsh

Credit: Right Whale #2040 'Naevus' and her calf in the Great South Channel off the New England coast. Image collected under MMPA Research permit number 17355. Photo Credit: NOAA/NEFSC/Christin Khan.

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA Technical Memorandum NMFS-OPR-68
December 2020

North Atlantic Right Whale (*Eubalaena glacialis*) Scenario Planning Summary Report

Diane L. Borggaard[1], Dorothy M. Dick[2], Jonathan Star[3], Barbara Zoodsma[4], Michael A. Alexander[5], Michael J. Asaro[6], Lynne Barre[7], Shannon Bettridge[8], Peter Burns[9], Julie Crocker[1], Quay Dortch[10], Lance Garrison[11], Frances Gulland[12], Ben Haskell[13], Sean Hayes[14], Allison Henry[14], Kimberly Hyde[15], Henry Milliken[14], John Quinlan[16], Teri Rowles[7], Vincent Saba[17], Michelle Staudinger[18], and Harvey Walsh[19]

[1] NOAA Fisheries, Greater Atlantic Region, Protected Resources Division
[2] Ocean Associates, Inc. in support of NOAA Fisheries, Office of Protected Resources
[3] Scenario Insight
[4] NOAA Fisheries, Southeast Regional Office, Protected Resources Division
[5] NOAA, Office of Oceanic and Atmospheric Research, Physical Sciences Laboratory
[6] NOAA Fisheries, Greater Atlantic Region, Protected Resources Division (current affiliation NOAA, Northeast Fisheries Science Center, Social Science Branch)
[7] NOAA Fisheries, West Coast Regional Office, Protected Resources Division
[8] NOAA Fisheries, Office of Protected Resources
[9] NOAA Fisheries, Greater Atlantic Region, Sustainable Fisheries Division
[10] NOAA, National Centers for Coastal Ocean Science
[11] NOAA Fisheries, Southeast Fisheries Science Center, Protected Resources and Biodiversity Division
[12] Marine Mammal Commission
[13] NOAA, Office of National Marine Sanctuaries, Stellwagen Bank National Marine Sanctuary
[14] NOAA Fisheries, Northeast Fisheries Science Center, Protected Species Branch
[15] NOAA Fisheries, Northeast Fisheries Science Center, Ecosystem Assessment and Dynamics Branch
[16] NOAA Fisheries, Southeast Fisheries Science Center, Sustainable Fisheries Division
[17] NOAA Fisheries, Northeast Fisheries Science Center, Geophysical Fluid Dynamics Laboratory
[18] USGS, DOI Northeast Climate Adaptation Science Center
[19] NOAA Fisheries, Northeast Fisheries Science Center, Oceans and Climate Branch

NOAA Technical Memorandum NMFS-OPR-68
December 2020

U.S. Department of Commerce
Wilbur L. Ross, Jr., Secretary

National Oceanic and Atmospheric Administration
Neil A. Jacobs, Ph.D., Acting NOAA Administrator

National Marine Fisheries Service
Chris Oliver, Assistant Administrator for Fisheries

Recommended citation:

Borggaard, D. L., D. M. Dick, J. Star, B. Zoodsma, M. A. Alexander, M. J. Asaro. L. Barre, S. Bettridge, P. Burns, J. Crocker, Q. Dortch, L. Garrison, F. Gulland, B. Haskell, S. Hayes, A. Henry, K. Hyde, H. Milliken, J. Quinlan, T. Rowles, V. Saba, M. Staudinger, and H. Walsh. 2020. North Atlantic Right Whale (*Eubalaena glacialis*) Scenario Planning Summary Report. NOAA Tech. Memo. NMFS-OPR-68, 88 p.

Copies of this report may be obtained from:

Office of Protected Resources
National Oceanic and Atmospheric Administration
1315 East-West Highway, F/OPR
Silver Spring, MD 20910

Or online at:
https://repository.library.noaa.gov/

Contents

Executive Summary ... 1
Introduction ... 2
North Atlantic Right Whale Overview ... 3
Methods ... 4
  Phase 1: Orientation ... 5
    Purpose and Focal Question ... 5
    Participant Selection ... 6
  Phase 2: Exploration ... 6
    Critical Driver Identification and Early Scenario Development ... 6
    Establishing a Common Understanding of Issues ... 7
  Phase 3: Synthesize and Create Scenarios ... 7
    Future Scenario Matrix ... 7
    Scenario Narratives ... 8
  Phase 4: Application ... 9
    Scenario Deepening ... 9
    Generating Options for Management and Research Priorities ... 10
    Prioritization Breakout Groups ... 11
Results ... 11
    Scenario Deepening ... 11
    Generating Options for Management and Research Priorities ... 12
    Prioritization Breakout Groups ... 12
Discussion ... 15
Next Steps: Actions/Activities ... 16
Acknowledgements ... 18
References ... 19
List of Acronyms ... 22
Webinar and Workshop Agendas ... 23
APPENDIX 1. Five phases of the scenario planning process. ... 29
APPENDIX 2. Participant list ... 30
APPENDIX 3. Climate (physical) drivers table. ... 32
APPENDIX 4. Non-climate drivers table ... 35
APPENDIX 5. Literature compiled by participants ... 38
APPENDIX 6. Available workshop presentation slides ... 42
APPENDIX 7. Full transcripts of workgroup Scenario Deepening worksheets ... 79
APPENDIX 8. Full transcripts of workgroup Generating Options worksheets.. ... 82
APPENDIX 9. Full transcripts of breakout group priorities ... 86

Executive Summary

Scenario planning provides a structured framework that can be used in strategic planning to help manage risk and prioritize actions (Schwartz 1996; Peterson *et al.* 2003). By providing a mechanism to communicate about complex situations, scenario planning encourages "out-of-the-box" thinking to help groups assess the impacts of plausible future scenarios on a target or resource. The outcomes from scenario planning can be used to improve management decisions, highlight data gaps, and/or identify future science priorities (Star *et al.* 2015; Borggaard *et al.* 2019).

The application of scenario planning by resource management organizations (e.g., Borggaard *et al*. 2019; Runyon *et al*. 2020; Star *et al*. 2015) and the urgency surrounding the recovery of the critically endangered North Atlantic right whale (*Eubalaena glacialis*), led to a 2018 NOAA Fisheries scenario planning initiative for the species. In addition to complementing the many management and conservation efforts already underway, this initiative was designed to address the uncertainties around future anthropogenic and environmental changes and how these uncertainties may impact species recovery.

We used a scenario planning framework to explore plausible future conditions for North Atlantic right whales and to develop possible options to address those conditions and improve recovery. Specific objectives were to: 1) better understand the challenges of right whale management in changing conditions; 2) identify potential research activities and recovery needs across the species' range; 3) increase coordination and collaboration related to recovery efforts; and 4) explore how scenario planning can be used to support decisions.

Using projected changes in ocean conditions coupled with anthropogenic stressors, we built four plausible future scenarios for right whales. These scenarios helped identify priority research and management actions that NOAA Fisheries and our partners can undertake to improve right whale recovery. We identified priority actions related to science, management, and partnerships including, but not limited to: 1) research shifting spatial and temporal distributions of right whales and prey in a changing climate; 2) develop technology to further reduce impacts from human activities; 3) continue ongoing management efforts related to vessel traffic and fishing; and 4) maintain existing and develop new partnerships (e.g., industry engagement in problem solving).

This scenario planning exercise helped prioritize North Atlantic right whale management and science needs in light of changing ocean conditions and anthropogenic impacts. It can also serve as a reference for how NOAA Fisheries and its partners can better prepare for multiple plausible futures while complementing other on-going initiatives. Priorities identified here can be considered in conjunction with implementation and monitoring actions such as with the Atlantic Large Whale Take Reduction Team (ALWTRT) and/or regional Right Whale U.S. Implementation Teams. The framework can also be repeated and improved upon as additional information becomes available to support future exercises.

Introduction

Scenario planning is an effective tool to help inform natural resource management decision-making in light of short- and long-term uncertainty (Rowland et al. 2014). The tool can be used to generate and evaluate management options associated with adapting to, and managing for, climate change (Moore et al. 2013), as well as other uncertain or unexpected changes in environmental conditions or human activity (Rowland et al. 2014). Scenarios are not predictions or forecasts. Thus, scenario planning does not have to be data intensive to be useful (Borggaard et al. 2019). Instead, the use of scenarios help scientists and managers explore plausible alternative future conditions to identify risks and generate/prioritize a range of management options and research needs (Borggaard et al. 2019). Indeed, much of its value comes from the structured discussions and conversations that the scenarios help frame. By providing a mechanism to communicate about complex situations, scenario planning encourages "out-of-the-box" thinking to help groups assess the impacts of plausible future scenarios on a target or resource (Schwartz 1996; Peterson *et al.* 2003). Outcomes are typically used to improve management decisions, highlight data gaps, and/or identify future science priorities, and often complement other more data intensive modeling efforts (Star *et al.* 2015; Borggaard *et al.* 2019). The consideration of multiple futures makes scenario planning particularly useful for early and broad risk identification, which can facilitate greater flexibility/adaptability of management actions to changing conditions (Borggaard *et al.* 2019).

In 2017, NOAA Fisheries piloted a scenario planning exercise for Atlantic salmon *(Salmo salar*) to explore what the agency could do to improve the population's resilience to changing climate conditions in riverine, estuarine, and marine environments across its current range (U.S. headwaters to Greenland) (Borggaard *et al.* 2019). The active consideration of climate change throughout the process resulted in multiple outcomes (see Borggaard *et al.* 2019 for full details), including the identification and integration of several priority actions into the revised Atlantic Salmon Recovery Plan (USFWS and NMFS 2019). In addition, the pilot demonstrated that the forward-looking scenario planning process was well aligned with long-term recovery planning by providing scientists and managers a way to prepare for multiple potential futures by implementing immediate and near-term actions. The success of this pilot, and the urgency surrounding the recovery of the critically endangered North Atlantic right whale (*Eubalaena glacialis*) [hereafter referred to as right whale], led to a 2018 NOAA Fisheries scenario planning initiative for this species.

The effort described here used scenario planning to explore future conditions for right whales and develop possible options to address those conditions to improve recovery. Specific objectives were to: 1) better understand the challenges of right whale management in changing conditions; 2) identify potential research activities and recovery needs across the species' range; 3) increase coordination and collaboration related to recovery efforts; and 4) explore how scenario planning can be used to support decisions.

This initiative and the outcomes provided here are meant to complement and enhance the many important ongoing efforts to recover right whales.

North Atlantic Right Whale Overview

Right whales are listed as endangered under the Endangered Species Act (ESA) in the United States (35 FR 18319, December 2, 1970) and the Species at Risk Act (SARA) in Canada (SOR/2005-14, January 12, 2005). Moreover, in light of its status, the species was recently included as a NOAA Fisheries' Species in the Spotlight[1].

The right whale population is currently experiencing: 1) low rate of reproduction, 2) longer calving intervals, 3) declining abundance, 4) continued mortality from vessel and fishing gear interactions, 5) changes in prey availability, and 6) increased transboundary movement (NMFS 2017). Estimated at 270 animals in 1990, the population increased to roughly 483 in 2010 but has since undergone a consistent decline (Pace *et al.* 2017). Scientists currently estimate the right whale population is less than 400 (Pettis et al. *in review*). Beginning in early 2017, the population experienced an Unusual Mortality Event (UME)[2] that has continued into 2020 (NMFS 2019) causing added concern for the future of this species in both the United States and Canada.

These recent events highlight the important need to continue, and expand upon, actions that promote the species recovery. The *North Atlantic Right Whale Recovery Plan*[3] (NMFS 2005) identified three critical priorities to improve species survival (listed in order of importance): 1) to reduce or eliminate deaths and injuries from human activities, namely shipping and commercial fishing operations; 2) to obtain better data on population trends, distribution, and health, as well as on habitat needs and uses; and 3) to study and address other potential threats, such as habitat degradation, noise, contaminants, and climate and ecosystem changes. In the United States, federal regulations for vessel and fishing restrictions to protect right whales have aimed to reduce serious injuries and mortalities (NMFS 2019). Additionally, in response to the 2017 mortalities, Canada adopted regulations for its commercial fishing[4] and vessel[5] industries. Yet, the high mortality, decline in abundance, and continued risk from human activities remain a serious concern.

Despite the critical need to protect right whales, additional factors such as uncertainties in prey availability, changing environmental conditions, and other threats complicate management

---

[1] https://www.fisheries.noaa.gov/topic/endangered-species-conservation#species-in-the-spotlight

[2] Under the MMPA, an Unusual Mortality Event (UME) is defined as a stranding that is unexpected; involves a significant die-off of any marine mammal population; and demands immediate response.

[3] https://www.fisheries.noaa.gov/resource/document/recovery-plan-north-atlantic-right-whale-eubalaena-glacialis

[4] https://www.dfo-mpo.gc.ca/fisheries-peches/commercial-commerciale/atl-arc/narw-bnan/narw-timeline-eng.html

[5] https://tc.canada.ca/en/marine-transportation/navigation-marine-conditions/protecting-north-atlantic-right-whales-collisions-vessels-gulf-st-lawrence#toc_1

decisions and actions. In the United States, actions needed to support recovery are listed in the Right Whale Recovery Plan (NMFS 2005) (Figure 1). This plan also recognizes the critical role of partnerships between federal and state agencies, Canadian government, and others in recovery. For example, the multi-partner Atlantic Large Whale Take Reduction Team (ALWTRT), established under the Marine Mammal Protection Act (MMPA), helps NOAA Fisheries reduce serious injury/mortality of right whales (and other large whales) due to fishing entanglement. Moreover, regional U.S. Right Whale Recovery Implementation Teams are composed of partners who assist in recovery plan implementation in the northeast and southeast United States. To better equip the agency and its partners to improve right whale recovery under changing conditions, NOAA Fisheries conducted a scenario planning exercise.

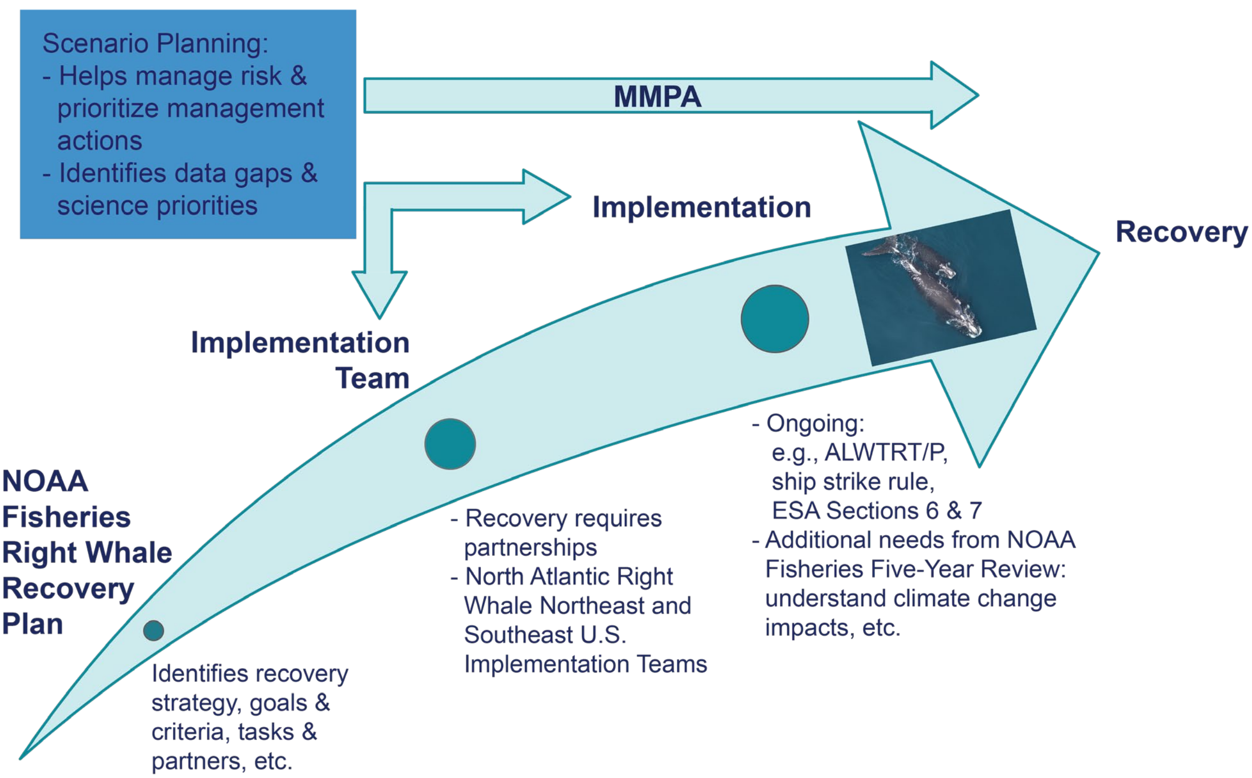


Figure 1. Key steps in North Atlantic right whale recovery under the ESA (e.g., Section 4(f)) and MMPA, and how scenario planning can fit into the process. Photo Credit: NOAA/NEFSC/ Christin Khan, image collected under MMPA Research permit number 17355.

Methods

We followed the first four phases of the scenario planning process described by the National Park Service (Figure 2, NPS 2013) and the Atlantic Salmon Climate Scenario Planning Pilot (Borggaard *et al.* 2019). We also included portions of the NPS's (2013) final fifth phase (Figure 2). To help with critical driver identification, we added participant interviews and a face-to-face small group meeting (see below).

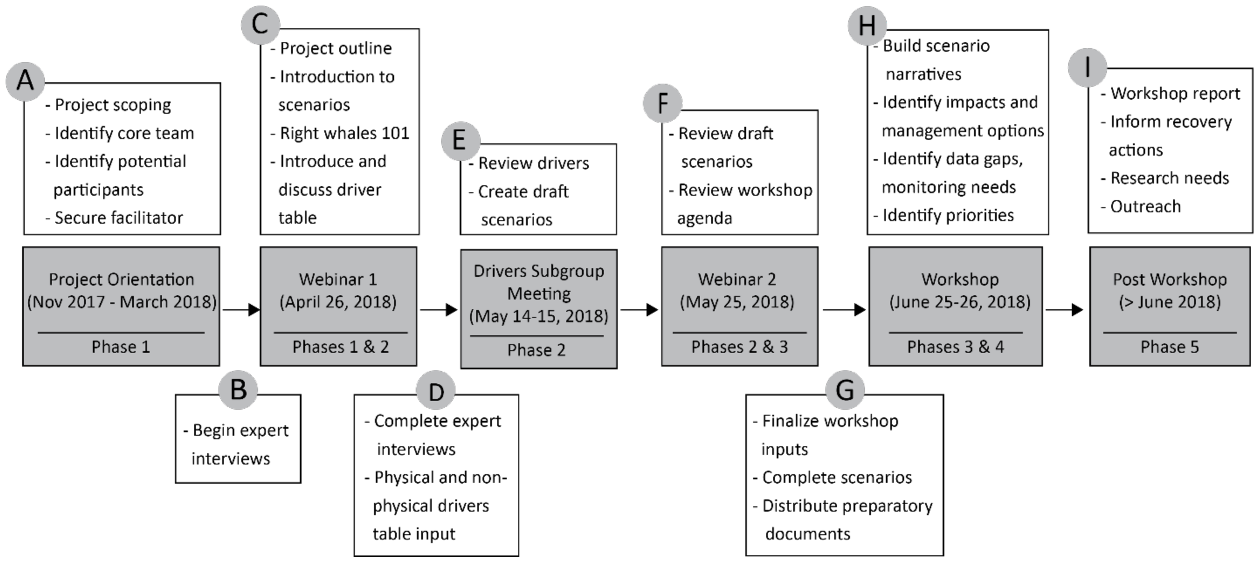


Figure 2. Outline of the process used for the North Atlantic Right Whale Scenario Planning Exercise and how it aligns with the five NPS Scenario Planning Phases, where Phase 1 = orientation, Phase 2 = exploration, Phase 3 = synthesize and create scenarios, Phase 4 = application and Phase 5 = monitoring (NPS 2013, see Appendix 1 for more details). Note: Box A includes items that supported project orientation; boxes C, E, F, H and I include items discussed with the full group (or smaller subgroup for box E) via phone/webinar/email or in person during one of the events noted in a shaded grey box; boxes B, D, and G include items that were completed outside of the events noted in a shaded grey box.

We conducted Phases 1 through 3 using two working webinars (26 April and 25 May 2018), select participant interviews (n = 7), and a face-to-face small group meeting in Gloucester, Massachusetts (14-15 May 2018). A 2-day, full group, in-person workshop in Gloucester, Massachusetts (27-28 June 2018) was used to review and finalize Phase 3 and conduct Phase 4 (Figure 2). Participants were encouraged to attend both webinars and the 2-day, full group workshop. For those unable to do so, materials and webinar recordings were made available for review to ensure participants remained informed and could provide input throughout the exercise. Additionally, participants unable to attend the full group workshop provided alternate attendees to assure representation of specific expertise. Portions of Phase 5 were conducted following the workshop (e.g., outreach on scenarios and draft workshop outcomes were provided to the Northeast and Southeast Implementation Teams).

Phase 1: Orientation

<u>*Purpose and Focal Question*</u>

Our purpose was to explore future conditions for right whales throughout their range and develop possible options to address those conditions to improve recovery. Our focal question was: What might affect/influence the recovery of right whales throughout their range over the next 60 years? We selected 60 years because it aligned with climate projections from the Intergovernmental Panel on Climate Change (IPCC 2013) and some of the recovery goals established by NMFS (2005) and Fisheries and Oceans Canada (2014).

Participant Selection

A facilitation and scenario planning expert and an array of federal experts gathered to implement the project (Appendix 2). Participants were selected based on their expertise in right whale-related science (e.g., large whale, fishing gear, climate, oceanography, zooplankton, ecosystem, ecology, health, harmful algal blooms) and management (e.g., aquaculture, wind energy, fisheries, entanglement, vessel strike, acoustics). Our goal was to bring together a multi-disciplinary group with broad expertise, but we limited expert participation ($n \leq 32$) to facilitate discussion.

Phase 2: Exploration

Critical Driver Identification and Early Scenario Development

We began the exercise without a specific climate focus to ensure equal consideration of all species-related aspects. To help identify variables thought to be critical to the future of right whales (i.e., "critical drivers"), we identified and interviewed seven participants for their science and management perspective. Interview questions included: 1) what factors could shape right whale recovery, and their habitat more generally, in the next 10, 30, and 60 years?; and 2) of these factors, which are certain/predictable, and which are uncertain/unpredictable? Using this information, we developed critical driver tables on climate (e.g., physical such as ocean temperature) (Appendix 3) and non-climate (biological, social, political, economic, and technological) variables (Appendix 4); additional information on trend direction, degree of certainty/uncertainty, and associated references/sources were also included. This list and associated information were further refined by all participants (via e-mail and webinar) and a small "driver subgroup" (in-person meeting) composed of scientific and management experts.

The driver subgroup discussed and identified those drivers they considered the most important and the most uncertain. Using one of the more common scenario planning methods to explore critical drivers and associated uncertainties (NPS 2013; Borggaard et al. 2019), the selected drivers were combined into several 2-driver 2x2 matrix configurations with each quadrant representing a future scenario. The driver subgroup then assessed the resulting future scenarios for relevance, plausibility, and divergence. Several driver combinations were shared with the full group during a webinar to illustrate how we narrowed down to a single, final scenario matrix. Using feedback from the full group we further refined the selected matrix prior to the workshop. Early scenario development enabled the workshop to focus on, and maximize the time available for, considering the impacts of the future scenarios to right whales.

Establishing a Common Understanding of Issues

To ensure there was a common understanding of the issues affecting right whales, we provided relevant reference materials and presentations to all participants. This included a list of literature on scenario planning and species-specific issues (Appendix 5). Presentations (Appendix 6) included information on the scenario planning process, right whales (e.g., distribution, foraging, calving), and various research and/or management activities related to right whales. Climate-related driver presentations (current conditions and future predictions) included global and high-resolution climate change projections for the northwest Atlantic, high-resolution projections for *Calanus finmarchicus* (key right whale prey item), southeast U.S. climate, harmful algal blooms, and zooplankton distribution and phenology. Presentations on non-climate drivers (what is happening now and future expectations) included mitigation of fishing and vessel interactions, aquaculture, acoustic effects and related policy, wind energy, and health/disease.

Phase 3: Synthesize and Create Scenarios

Future Scenario Matrix

Similar to Borggaard *et al.* (2019), we used a 2x2 matrix to develop four future scenarios (Figure 3). To help distinguish scenarios, it was important to use axes that yielded plausible, challenging, relevant, and divergent scenarios. We selected ocean conditions and human activity for axes. Here, ocean conditions important for right whales ranged from positive to negative, based on the uncertainty in the Atlantic Meridional Overturning Circulation (AMOC) and its influence on ocean nutrients, prey availability, and foraging conditions. Although the AMOC experiences natural decadal fluctuations that could lead to its strengthening in the short-term, its magnitude is likely to weaken over the 21st century (e.g. 60-year time frame). Conversely, based on the uncertainty in future anthropogenic actions and available conservation measures, the human activity axis ranged from effective options available to few known options. To inform and further distinguish each scenario, potential right whale population trends were attributed to each future based on expert opinion from our participants. Conditions common across all scenarios (e.g., increasing ocean temperature) were also noted. Participants confirmed the future scenarios captured plausible, challenging, relevant, and divergent descriptions of issues facing right whales over the next 60 years. Each scenario was given a descriptive name to help facilitate discussions.

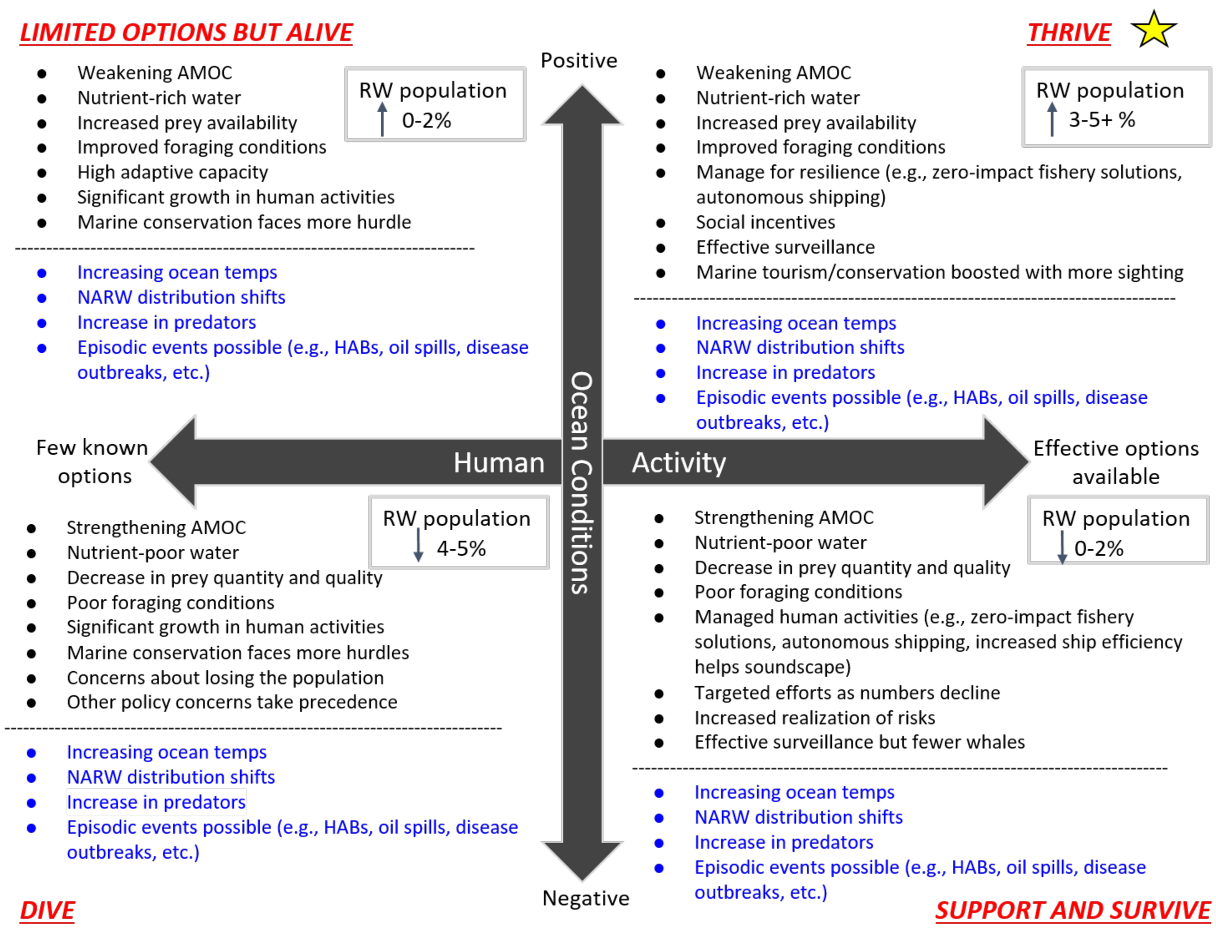


Figure 3. The final scenario matrix describing the four future scenarios. Items listed below the dashed line (blue text) denote elements common in all scenarios. Note: AMOC is Atlantic Meridional Overturning Circulation, HABs is harmful algal blooms, and NARW or RW is North Atlantic right whale. Potential right whale population trends were included to inform and further distinguish the scenarios. The yellow star in the Thrive scenario (upper right quadrant), denotes what participants considered the best future for right whales.

Scenario Narratives

Below are brief descriptive narratives for each scenario from Figure 3. Note common elements among all scenarios include increasing ocean temperature, increasing ocean predators, the possibility of episodic events, and a shift in right whale distribution.

1. *Limited Options but Alive*: In this future, there is a weakening AMOC leading to nutrient-rich water, increased prey availability, and improved foraging conditions for right whales. Right whales are easily able to adapt to the favorable (positive) ocean conditions and the population increases between 0 to 2 percent per year. However, because in this scenario there are few known options to minimize anthropogenic activity, right whales continue to be threatened as

human activities grow significantly and marine conservation efforts are more challenging to implement.

2. *Dive*: In this future, there is a strengthening AMOC leading to nutrient-poor water, decreased prey quantity and quality, and poor foraging conditions for right whales. There is also a significant increase in human activities as other policy concerns take precedence. As a result, marine conservation faces more hurdles and the right whale population declines between 4 to 5 percent per year.

3. *Thrive*: In this future, there is a weakening AMOC leading to nutrient-rich water, increased prey availability, and improved foraging conditions for right whales. Right whales easily adapt to the more favorable (positive) marine conditions. Managing for resilience such as zero-impact fishery solutions and autonomous shipping occurs and there are social incentives for improving marine conservation. Effective surveillance of the right whale population shows it is increasing by at least 3 to 5 percent per year. Marine tourism/conservation is boosted with more sightings.

4. *Support and Survive*: In this future, there is a strengthening AMOC leading to nutrient-poor water, decrease in prey quantity and quality, and poor foraging conditions for right whales. There is greater support for managing human activities to improve conditions for right whales including zero-impact fishery solutions, autonomous shipping, and increased ship efficiency to reduce ocean noise. Despite effective surveillance, there are fewer whales, and the population is decreasing between 0 to 2 percent per year, spurring additional targeted conservation efforts.

Phase 4: Application

Prior to the full-group workshop, we developed two worksheets to facilitate meeting discussions. The *Scenario Deepening* worksheet focused on future scenario conditions and how those conditions might affect right whales. The *Generating Options* worksheet asked for the identification of possible scenario-specific options (e.g., management, research).

At the workshop, participants were divided into one of four breakout groups and assigned a scenario. Each group contained a mix of management and scientific experts (e.g., marine mammal policy, large whale biology, climate modeling, ecosystem conditions) to facilitate multi-disciplinary discussions.

Scenario Deepening

Scenario Deepening focused group discussions on scenario-specific conditions and how those conditions might affect right whales over the next 60 years. Specific discussion points under each scenario included: 1) the main climate features; 2) the notable non-climate features that might occur (e.g., policy, demographics, technology); 3) a timeline of possible future events;

and 4) the identification of the main changes in conditions by region (where the right whale range was divided into 1 = southern, 2 = middle, and 3 = northern) and the potential impacts on right whales (Figure 4). Groups shared highlights across the scenarios prior to moving to the Generating Options worksheet.

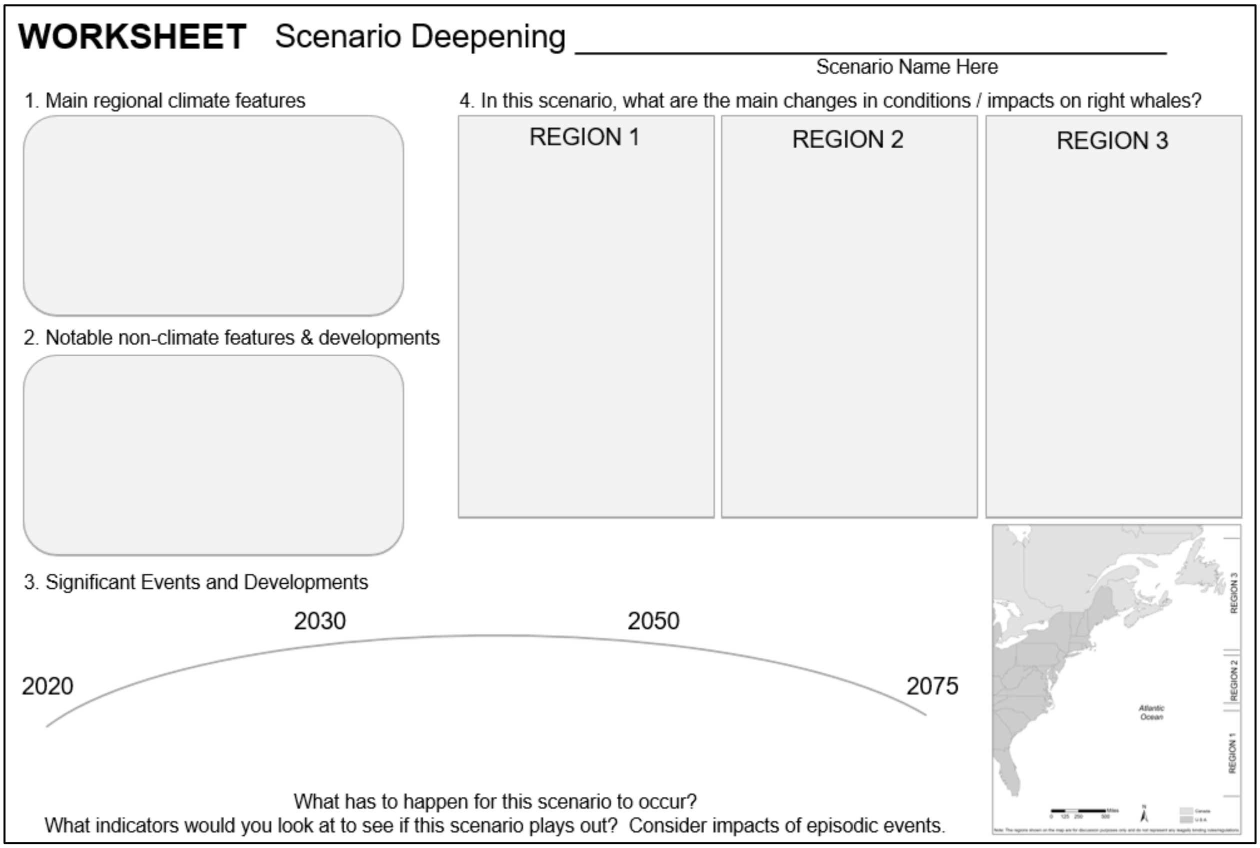
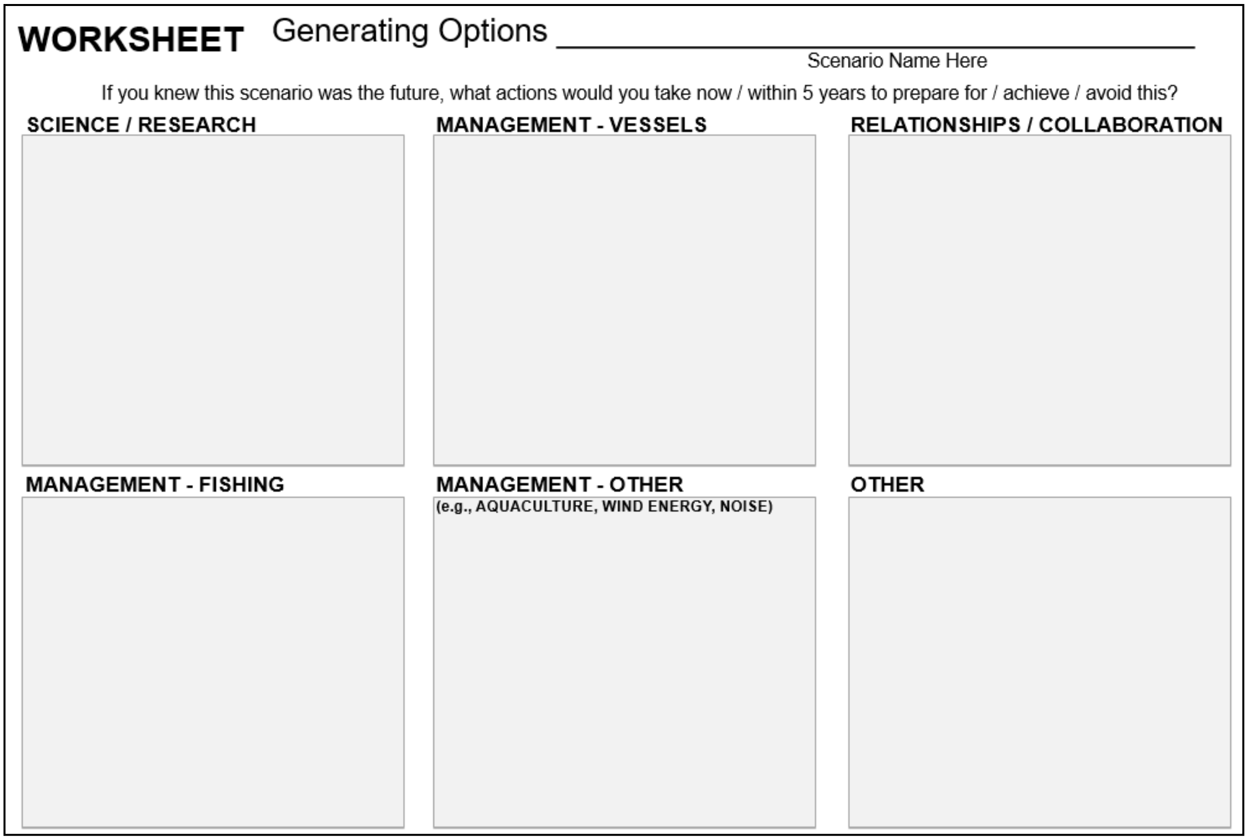


Figure 4. Scenario Deepening worksheet used in the North Atlantic Right Whale Scenario Planning exercise.

Generating Options for Management and Research Priorities

Based on in-depth, scenario-specific discussions, groups identified what actions could be taken now or within the next five years to prepare for their future scenario. Some discussion focused on what could be done to either help move toward or avoid a scenario, as well as factors/actions that could be taken under consideration to help us prepare for the next 30-50 years. Action/options were generated for science/research, management-vessels, management-fishing, management-other, relationships/collaborations, and other factors not already considered (Figure 5). Groups shared actions for specific categories to identify similarities across some or all scenarios.


WORKSHEET Generating Options ______________________
Scenario Name Here

If you knew this scenario was the future, what actions would you take now / within 5 years to prepare for / achieve / avoid this?

SCIENCE / RESEARCH

MANAGEMENT - VESSELS

RELATIONSHIPS / COLLABORATION

MANAGEMENT - FISHING

MANAGEMENT - OTHER
(e.g., AQUACULTURE, WIND ENERGY, NOISE)

OTHER

Figure 5. Generating Options worksheet used in the North Atlantic Right Whale Scenario Planning exercise.

Prioritization Breakout Groups

The actions identified in Generating Options served as the basis from which to identify priority, near-term actions. Participants were divided into four new groups and asked to select two actions to prioritize within the next 1-3 years in each category based on the Generating Options worksheets as well as two additional "wild card" priorities (i.e., two additional actions from any category). Participants selected near-term actions based on needed attention, investment, and urgency. These priority actions were further synthesized following the workshop to provide a combined list of priorities by category.

Results

Scenario Deepening

The Scenario Deepening worksheet enabled groups to delve further into each possible future, while considering scenario-specific conditions and how those conditions might impact right whales. Common across all scenarios was the recognition that right whales have, and will continue to experience, multiple climate and non-climate stressors. Despite being considered the best future for right whales, the *Thrive* scenario could still present significant challenges to the species survival. For example, an unexpected episodic event (e.g., oil spill or harmful algal bloom) could shift the species into the *Limited Options but Alive* scenario or move directly into the worst-case scenario, *Dive*. In addition, effective management and partnerships were considered critical and influential components. For example, ongoing and continued regulatory efforts would help to enhance the *Support and Survive* future, while the *Dive* scenario would be accelerated without proactively managing emerging threats. Additional information from the Scenario Deepening worksheets is included in Appendix 7.

<u>Generating Options for Management and Research Priorities</u>

Using the Generating Options worksheet, groups explored possible scenario-specific management and research actions that could improve species recovery. Some identified actions were unique to one scenario, while others were common in two or more scenarios. Actions common across all or most future scenarios included:

- Science/research: Continued investment in science (e.g., information on whale and prey distribution, threats, and impacts).

- Management: Dynamic and adaptive approaches to management, proactive considerations (e.g., vessels <65 feet, aquaculture, ropeless fishing, quieter ships), modify/assess ship speed rule[6].

- Relationships/collaborations: Partner engagement (e.g., industries).

- Other: Improve social science and public awareness.

Additional scenario-specific information from the Generating Options worksheets is included in Appendix 8.

<u>Prioritization Breakout Groups</u>

Based on the Generating Options worksheets and workshop discussions, near-term (1-3 years) priority actions in need of attention, investment, and urgency were identified. These actions were not scenario-specific and were synthesized following the workshop (see below).

Science and Research

- Conduct modeling studies (present conditions and projected into future) focused on:

[6] https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-ship-strikes-north-atlantic-right-whales

    - Spatial and temporal movement of right whales and copepods (e.g., current and future whale habitat use and distribution)
    - Climate
- Improve understanding of right whale distribution, reproduction, and behavior
- Better understand right whale response to vessels
- Understand right whales' sensing abilities and reaction to obstacles (e.g., wind turbines, fishing gear, vessels)
- Collect long-term monitoring data on plankton
- Maintain current right whale monitoring/detection/response programs
- Identify and understand cumulative stressors
- Improve understanding of acoustics related to:
    - Whale hearing thresholds
    - Impacts of sound sources and soundscapes on right whales
- Develop and test telemetry/tag technology that is appropriate for right whales
- Gear technology research and development

Fishing

- Reduce amount of line in the water column via:
    - Ropeless fishing – gear research, development, and testing
    - Trap/pot limits, etc.
- Initiate management rulemaking for ropeless fishing so prepared when gear is ready
- Proactive emerging fisheries management

Vessels

- For rules/measures:
    - Address risk to right whales from small boats (<65 feet)
    - Evaluate effectiveness of ship speed rule
    - Maintain/strengthen enforcement
- Incentives to vessels (large and small) to slow down/avoid right whales
- Analyze vessel traffic relative to whale distribution and planned activities to inform ship speed rule
- Whale safe ships of the future (e.g., advancement in ship design with whale safe features)

Relationships/Collaborations

- Protect and maintain current relationships with partners such as:
  - Industry, other federal agencies, Canada
- Engage with mariner community to:
  - Help solve problems
  - Develop incentives
  - Gain buy-in for solutions
- Increase public support/consumer awareness via:
  - Social science
  - Marketing campaigns – partner with NGOs and others who have had successful marketing
  - Social media and consumer driven efforts
- Incentivize innovation through non-traditional means (e.g., technological competitions (e.g., XPrize), engineering competitions, hi-tech companies, etc.)

Other

- Consider blue economy such as:
  - Aquaculture – be proactive and whale safe
  - Renewables (e.g., wind farms)
- For management/regulatory:
  - Maintain current regulatory framework
  - Dynamic/flexible management and enforcement
- Develop emergency response for episodic events (e.g., HABs, oil spill, etc.)

Additional information from the prioritization breakout groups is included in Appendix 9.

Discussion

Our scenario planning exercise offers a complementary, yet different, approach to priorities identified elsewhere (e.g., NMFS 2005; ALWTRT 2017; NMFS 2017) to enhance future right whale management and research efforts that support recovery. Continued efforts to reduce impacts from vessel strike and fishery entanglements were underway before we conducted this exercise, and their importance to right whale recovery was reinforced here. For example, NOAA Fisheries was preparing to evaluate the effectiveness of the ship speed rule as well as work with the ALWTRT to further reduce entanglement risk from vertical fishing lines (e.g., feasibility of ropeless fishing). Discussions during our workshop reaffirmed the importance and need to continue these efforts. In addition, this exercise helped highlight the importance of putting additional resources/efforts towards "novel" actions and/or identified new, emerging threats to right whales. For example, expanding right whale appropriate tagging efforts to help locate whales and their habitat in a changing ocean environment. Furthermore, new research/modeling exercises on climate and zooplankton will enable a better understanding of how the changing ocean has, and will continue to, affect right whales. Finally, the effort stressed the need to develop an emergency response plan for episodic events (e.g., harmful algal blooms, oil spills) by emphasizing the significance of such events as tipping points to the survival of the species.

Despite yielding outcomes to inform recovery planning, this exercise presented several challenges. First, we conducted this initiative on the heels of the 2017 right whale mortality event when there was heightened concern for the species' survival. The immediacy of issues related to this event (e.g., entanglement in fishing gear and vessel strikes) made it difficult to assess whether this prevented or enhanced participants from fully exploring "out-of-the-box" thinking/options typical of scenario planning. Second, the long-term survival and recovery of right whales is not a simple, straightforward problem, but instead, complicated by any number of climate and non-climate factors. To gain a common understanding of these complexities and to help navigate the challenges associated with developing priorities, we provided participants with relevant background information on right whale science and management. Finally, because we took the time for participants to share and understand the aforementioned complexities related to right whale conservation and management, we did not have time at the in-person workshop to refine the identified priorities into a more immediate (or higher priority) near-term list of actions.

Scenario planning can be used broadly for resource management applications, including how to better understand and address climate change-related uncertainties (see Rowland *et al.* 2013; Borggaard *et al.* 2019; Runyon *et al.* 2020). We began the right whale exercise without a specific climate focus to ensure equal consideration of all species-related aspects. We also used expertise, qualitative insight, and available quantitative information to identify drivers most important and uncertain to right whales. In the end, our group selected a climate-related driver for one of the matrix axes, highlighting the critical importance, and related uncertainties, a changing environment will have on the species (see Link *et al.* 2015; Hare *et al.* 2016).

Next Steps: Actions/Activities

This effort fostered increased partnerships and discussions for right whale recovery. Post-workshop, discussion and collaboration among participants and others continued, leading to several action items that are either completed or underway. In addition, there have been advances in areas (e.g., ropeless fishing) that this exercise reinforced the need to continue; however, they are not included here because they were underway before this scenario planning initiative. Finally, a number of initiatives (see 1, 2, and 3 below) also align with NOAA Fisheries climate priorities identified by Hare *et al*. (2016). Activities to date that were in direct response to this exercise include:

1. Funding from NOAA Fisheries (Office of Science and Technology) to support a Northeast U.S. continental shelf study to determine copepod *Calanus finmarchicus* biomass, trends, and variability.
2. A NOAA Fisheries (Office of Science and Technology) funded multi-year investigation of potential climate-induced right whale prey changes in southern New England.
3. Expanded discussions between NOAA Fisheries' Northeast Fisheries Science Center and Greater Atlantic Region on right whale climate and zooplankton science and management needs.
4. The initiation of a Greater Atlantic Region *North Atlantic Right Whale Emergency Response Plan* to increase preparedness to catastrophic natural or anthropogenic caused events that may impact a significant number (one or more) of right whales.
5. Continued and new collaborations with external and internal partners to develop and optimize right whale satellite tracking to support ongoing management needs.
6. Expanded collaboration with Fisheries and Oceans Canada and other partners to ensure their participation in the newly reconvened Right Whale Northeast Implementation Team (NEIT) and newly convened Right Whale Implementation Team Population Evaluation Tool Subgroup (PET Subgroup). The NEIT will coordinate recovery plan implementation in the northeast United States and work closely with the Southeast Implementation Team (SEIT) to ensure recovery activities are coordinated across the species' full range. The PET Subgroup will develop a population viability analysis to characterize the right whale extinction risk and include consideration of current and future threats.
7. Consideration and selection of actions from this scenario planning exercise as priorities for the NEIT to coordinate and help implement in the northeast United States. For example, the NEIT will consider and discuss renewable energy (e.g. wind) and aquaculture among other selected topics from this initiative.

8. Further exposure and capacity building of scenario planning within NOAA Fisheries across multiple regions.

Communication about the future scenarios we developed and workshop outcomes are part of the final scenario planning phase (NPS 2013). This was accomplished via presentations to relevant groups (e.g., regional implementations teams (NEIT and SEIT) and PET Subgroup) and the completion of this report. In addition, continued coordination with partners and monitoring of various important research efforts (e.g., climate-driven circulation changes, Record *et al.* 2019) play an important role in this final phase. The ALWTRT and regional implementation teams, for example, will be important in monitoring a number of priority actions similarly identified in this exercise. Additionally, research and management needs identified here can help to inform and implement needs for current and future regional climate actions plans (e.g., Hare *et al*. 2016). Priorities from this exercise can also inform the ongoing efforts of the bilateral work group between NOAA Fisheries and Canada that is focused on addressing the science and management gaps impeding the recovery of right whales in United States and Canadian waters.

This initiative provides another example of applying scenario planning to marine species/environments and may help others challenged with similar conservation issues. The forward-looking process of scenario planning provided a framework for how NOAA Fisheries and our partners can focus and align towards a common vision to prepare for multiple futures by acting now with near term actions that help advance right whale recovery. Our exercise offered a multi-disciplinary perspective to right whale recovery resulting in the identification of priorities for research, management, and partnerships to help improve the species' resilience. There are many important efforts underway by NOAA Fisheries and its partners to recover right whales, this report can be a useful resource by helping to: 1) encourage a strategic look at recovery; 2) further consider new and emerging threats to right whales; and 3) explore broader ideas based on possible future challenges. Scenario planning is an iterative process and as information becomes available (e.g., regional climatologies, vulnerability assessments, see Lettrich *et al*. 2019), it will be important to consider conducting an additional scenario planning exercise, using established bodies such as the ALWTRT, with an understanding of the challenges highlighted here. One important outcome of this exercise was the need to continue and expand partnerships across the species' range to help understand what the future might look like and how to best prepare given the inherent complexities and uncertainties. Partnerships are an essential part of recovery and will be critical to ensuring right whale survival under changing conditions.

Acknowledgements

Funding was provided by NOAA Fisheries Office of Science and Technology. We appreciate all participants including Michael Asaro, Lance Garrison, Sean Hayes, and Vince Saba who kindly offered to dedicate their time to participate in the driver subgroup; and Jonathan Star for guiding the group throughout this process. We thank, in alphabetical order, Colleen Coogan, Kim Damon-Randall, Laura Engleby, Kevin Madley, David Morin, Jacqueline Pearson-Meyer, Jessica Powell, Mike Runge, Becky Shortland, Peter Thomas, Donna Wieting, and David Wiley for their support in the process. Thanks also to Peter Corkeron for his introduction to right whales presentation during webinar 1 and Catherine Johnson for her contributions to the workshop presentation on Zooplankton Distribution in the Northwestern Atlantic. Thank you to Ainsley Smith who captured notes of the discussions throughout the workshop which helped us develop this report. This document was improved by comments from three external reviewers.

References

35 FR 18319. December 2, 1970. Conservation of Endangered Species and Other Fish and Wildlife: List of Endangered Foreign Fish and Wildlife.

SOR/2005-14. January 12, 2005. Species at Risk Act: Order Amending Schedules 1 to 3 to the Species at Risk Act.

ALWTRT. 2015. Gear Research Needs and the Atlantic Large Whale Take Reduction Plan. Working Draft Matrix. Available from NMFS Greater Atlantic Region, Gloucester, MA.

Borggaard, D. L., D. M. Dick, J. Star, M. A. Alexander, M. Bernier, M. Collins, K. Damon-Randall, R. Dudley, R. Griffis, S. Hayes, M. Johnson, D. Kircheis, J. Kocik, B. Letcher, N. Mantua, W. Morrison, K. Nislow, V. Saba, R. Saunders, T. Sheehan, and M. Staudinger. 2019. Atlantic Salmon (*Salmo salar*) Climate Scenario Planning Pilot Report. Greater Atlantic Region Policy Series [19-05]. NOAA Fisheries Greater Atlantic Regional Fisheries Office. 89 p. Available from: https://www.greateratlantic.fisheries.noaa.gov/policyseries/index.php/GARPS/article/view/15.

Fisheries and Oceans Canada. 2014. Recovery Strategy for the North Atlantic Right Whale (*Eubalaena glacialis*) in Atlantic Canadian Waters [Final]. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. vii + 68 p. https://www.sararegistry.gc.ca/virtual_sara/files/plans/rs_bnan_narw_am_0414_e.pdf.

Hare, J. A., D. L. Borggaard, K. D. Friedland, J. Anderson, P. Burns, K. Chu, P. M. Clay, M. J. Collins, P. Cooper, P. S. Fratantoni, M. R. Johnson, J. F. Manderson, L. Milke, T. J. Miller, C. D. Orphanides, and V. S. Saba. 2016. Northeast Regional Action Plan - NOAA Fisheries Climate Science Strategy. NOAA Technical Memorandum NMFS-NE-239, 94 p. http://doi.org/10.7289/V5/TM-NEFSC-239.

Lettrich, M. D., M. J. Asaro, D. L. Borggaard, D. M. Dick, R. B. Griffis, J. A. Litz, C. D. Orphanides, D. L. Palka, D. E. Pendleton, and M. S. Soldevilla. 2019. A Method for Assessing the Vulnerability of Marine Mammals to a Changing Climate. NOAA Technical Memorandum NMFSF/SPO-196, 73 p. https://spo.nmfs.noaa.gov/sites/default/files/TMSPO196_508.pdf.

Link, J. S., R. Griffis, and S. Busch (Eds). 2015. NOAA Fisheries Climate Science Strategy. U.S. Dept. of Commerce, NOAA Technical Memorandum NMFS-F/SPO-155, 70p. https://spo.nmfs.noaa.gov/sites/default/files/TM155.pdf.

Moore, S. S., N. E. Seavy, and M. Gerhart. 2013. Scenario planning for climate change adaptation: a guidance for resource managers. Point Blue Conservation Science and California Coastal Conservancy.

NMFS (National Marine Fisheries Service). 2005. Recovery Plan for North Atlantic Right Whale (*Eubalaena glacialis*). National Marine Fisheries Service, Silver Spring, MD. Available from: https://www.fisheries.noaa.gov/resource/document/recovery-plan-north-atlantic-right-whale-eubalaena-glacialis.

NMFS (National Marine Fisheries Service). 2017. North Atlantic right whale (*Eubalaena glacialis*) 5-year review: Summary and evaluation. NMFS Greater Atlantic Regional Fisheries Office, Gloucester, MA. 34 pp. https://www.greateratlantic.fisheries.noaa.gov/protected/final_narw_5-year_review_2017.pdf.

NMFS (National Marine Fisheries Service). 2019. Recovering Threatened and Endangered Species, FY 2017-2018 Report to Congress. 105 p. Available from: https://www.fisheries.noaa.gov/feature-story/recovering-threatened-and-endangered-species-report-congress-2017-2018.

NPS (National Park Service). 2013. Using Scenarios to Explore Climate Change: A Handbook for Practitioners. National Park Service, Natural Resource Stewardship & Science, Climate Change Response Program. Ft. Collins, CO.

Pace, R. M., III, P. J. Corkeron, and S. D. Kraus. 2017. State-space mark-recapture estimates reveal a recent decline in abundance of North Atlantic right whales. Ecology and Evolution. 7:8730–8741. https://doi.org/10.1002/ece3.3406.

Peterson, G. D., G. S. Cumming, and S. R. Carpenter. 2003. Scenario planning: a tool for conservation in an uncertain world. Conservation Biology. 17(2): 358-366.

Pettis, H. M., R. M. Pace, and P. K Hamilton. *in review*. North Atlantic Right Whale Consortium 2020 Annual Report Card. Report to the North Atlantic Right Whale Consortium. Will be available online at: www.narwc.org.

Record, N., J. Runge, D. Pendleton, W. Balch, K. Davies, A. Pershing, C. Johnson, K. Stamieszkin, R. Ji., Z. Feng, S. Kraus, R. Kenney, C. Hudak, C. Mayo, C. Chen, J. Salisbury, and C. Thompson. 2019. Rapid Climate-Driven Circulation Changes Threaten Conservation of Endangered North Atlantic Right Whales. Oceanography. 32(2):162–169. https://doi.org/10.5670/oceanog.2019.201.

Rowland, E. R., M. S. Cross, and H. Hartmann. 2014. Considering Multiple Futures: Scenario Planning to Address Uncertainty in Natural Resource Conservation. Washington, DC: US Fish and Wildlife Service. https://www.fws.gov/home/feature/2014/pdf/Final%20Scenario%20Planning%20Document.pdf.

Runyon, A. N., A. R. Carlson, J. Gross, D. J. Lawrence, and G.W. Schuurman. 2020. Repeatable approaches to work with scientific uncertainty and advance climate change adaptation in US national parks. Parks Stewardship Forum. 36(1): 98–104. https://escholarship.org/uc/psf.

Schwartz, P. 1996. The art of the long view: planning for the future in an uncertain world. Currency Doubleday, New York. 272 p.

Star, J., N. Fisichelli, A. M. Bryan, A. Babson, R. Cole-Will, and A. Miller-Rushing. 2015. Acadia National Park Climate Change Scenario Planning Workshop Summary October 5-6, 2015; Schoodic Institute, Acadia National Park, Maine. 50 p. https://www.nps.gov/subjects/climatechange/upload/Scenario-Workshop-ACAD-508compliant.pdf.

USFWS (U. S. Fish and Wildlife Service) and NMFS (National Marine Fisheries Service). 2019. Recovery plan for the Gulf of Maine Distinct Population Segment of Atlantic salmon (*Salmo salar*). 74 pp. https://www.fisheries.noaa.gov/resource/document/recovery-plan-2019-gulf-maine-distinct-population-segment-atlantic-salmon-salmo.

List of Acronyms

ALWTRT: Atlantic Large Whale Take Reduction Team

AMOC: Atlantic Meridional Overturning Circulation

DOI: Department of the Interior

ESA: Endangered Species Act

GOM: Gulf of Maine

HABs: Harmful Algal Blooms

IPCC: Intergovernmental Panel on Climate Change

MMPA: Marine Mammal Protection Act

NAO: North Atlantic Oscillation

NEIT: Northeast Implementation Team

NMFS: National Marine Fisheries Service

NGO: Non-Governmental Organization

NOAA: National Oceanic and Atmospheric Administration

NOS: National Ocean Service

NPS: National Park Service

RCP: Representative Concentration Pathway

SARA: Species at Risk Act (Canada)

SEIT: Southeast Implementation Team

UME: Unusual Mortality Event

USGS: United States Geological Survey

Webinar and Workshop Agendas

North Atlantic Right Whale Scenario Planning Exercise
April 26, 2018
2:00-4:00 pm EDT
Webinar 1

Goals:

- Background on initiative
- Introduction to scenario planning
- Future drivers of change affecting right whales
- Next steps
- Right whales 101 (basic information)

Time	Topic
2.00pm	**Introductions, round robin**
2.10pm	**Project background & context** • Relationship to other RW initiatives • Ground rules
2.25pm	**Scenario Planning 101** • Principles, benefits • Example applications • Atlantic Salmon pilot • Questions / Discussion
2.40pm	**Project Outline** • Specific tasks / requirements for each phase • Questions / Discussion
3.00pm	**Drivers Discussion** • Outline of drivers table • Insights from interviews • Suggestions for additional drivers
3.20pm	**Questions and Next Steps**
3.30pm	**Right whales 101 (introduction to right whales)** • Basic information • Q&A • Discussion
4.00pm	ADJOURN

North Atlantic Right Whale Scenario Planning Exercise
Friday May 25, 2018 1:00-3:00 pm EDT
Webinar 2

Time	**Topic**
1.00pm	Welcome, Round Robin
1.05pm	Project Updates
1.15pm	Drivers Sub-Group workshop Report
1.30pm	Explanation of Draft Candidate Scenario Matrix
1.45pm	Questions and Discussion
2.15pm	Plans for Face-to-Face Workshop
2.30pm	Questions and Discussion
2.45pm	Additional Issues
3.00pm	ADJORN

North Atlantic Right Whale Scenario Planning Exercise
Driver Subgroup Workshop
Greater Atlantic Regional Fisheries Office
Gloucester, MA, May 14-15, 2018

Goals:

- Review and further develop a list of drivers (contained in a drivers table) that could shape the environment for Right Whales over the next 60 years (e.g. economic, climate, commercial, regulatory etc.)
- Discuss and identify which drivers are most important/most uncertain
- Create a number of potential scenario matrices/frameworks by combining different drivers together
- Determine which frameworks are most effective in creating plausible, relevant scenarios
- Review and refine a small number of preferred frameworks as candidates for presentation to the broader RW scenario planning group

DAY 1 – MAY 14

Time	Topic
9:00	Welcome, Introductions
9:15	Review and Exploration of Climate/Physical Drivers
10:45	**BREAK**
11:00	Review and Exploration of Social / Economic / Political / Technological Drivers
12:30	**LUNCH**
1;15	Drivers: Summary and Additional Thoughts
2:15	Assessment and Prioritization
2:45	**BREAK**
3:00	Combining Drivers to Create Candidate Frameworks
4:45	Reflections
5:00	**ADJOURN**

DAY 2 - MAY 15

Time	Topic
8:00	Reflections
8:15	Review of Candidate Frameworks
9;00	Selection of Preferred Frameworks(s), Outline of Scenario Descriptions
10:30	Next Steps
11:00	**ADJOURN**

North Atlantic Right Whale Scenario Planning Workshop
June 25th & 26th 2018
Greater Atlantic Region, 55 Great Republic Drive, Gloucester, MA

Day 1 – Monday June 25th – Drivers of Change and Scenario Deepening/Development

Time	Topic
8:30am	**ARRIVAL**
9:00am	**Welcome, introductions, objectives, agenda etc.** • Welcome participants, provide very brief background and context, including 'focal question' and outputs. (NMFS, includes Donna Wieting's opening remarks) • Introductions, objectives, agenda, etc. (Jonathan Star)
9:30am	**Right Whales** • Right whale 101 (distribution, foraging, calving, etc.) (Sean Hayes)
9:45am	**Drivers of Change** • Presenters outline research and/or management on the drivers and sources of future uncertainty affecting North Atlantic Right Whales. (10 minute "Lightning Speed" presentations to set the stage except for select talks) o Climatic/physical drivers (current conditions and predictions for the future) • Climate Change Projections for the NW Atlantic ▪ Mike Alexander, 15 min ▪ Vince Saba, 15 min; includes *Calanus* climate study • Southeast climate (John Quinlan) • Harmful algal blooms and productivity (Quay Dortch; 15 min) • Zooplankton distribution and phenology (Harvey Walsh) o Questions for any of the presenters (15 min)
11:00am	**BREAK**
11:15am	**Drivers of Change (Continued)** o Non-climate/physical drivers (what's happening now and future expectations) • Fishing Interaction Mitigation (Mike Asaro) • Shipping Interaction Mitigation (Mike Asaro) • Aquaculture (Kevin Madley) • Acoustic impacts and policy (Jacqueline Pearson-Meyer) • Wind energy (Julie Crocker) • Health/Disease (Teri Rowles, pending) o Questions for any of the presenters (15 min)
12:30pm	**Scenario Planning and Presenting Scenarios** • Background scenario planning principles, present the draft scenario framework for consideration and use for the workshop conversations. (Jonathan Star)
12:45pm	**LUNCH**

Time	Topic
1:45pm	**Scenario Matrix - Large Group** ● Full group discusses/validates the matrix. Does the scenario allow them to tell a plausible, challenging, relevant story about the issues facing right whales over the next 60 years? Are there points that are missing or that could be expanded (e.g., can we be more specific about NARW distribution shifts)? Do they work as a set? Are they different from each other? Is there an important development or story that is missing from the set?
2:15pm	**Scenario Deepening and Development - Scenario Subgroups** ● Exercise set up. Groups are given a briefing document on the scenarios, and asked to focus on describing one scenario. ● Small groups (~6 participants per group) tell right whale-specific stories and outline the implications and impacts of their scenario ● Groups include story elements based on climate (e.g., AMOC, prey) and non-climate/physical (e.g., shipping, fishing, aquaculture, wind energy) drivers. ● Include a timeline of plausible, indicative events that add color to the stories. ● Impacts and implications categorized into different aspects considering all life stages (where possible) Conversations recorded on pre-printed large worksheets
3:30pm	**BREAK**
3:45pm	**Sharing across scenarios - Large Group** Display each of the scenario worksheets so that participants can review other groups' work. Then report-out for groups to share their stories with others
4:30pm	**Wrap-up, reflections, and early thoughts on options** ● Plenary conversation that discusses the overall scenarios and how they fit together. Have we told provocative stories? Are they plausible? Will they help us generate ideas and investigate the decision issues tomorrow? Any early thoughts on options (to be further discussed in Day 2)?
5:00pm	**ADJOURN**

Day 2 – Tuesday June 26th - Generating and Assessing Options

Time	Topic
7:30am	**ARRIVAL**
8:00am	**Overnight Thoughts** • Plenary discussion to reflect on Day 1, and suggest any 'must-dos' for Day 2
8:30am	**Generating Options - Scenario Subgroups** • Groups identify options (e.g., actions and research) that would make sense to pursue in each of the scenarios. Include consideration of how we may have gotten to this scenario (e.g., how to move in or avoid the direction depending on the scenario, how to prepare). • Conversations recorded on pre-printed large worksheets
10:30am	**BREAK**
10:45am	**Report Out and Common Options - Large Group** • Each group reports out their findings per scenario. Then we look across all scenarios to assess any common options. • We also discuss if there are ways to push towards a preferred scenario (and away from a worst case) • Discuss which and how to monitor indicators to see a particular plays out • This conversation will provide us with a sense of priority actions.
12:00pm	**LUNCH**
1:00pm	**Specific Conversations - Regional Subgroups (split into region 1 and 2 groups of regions 2 & 3)** • Opportunity for specific regions to be the focus of targeted conversations about issues of most importance in the near-term. What would need to be done differently in this region based on changing right whale behavior and/or human activity? How would this influence recovery needs/efforts (e.g., science/research, management, relationships/collaboration). These conversations are now based not only on the scenarios, but on the other near-term factors that affect strategy (goals, capabilities, resources etc.). Includes discussion of what is most important to do.

1:45pm	**Specific Conversations - Large Group**
	• Report out (5 minutes per group)
	    ◦ Read-out exercise and plenary discussion
	    ◦ Does the exercise reveal a clear way forward for a specific management option and/or research need?
	Larger group discussion. Prioritize actions.

3:00pm	**BREAK**
3:15pm	**Wrap-up, Review Conversations & Next Steps** • Wrap-up and review • Discuss next steps on priority actions (management and research needs) and monitoring, product development, additional meeting. Discuss possible future directions to extend outcomes, new projects and meetings, new avenues for collaborations, etc.
4:00pm	**ADJOURN**

APPENDIX 1. Five phases of the scenario planning process as outlined in the National Park Service Handbook (NPS 2013).

Phase	Goal	Steps	Outcomes/Products
Phase 1: Orientation	Set up project for success	• Establish purpose of project • Determine desired outcomes • Specify Issue or "Strategic Challenge" to explore using scenarios • Recruit core team	• An understanding of the purpose, desired outcomes, and scope of project • Core team to help with exercise • Statement describing issue or "strategic challenge" • Clearly articulated focal question • Draft/final project schedule • Draft/final participant list
Phase 2: Exploration	Identify and analyze critical forces, variables, trends, and uncertainties that may affect strategic challenge and focal question	• Identify critical forces (drivers) that affect strategic challenge • Identify potential impacts • Engage participants before workshop (webinars, conf. calls) to help familiarize with scenario planning process	• Tables and charts that capture drivers, variables, uncertainties, and impacts that may affect focal question • Graphics, maps to help with discussion • Any materials and background information that participants should review before workshop
Phase 3: Synthesize & Create Scenarios	Produce small number of scenarios using critical forces and impacts identified in Phase 2	• Divide critical forces into important elements* and critical uncertainties** • Build scenario frameworks and choose scenarios • Identify scenario impacts • Describe scenarios in detail and develop scenario narratives • Review scenarios for plausibility and consistency	• 3-5 plausible, relevant, challenging and divergent scenarios using critical uncertainties to inform, inspire and test actions/strategies
Phase 4: Application	To answer "So what?" questions: What do these scenarios mean to NMFS? What do they mean to focal question and strategic challenge? What do we do about it?	• Identify scenario implications • Develop, test and prioritize actions • Use scenarios to inform strategies	• List of actions, strategies, or areas for additional research based on discussions initiated by scenarios
Phase 5: Monitoring	To identify important indicators (trigger points) that can signal changes in the environment as future unfolds	• Select indicators to monitor • Scan and monitor environment changes • Communicate scenarios and workshop outcomes • Workshop deliverables	• List of indicators and early warning signals for continued research and monitoring • A monitoring strategy • Workshop deliverables e.g., scenarios, implications, actions, indicators to monitor, monitoring strategies

* Important or predetermined elements are forces important to focal question for which available information includes a high degree of confidence and direction and magnitude of future changes.
** Critical uncertainties are variables very important to focal question for which available information is limited or unknown and characterized by significant uncertainties.

APPENDIX 2. Participants who supported the scenario planning exercise in various capacities; those who were part of the subdriver group (SGD) or at the workshop (W) are noted in the participation column.

Name	Affiliation	Participation
Mike Alexander	NOAA, Office of Oceanic and Atmospheric Research, Physical Sciences Laboratory	SDG, W
Mike Asaro	NOAA, National Marine Fisheries Service, Greater Atlantic Region, Protected Resources Division (current affiliation: NOAA, Northeast Fisheries Science Center, Social Science Branch)	SDG, W
Lynne Barre	NOAA, National Marine Fisheries Service, West Coast Region, Protected Resources Division	W
Shannon Bettridge	NOAA, National Marine Fisheries Service, Office of Protected Resources	W
Diane Borggaard	NOAA, National Marine Fisheries Service, Greater Atlantic Region, Protected Resources Division	SDG, W
Peter Burns	NOAA, National Marine Fisheries Service, Greater Atlantic Region, Sustainable Fisheries Division	W
Colleen Coogan	NOAA, National Marine Fisheries Service, Greater Atlantic Region, Protected Resources Division	W
Julie Crocker	NOAA, National Marine Fisheries Service, Greater Atlantic Region, Protected Resources Division	W
Kim Damon-Randall	NOAA, National Marine Fisheries Service, Greater Atlantic Region	
Dori Dick	Ocean Associates Inc. in support of NOAA, National Marine Fisheries Service, Office of Protected Resources	SDG, W
Quay Dortch	NOAA, National Ocean Service, National Centers for Coastal Ocean Science	W
Laura Engleby	NOAA, National Marine Fisheries Service, Southeast Regional Office, Protected Resources Division	
Lance Garrison	NOAA, Southeast Fisheries Science Center	SDG, W
Francis Gulland	Marine Mammal Commission	W
Ben Haskell	NOS, Stellwagen Bank National Marine Sanctuary	W
Sean Hayes	NOAA, Northeast Fisheries Science Center, Protected Species Branch	SDG, W
Allison Henry	NOAA, Northeast Fisheries Science Center, Protected Species Branch	W
Kevin Madley	NOAA, National Marine Fisheries Service, Greater Atlantic Region	W

Name	Affiliation	Participation
Kimberly Hyde	NOAA, Northeast Fisheries Science Center, Narragansett Laboratory	W
Henry Milliken	NOAA, Northeast Fisheries Science Center, Protected Species Branch	W
David Morin	NOAA, National Marine Fisheries Service, Greater Atlantic Region, Protected Resources Division	W
Jacqueline Pearson-Meyer	NOAA, National Marine Fisheries Service, Office of Protected Resources	W
Jessica Powell	NOAA, National Marine Fisheries Service, Southeast Regional Office, Protected Resources Division	W
John Quinlan	NOAA, Southeast Fisheries Science Center, Sustainable Fisheries Division	W
Teri Rowles	NOAA, National Marine Fisheries Service, Office of Protected Resources	W
Michael C. Runge	USGS, Patuxent Wildlife Research Center	
Vince Saba	NOAA, Northeast Fisheries Science Center	SDG
Becky Shortland	NOS, Gray's Reef National Marine Sanctuary	
Ainsley Smith	Integrated Statistics, Inc. In support of NOAA Fisheries Greater Atlantic Region	W
Jonathan Star	Scenario Insight	SDG, W
Michelle Staudinger	Department of the Interior, Northeast Climate Science Center; USGS	W
Harvey Walsh	NOAA, Northeast Fisheries Science Center, Ecosystem Monitoring Program	W
Donna Wieting	NOAA, National Marine Fisheries Service, Office of Protected Resources	W
Dave Wiley	NOS, Stellwagen Bank National Marine Sanctuary	
Barb Zoodsma	NOAA, National Marine Fisheries Service, Southeast Regional Office, Protected Resources Division	SDG, W

APPENDIX 3. Climate (physical) drivers table and includes several biogeochemical variables. Note: This table lists only those drivers initially considered for this scenario planning exercise. Note: Participants were encouraged to think as broadly and unrestrained as possible, therefore, what is recorded here includes thoughts that were considered for the scenario planning exercise and do not represent agency policy.

Driver	Trend Direction	Degree of Certainty/Uncertainty	Comments/Link to Support Statements	NOAA's Climate Change Webportal Inputs (if used)
Ocean temperature	Increase +2-4°C (lower estimate); 6 in the upper water column, 6+ in the bottom temp	High confidence (only for the coarse IPCC models)	https://www.esrl.noaa.gov/psd/ipcc/ocn/ *Note that these SST projections are based on coarse global climate models that show uniform warming across much of the NW Atlantic. The projected warming by these models may be too low such that the high-res. Saba *et al.*'s (2016) CM2.6, which resolves Shelf dynamics much better than these coarse models, projects warming of up to 6-9C in some regions of the Gulf of Maine.	RCP 8.5, Average of all models, Ensemble spread of future change, Entire year, 2055-2099, Extent: 23-55°N, & 86-50W°E
Wind fields			Assumed calm winds in calving habitat is needed	
Primary productivity	Decreases nearshore, with biggest decrease closest to shoreline, Increases as move offshore	Low confidence (based on the coarse IPCC models); not reliable for smaller regional scale	https://www.esrl.noaa.gov/psd/ipcc/ocn/	RCP 8.5, Average of all models, Ensemble spread of future change, Entire year, 2055-2099, Extent: 23-55°N, & 86-50W°E
Sea surface chlorophyll	Decreases nearshore, with biggest decrease closest to shoreline	Low confidence	https://www.esrl.noaa.gov/psd/ipcc/ocn/	RCP 8.5, Average of all models, Ensemble spread of future change, Entire year, 2055-2099, Extent: 23-55°N, & 86-50W°E

Driver	Trend Direction	Degree of Certainty/Uncertainty	Comments/Link to Support Statements	NOAA's Climate Change Webportal Inputs (if used)
Availability of prey	By 2081–2100, we project average *C. finmarchicus* density will decrease by as much as 50% under a high greenhouse gas emissions scenario. These decreases are particularly pronounced in the spring and summer in the Gulf of Maine and Georges Bank. When compared to a high-resolution global climate model, the ensemble showed a more uniform change throughout the Northeast U.S. Shelf, while the high-resolution model showed larger decreases in the Northeast Channel, Shelf Break, and Central Gulf of Maine. Grieve *et al*. 2017 based on temp only	Medium confidence (evidence that water is higher in nitrate that could lead to spike in productivity)	Grieve *et al*. 2017 (Note: Information on observations in Canada such as Gulf of St. Lawrence can be found at: http://waves-vagues.dfo-mpo.gc.ca/Library/362284.pdf; e.g., "The abundance of the biomass-dominant copepod species *C. finmarchicus* and zooplankton biomass overall were lower than average overall in 2015, as was the abundance of Arctic *Calanus* species, continuing a pattern started during the last 4-7 years. In contrast, the abundances of offshore copepods were higher than average. ")	
North Atlantic Oscillation	Unclear - since 2000 relationship between NAO and zooplankton has changed; CC projections are mixed, very unclear since of what relationships are today; have better understanding of other indices (e.g. Pacific, AMOC) than NAO	High uncertainty	The relationship between the NAO and U.S. NES conditions is variable and unclear. For example, in the Gulf of Maine, the link between the NAO and zooplankton indices have changed since 2001. Refer to Hare and Kane, 2012 for more details: Zooplankton of the Gulf of Maine - A Changing Perspective AFS 2012	
Atlantic Meridional Overturning Circulation (AMOC)	Weakening	1. High uncertainty for the historical AMOC weakening 2. Low to Medium uncertainty for climate change projections of AMOC	1. Caesar *et al*. 2018 2. IPCC AR5 report (IPCC 2013)	
Sea level rise	Increase in mean sea level across U.S. East Coast	High Confidence (high uncertainty, based on thermal projections of water but NOT freshwater influence from icesheet melting) Might have even higher SLR than expected with weakening AMOC		

Driver	Trend Direction	Degree of Certainty/Uncertainty	Comments/Link to Support Statements	NOAA's Climate Change Webportal Inputs (if used)
Harmful Algal Blooms	Since systematic sampling of PSP toxins in ME shellfish began in 1977, toxicity has oscillated on decadal scale, currently in low phase. Could oscillate upward at any time or recent fundamental changes in GOM hydrography could keep it low. Pseudo-nitzschia emerged as a threat to shellfish in last 3 years with unpredictable but increasing toxicity and geographic distribution. Most data are near shore, so changes offshore are unknown.	High uncertainty	Alexandrium (PSP), Pseudo-nitzschia (ASP), emerging. Both PSP and ASP toxins have caused marine mammal mortalities. Dinophysis (DSP) has also emerged in region, but shellfish closures have only occurred in Canadian waters. State of Maine is monitoring for all 3 at coastal sites. Anderson *et al*. 2014, Doucette *et al*. 2006, Clark *et al*. 2019 Kanwit, K. 2019. Restructuring traditional biotoxin monitoring programs for proactive management of new and emerging threats. https://www.mass.gov/files/documents/2019/04/22/K.Kanwit_Day2_EmergingToxin.pdf	
Ocean acidification (copepod implications)	Decrease in ocean pH (more acidic)	High confidence		
Gulf of Maine water mass and nutrient sources	Higher proportion of Gulf Stream Slope Water (Atlantic Temperate Slope Water) entering the Gulf of Maine via the Northeast Channel. This water is warmer and saltier than Labrador Slope Water (Labrador Sub-Arctic Slope Water) and is higher in nutrients (nitrate).	Medium confidence	Saba *et al*. 2016 Caesar *et al*. 2018	

APPENDIX 4. Non-climate (biological, social, political, economic and technological) drivers table. Note: This table lists those drivers initially considered for this scenario planning exercise. Note: Participants were encouraged to think as broadly and unrestrained as possible, therefore, what is recorded here includes thoughts that were considered for the scenario planning exercise and do not represent agency policy.

Biological, social, political, economic, technological	Projected change (if applicable)	Degree of certainty/uncertainty	Source and context
Offshore wind farms	Increase	High confidence	https://e360.yale.edu/features/after-an-uncertain-start-u-s-offshore-wind-is-powering-up https://www.boem.gov/National-Offshore-Wind-Strategy/ https://www.boem.gov/Renewable-Energy-Path-Forward/ Impacts to consider are direct effects of construction (noise, vessels, displacement etc.), effects during operations and how wind farms will result in changes in distribution of fishing effort and changes in distribution of vessel traffic patterns which may increase and/or shift risk to right whales
Harbor Channel Deepening to accommodate large ships	Channels may be lengthened (may span width of SMAs). Dredging may be required more frequently and for longer durations. Implications to right whales from collisions from project vessels.	High confidence in Southeast U.S. In Northeast many of the major ports (New York/New Jersey, Boston, and Philadelphia) have already been deepened to 50' to accommodate larger post Panamax ships. Some of the Chesapeake Bay ports/entrance channels have been deepened and some have been authorized but projects not completed	http://www.sas.usace.army.mil/Missions/Civil-Works/Savannah-Harbor-Expansion/ http://www.sac.usace.army.mil/Missions/Civil-Works/Charleston-Harbor-Post-45/ http://www.saj.usace.army.mil/Missions/Civil-Works/Navigation/Navigation-Projects/Jacksonville-Harbor-Channel-Deepening-Study/ Important to tie this to the shipping industry development driver; will need to consider the direct effects of dredging as well as the consequences experienced in changes in vessel traffic
Development of surveillance technology	Increasing (35 yrs from now)	High confidence	Every individual whale tagged or public access to satellite imagery where get positions in near-real time
Role of policy/regulations	Dependent on factors including society	High uncertainty	MMPA and ESA could be a social luxury as demand for protein increases
Shipping industry developments (e.g. faster ships, bigger ships, autonomous ships, quieter ships)	Increase but uncertainty about where we are on the trend line (i.e., beginning of increase?)	High confidence	Important to tie this driver to the "harbor/channel deepening" driver above given the relationship. Some of the force behind the change in ship size is related to the expansion of the Panama Canal; ports want to be able to accommodate those ships which is part of the rationale for deepening channels, widening turning basins, etc. https://www.porttechnology.org/news/us_ports_preparing_for_post_panamax_ships

Biological, social, political, economic, technological	Projected change (if applicable)	Degree of certainty/uncertainty	Source and context
Consumer/public support for whale conservation	Dependent on factors including society	Uncertain	
Fishing technology developments (e.g. ropeless, different line strength, etc.)	Increasing	High confidence	
Shifting fish distributions	Increase in thermal habitat for southern species. Reduction in thermal habitat for northern species.	High confidence generally. Medium confidence if species specific	McHenry *et al*. 2019 paper and tool https://heatherwelch.shinyapps.io/beyond_temperature/
Aquaculture	Increase in demand	High confidence (uncertainty is centered around the entanglement risk from new fishery)	https://www.wri.org/resources/charts-graphs/aquaculture-expanding-meet-world-fish-demand
Seismic exploration	Possible increase	Uncertain	In Greater Atlantic Region, only aware of one proposal in last 10 years - was on Hudson River. State of NY denied the permit and project did not go forward. https://www.delawareonline.com/story/news/local/2018/02/09/delmarva-company-takes-risk-using-wave-energy-produce-drinking-water/310353002/ https://www.riverkeeper.org/campaigns/river-ecology/waterfront-development-review/united-water-desal/
Softshell lobster disease	Increase	Increase in prevalence is likely as it correlates with number of annual days with water temps exceeding 20 degrees Celsius. Disease prevalence has been monitored with increasing intensity over the past 30 years. Prevalence has increased in all SNE waters from MA to NY since the late 1990's, affecting up to 30% of observed animals in some years. There is a south to north gradient of decreasing prevalence with the first observations in ME in 2003.	http://www.asmfc.org/uploads/file//55d61d73AmLobsterStockAssmt_PeerReviewReport_Aug2015_red2.pdf
Offshore oil and gas extraction	Possible emergence	Uncertain given administration position/actions (pro-opening up additional Atlantic coast areas for oil and gas exploration and extraction but resistance from nearly all coastal state governors	https://www.boem.gov/Leasing/ https://www.boem.gov/Atlantic-Oil-and-Gas-Information/ https://www.boem.gov/National-OCS-Program/
Development marine tourism (relates to social concern)	Increase	Uncertainty around public support (if concern is high, so will be tourism)	

Biological, social, political, economic, technological	Projected change (if applicable)	Degree of certainty/uncertainty	Source and context
Large whale disease	Uncertain	Potential for big episodic events with big impacts	
Seafood Demand from Foreign Entities	Increasing (long term trend will be more aquaculture than wild caught)	High confident	
Ability to track / predict RW behavior (e.g., identify adaptation) -- related to surveillance technology	Increasing (35 yrs from now)	High confidence	Every individual whale tagged or public access to satellite imagery where get positions in near-real time
Oil spills and other contaminants	Oil spills - unchanging (more oil exploration in the Gulf of Mexico); contaminants - stable to increasing	Oil spills - high certainly; contaminants - less certain	
Naval activity (shipping, sonar, drones etc)	Increase	Highly uncertain	
Small vessels (capture vessels not regulating)	Increasing strike frequency, decreasing in noise	Medium confidence	Quieter technologies
Larger soundscape (cumulative, louder)	Unknown (large potential to decrease)	High uncertainty	Will be driven by efficiency
Predators			

APPENDIX 5. Literature compiled by participants to inform the initiative.

Primary Literature:

Borggaard, D. L., D. M. Dick, J. Star, M. A. Alexander, M. Bernier, M. Collins, K. Damon-Randall, R. Dudley, R. Griffis, S. Hayes, M. Johnson, D. Kircheis, J. Kocik, B. Letcher, N. Mantua, W. Morrison, K. Nislow, V. Saba, R. Saunders, T. Sheehan, and M. Staudinger. 2019. Atlantic Salmon (*Salmo salar*) Climate Scenario Planning Pilot Report. Greater Atlantic Region Policy Series [19-05]. NOAA Fisheries Greater Atlantic Regional Fisheries Office. 89 p. Available from: https://www.greateratlantic.fisheries.noaa.gov/policyseries/index.php/GARPS/article/view/15.

Brillant, S. W., T. Wimmer, R. W. Rangeley, and C. T. Taggart. 2017. A timely opportunity to protect North Atlantic right whales in Canada. Marine Policy. 81:160-166.

Davis, G. E., M. F. Baumgartner, J. M. Bonnell, J. Bell, C. Berchok, J. B. Thornton, S. Brault, G. Buchanan, R. A. Charif, D. Cholewiak, C. W. Clark, P. Corkeron, J. Delarue, K. Dudzinski, L. Hatch, J. Hildebrand, L. Hodge, H. Klinck, S. Kraus, B. Martin, D. K. Mellinger, H. Moors-Murphy, S. Nieukirk, D. P. Nowacek, S. Parks, A. J. Read, A. N. Rice, D. Risch, A. Širović, M. Soldevilla, K. Stafford, J. E. Stanistreet, E. Summers, S. Todd, A. Warde, and S. M. Van Parijs. 2017. Long-term passive acoustic recordings track the changing distribution of North Atlantic right whales (*Eubalaena glacialis*) from 2004 to 2014. Scientific Reports 7:13460. https://www.nature.com/articles/s41598-017-13359-3.

Fisheries and Oceans Canada. 2014. Recovery Strategy for the North Atlantic Right Whale (*Eubalaena glacialis*) in Atlantic Canadian Waters [Final]. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. vii + 68 p.

Moore, S. S, N. E. Seavy, and M. Gerhart. 2013. Scenario planning for climate change adaptation: a guidance for resource managers. Point Blue Conservation Science and California Coastal Conservancy.

NMFS (National Marine Fisheries Service). 2005. Recovery Plan for North Atlantic Right Whale (*Eubalaena glacialis*). National Marine Fisheries Service, Silver Spring, MD. Available from: https://www.fisheries.noaa.gov/resource/document/recovery-plan-north-atlantic-right-whale-eubalaena-glacialis.

NMFS (National Marine Fisheries Service). 2017. North Atlantic right whale (*Eubalaena glacialis*) 5-year review: Summary and evaluation. NMFS Greater Atlantic Regional Fisheries Office, Gloucester, MA. 34 pp. https://www.greateratlantic.fisheries.noaa.gov/protected/final_narw_5-year_review_2017.pdf.

NMFS (National Marine Fisheries Service). 2018. Draft 2017 Marine Mammal Stock Assessment Reports. 82 FR 60181, pp. 60181-60184. Final document available at: https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-stock-assessment-reports-species-stock.

NPS (National Park Service). 2013. Using Scenarios to Explore Climate Change: A Handbook for Practitioners. National Park Service, Natural Resource Stewardship & Science, Climate Change Response Program. Ft. Collins, CO.

Pace, R. M., III, P. J. Corkeron, and S. D. Kraus. 2017. State-space mark-recapture estimates reveal a recent decline in abundance of North Atlantic right whales. Ecology and Evolution. 7:8730–8741. DOI: 10.1002/ece3.3406.

Rowland, E. R., M. S. Cross, and H. Hartmann. 2014. Considering Multiple Futures: Scenario Planning to Address Uncertainty in Natural Resource Conservation. Washington, DC: US Fish and Wildlife Service. https://www.fws.gov/home/feature/2014/pdf/Final%20Scenario%20Planning%20Document.pdf.

Star, J., E. L. Rowland, M. E. Black, C. A. F. Enquist, G. Garfin, C. H. Hoffman, H. Hartmann, K. L. Jacobs, R. H. Moss, and A. M. Waple. 2016. Supporting adaptation decisions through scenario planning: Enabling the effective use of multiple methods. Climate Risk Management. 13:88-94. https://doi.org/10.1016/j.crm.2016.08.001.

Additional Literature:

Anderson, D. M., D. A. Couture, J. L. Kleindinst, B. A. Keafer, D. J. McGillicuddy Jr, J. L. Martin, M. L. Richlen, J. M. Hickey, and A. R. Solow. 2014. Understanding interannual, decadal level variability in paralytic shellfish poisoning toxicity in the Gulf of Maine: The HAB Index. Deep Sea Research Part II: Topical Studies in Oceanography. 103:264-276. https://doi.org/10.1016/j.dsr2.2013.09.018.

Caesar, L, S. Rahmstorf, A. Robinson,G. Feulner, and V. Saba. 2018. Observed fingerprinting of a weakening Atlantic Ocean overturning circulation. Nature. 556:191-196. https://www.nature.com/articles/s41586-018-0006-5.

Clark, S., K. A. Hubbard, D. M. Anderson, D. J. McGillicuddy Jr., D. K. Ralston, and D. W. Townsend. 2019. *Pseudo-nitzschia* bloom dynamics in the Gulf of Maine: 20012-2016. Harmful Algae. 88:101656. https://doi.org/10.1016/j.hal.2019.101656.

Doucette, G. J., A. D. Cembella. J. L. Martin, J. Michaud, T. V. N. Cole, and R. M. Rolland. 2006. Paralytic shellfish poisoning (PSP) toxins in North Atlantic right whales *Eubalaena glacialis* and their zooplankton prey in the Bay of Fundy, Canada. Marine Ecology Progress Series. 306:303-313. http://www.int-res.com/articles/meps2006/306/m306p303.pdf.

Doucette, G. J., C. M. Mikulski, K. L. King, P. B. Roth, Z. Wang, L. F. Leandro, S. L. DeGrasse, K. D. White, D. De Biase, R. M. Gillett, and R. M. Rolland. 2012. Endangered North Atlantic right whales (*Eubalaena glacialis*) experience repeated, concurrent exposure to multiple environmental neurotoxins produced by marine algae. Environmental Research. 112:67-76. doi: 10.1016/j.envres.2011.09.010.

Fortune, S. M. E., A. W. Trites, C. A. Mayo, D. A. S. Rosen, and P. K. Hamilton. 2013. Energetic requirements of North Atlantic right whales and the implications for species recovery. Marine Ecology Progress Series. 478:253-272. https://doi.org/10.3354/meps1000.

Greene, C. H. 2016. North America's iconic marine species at risk due to unprecedented ocean warming. Oceanography. 29(3):14-17.

Grieve, B. D., J. A. Hare, and V. S. Saba. 2017. Projecting the effects of climate changes on *Calanus finmarchicus* distribution within the U.S. northeast continental shelf. Scientific Reports. 7(6264):1-12. https://www.nature.com/articles/s41598-017-06524-1.

Henry, A. G., T. V. N. Cole, M. Garron, W. Ledwell, D. Morin, and A. Reid. 2017. Serious injury and mortality determinations for baleen whale stocks along the Gulf of Mexico, United States East Coast, and Atlantic Canadian Provinces, 2011-2015. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 17-19; 57 p. https://www.nefsc.noaa.gov/publications/crd/crd1719/.

Hodge, K. B., C. A. Muirhead, J. L. Morano, C. W. Clark, and A. N. Rice. 2015. North Atlantic right whale occurrence near wind energy areas along the mid-Atlantic US coast: Implications for management. Endangered Species Research. 28:225-234.

IPCC. 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Stocker, T. F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. M. Midgley, eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 p.

McHenry, J., H. Welch, S. E. Lester, and V. Saba. 2019. Projecting marine species range shifts form only temperature can mask climate vulnerability. Global Change Biology. 25: 4208-4221. https://doi.org/10.1111/gcb.14828.

Meyer-Gutbrod, E. L., C. H. Greene, P. J. Sullivan, and A. J. Pershing. 2015. Climate-associated changes in prey availability drive reproductive dynamics of the North Atlantic right whale population. Marine Ecology Progress Series. 535:243-258.

Montie, E. W., R. J. Letcher, C. M. Reddy, M. J. Moore, B. Rubinstein, and M. E. Hahn. 2010. Brominated flame retardants and organochlorine contaminants in winter flounder, harp and hooded seals, and North Atlantic right whales from the northwest Atlantic Ocean. Marine Pollution Bulletin. 60(8):1160-1169.

Morano, J. L., A. N. Rice, J. T. Tielens, B. J. Estabrook, A. Murray, B. L. Roberts, and C. W. Clark. 2012. Acoustically detected year-round presence of right whales in an urbanized migration corridor. Conservation Biology. 28:698-707.

Pettis, H. M., R. M. Pace III, R. S. Schick, and P. K. Hamilton. 2017. North Atlantic Right Whale Consortium 2017 Annual Report Card. https://www.narwc.org/uploads/1/1/6/6/116623219/2017_report_cardfinal.pdf.

Rolland, R. M., S. E. Parks, K. E. Hunt, M. Castellote, P. J. Corkeron, D. P. Nowacek, S. K. Wasser, and S. D. Kraus. 2012. Evidence that ship noise increases stress in right whales. Proc. R. Soc. B. https://doi.org/10.1098/rspb.2011.2429.

Rolland, R. M., R. S. Schick, H. S. Pettis, A. R. Knowlton, P. K. Hamilton, and J. S. Clark. 2016. Health of North Atlantic right whales (*Eubalaena glacialis*) over three decades: From individual health to demographic and population health trends. Marine Ecology Progress Series. 542:265-282.

Saba, V. S, S. M. Griffies, W. G. Anderson, M. Winton, M. A. Alexander, T. L. Delworth, J. A. Hare, M. J. Harrison, A. Rosati, G. A. Vecchi, and R. Zhang. 2016. Enhanced warming of the Northwest Atlantic Ocean under climate change. Journal of Geophysical Research: Oceans. 121(1):118-132.

van der Hoop, J. M., A. S. M. Vanderlaan, T. V. N. Cole, A. G. Henry, L. Hall, L., B. Mase-Guthrie, T. Wimmer, and M. J. Moore. 2014. Vessel strikes to large whales before and after the 2008 ship strike rule. Conservation Letters. 8:24-32.

van der Hoop, J. M., P. Corkeron, and M. Moore. 2016. Entanglement is a costly life-history stage in large whales. Ecology and Evolution. 7(1):92-106.

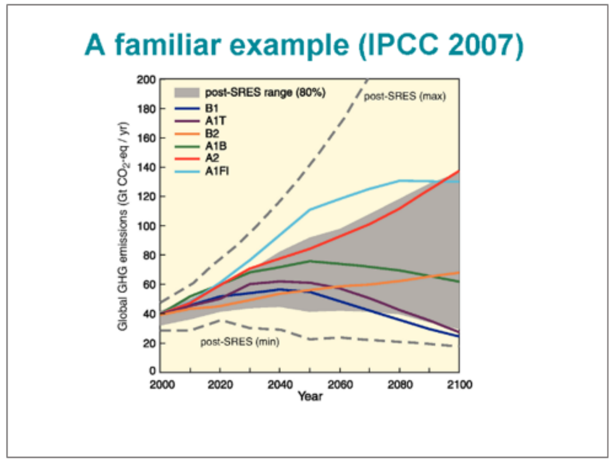
APPENDIX 6. Available workshop presentation slides.

Available workshop presentations included here. To request a copy of a specific presentation, please contact Diane Borggaard (diane.borgaarrd@noaa.gov or 978-282-8453) or Dori Dick (dori.dick@noaa.gov or 301-427-8430).

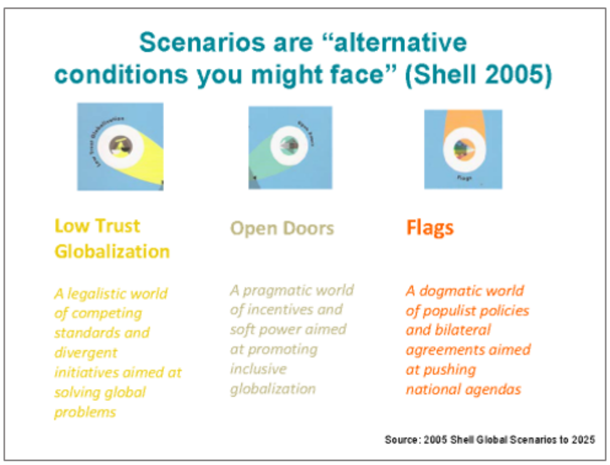
Introduction to Scenario Planning, Jonathan Star.

1

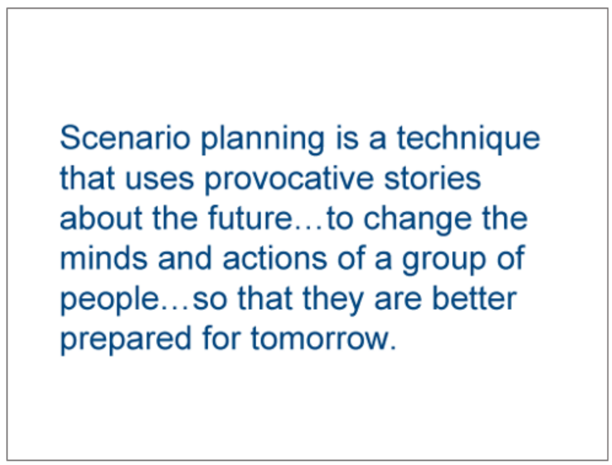
2



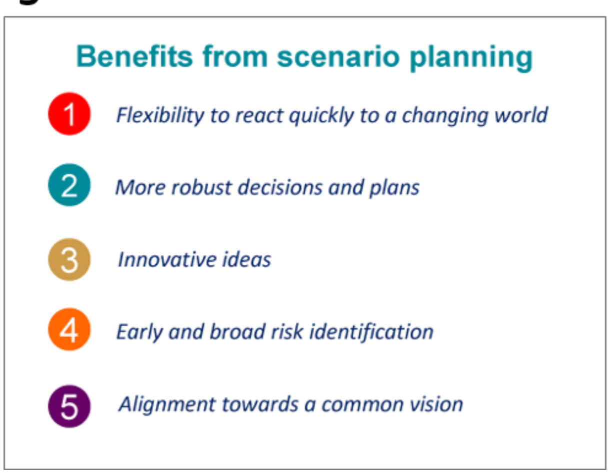
3



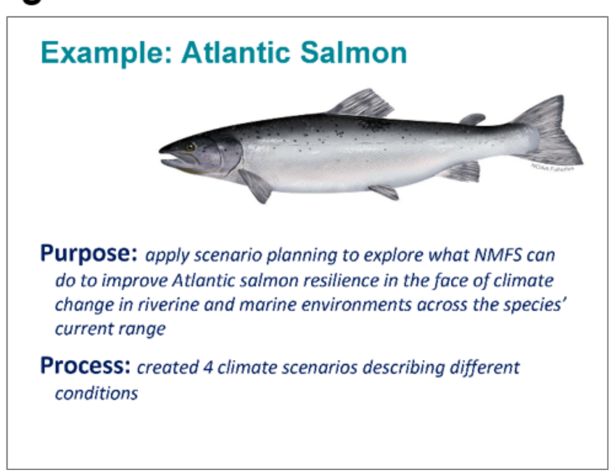
4



5

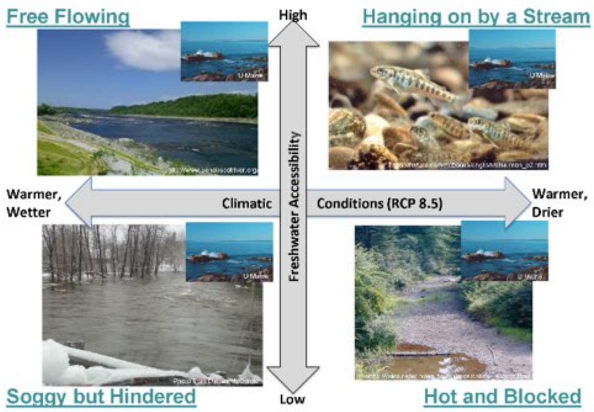


6



7

Atlantic Salmon Scenario Set



8

Example: Atlantic Salmon

Outcomes / Lessons:

- *Highlighted most critical and uncertain drivers to create 4 future scenarios*
- *Identified high priority actions that would be useful in any future and incorporated into Draft recovery plan*
- *Identified recovery needs and data gaps*
- *Increased federal coordination and collaboration*
- *Built capacity for future scenario work*

9

Views from Resource Managers

"The Atlantic salmon climate scenario project was one of the best prioritization exercises I have ever participated in for salmon. The process that was developed enabled us to focus on all of the threats to salmon, rather than the ones that are easiest to address."

- Kim Damon-Randall, Acting Deputy RA, GARFO

"The structure of the scenario planning brought together folks with diverse expertise and made tackling a "wicked" problem both manageable and intellectually stimulating. The outcome was truly a collective effort that I was pleased to be involved in."

- John Kocik, Protected Species Branch, NEFSC

10

Views from Resource Managers

"I found the scenario planning process surprisingly useful, both as a means to conceive a range of plausible scenarios and to think about actions that increase/decrease the likelihood of those scenarios becoming realized. It seems really useful for highly uncertain futures, and its values not too dissimilar from the value of doing safety drills in preparation for various disaster scenarios. If you have at least thought through possible scenarios, you can be much more flexible and adaptive in your responses"

- Matt Collins, Office of Habitat Conservation, HQ

11

A typical scenario creation process

1. *Clarify the focus and goals of the investigation (scope & time horizon)*

2. *Research to identify factors likely to shape the future (drivers)*

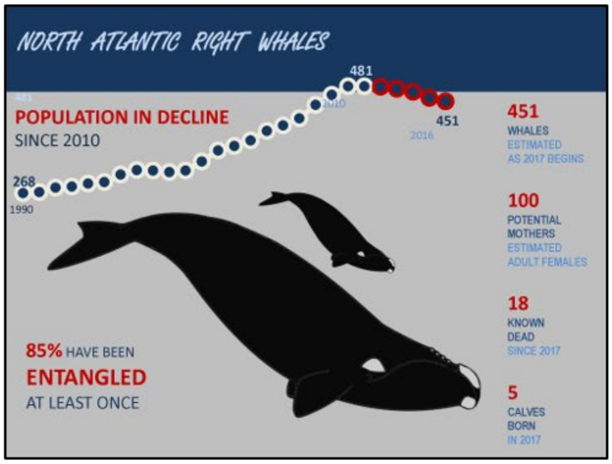
3. *Combine drivers to create a scenario framework*

4. *Craft a plausible, challenging story for each scenario*

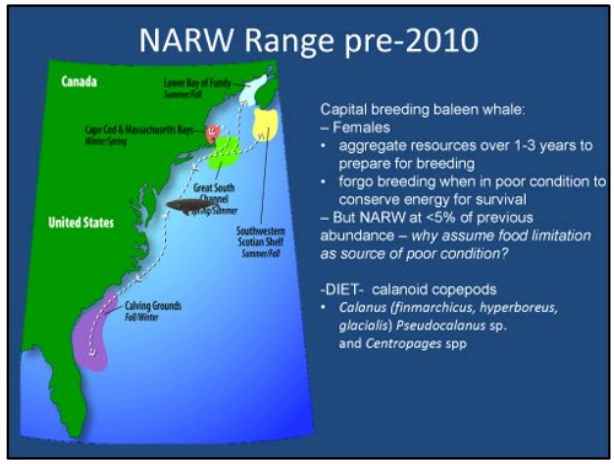
5. *Use the scenarios for strategy, innovation, risk, vision-setting*

Right whales 101: distribution, foraging, calving, etc. Sean Hayes.

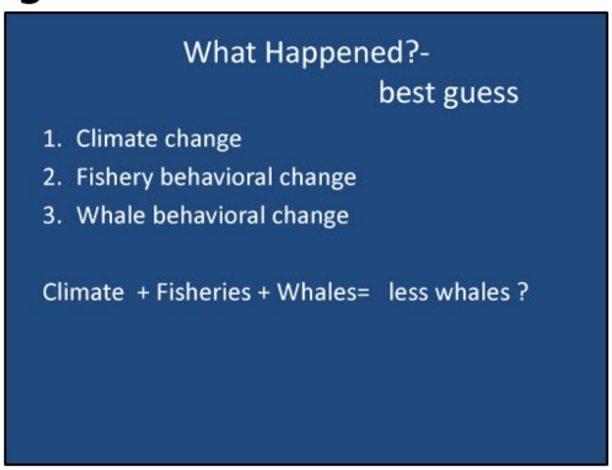
1



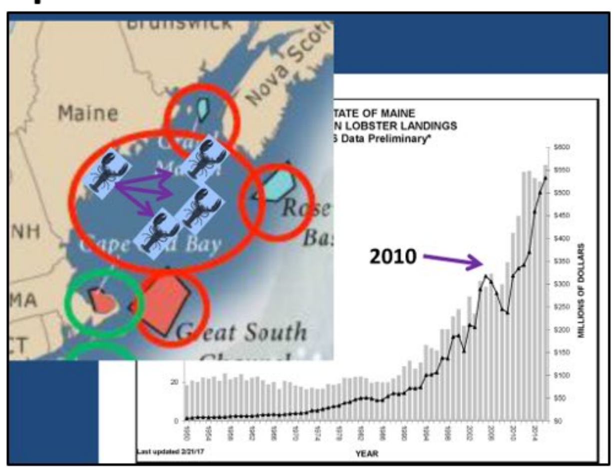
2



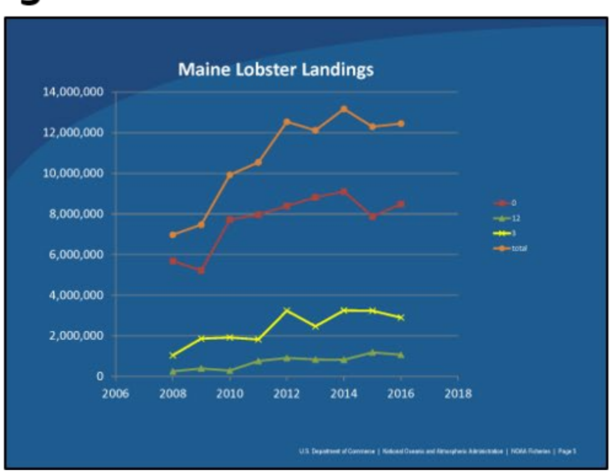
3



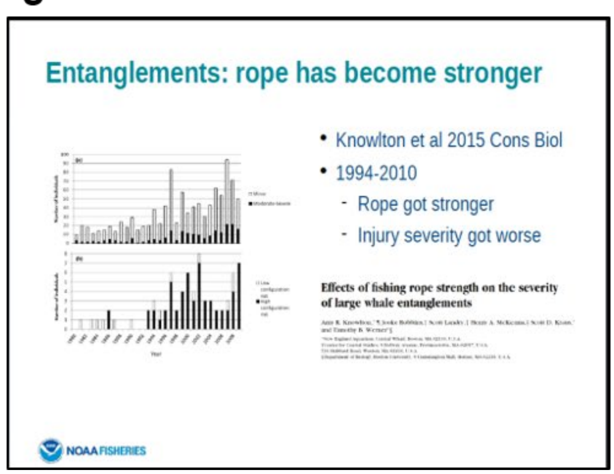
4



5



6



7

Newton's 3rd law

For every action there is an equal and opposite reaction

8

So what happens to whales?

"Distributional shift?"

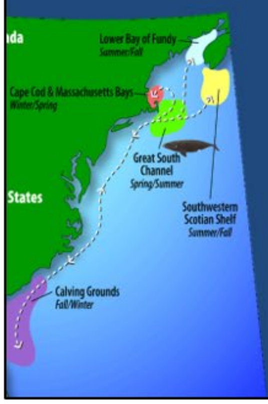
NARW Atlantis! (?)

Implies a 'one-way' trip…

this is not what we are seeing

9

The map didn't change….



10

It grew..

2 things:
- Historic movement pattern/speed increase
- Range expansion

Effects: "Reduced residence time"
Whales move through same areas, but harder to 'capture'
- Old min-number count model fails
- Need new mark & recap model

11

Impacts

- One fishery moves to overlap with whales
- Whales move to overlap with another fishery

Why?
- Entanglement/Ship strike
- Fear/Stress
- Food

12

Demography at its most basic

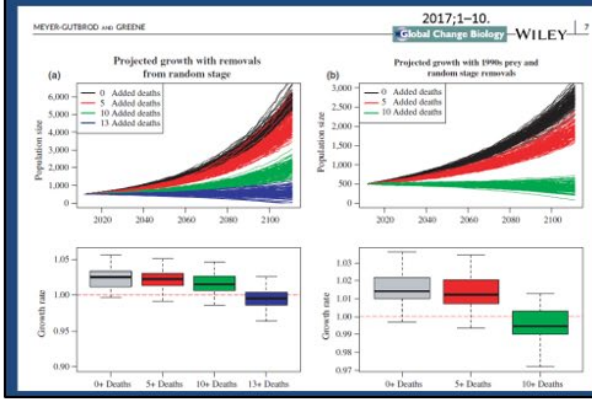
If more animals die in a year than are born in a year, a species will decline

Demography is about deaths and births….

NOAA FISHERIES

13

Food?



14

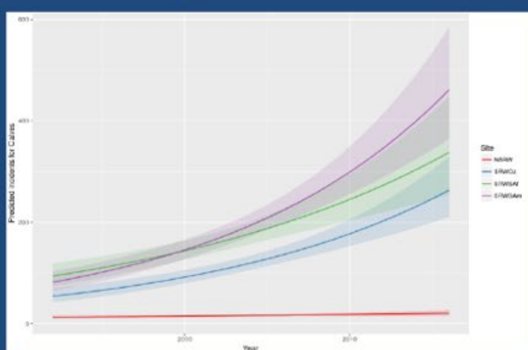
Or anthropogenic mortality?

Imagine a world where after decades of recovery Right whales…

- had not aged enough to die..
- No ship strike or entanglement..
- They were fat and happy
- Calving rates of 5-7% and hundreds born/year…

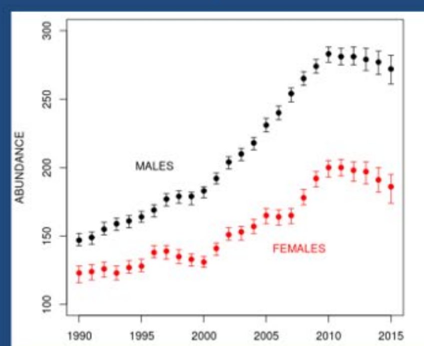
15

Calving- North vs South



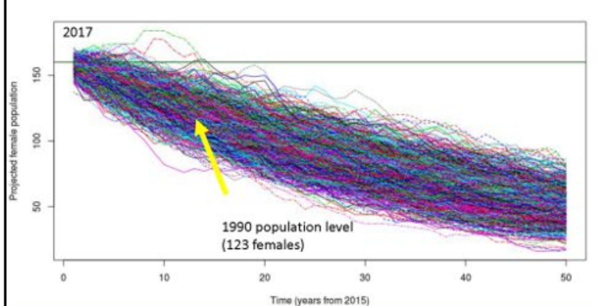
16

Sex bias- the problem is worse



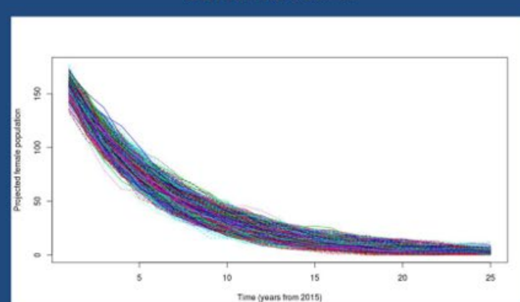
17

Current trajectory – NARW Females

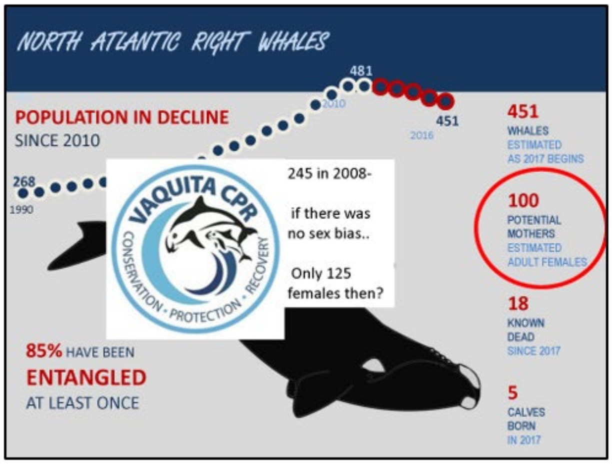


18

Trajectory if 2017 mortality rate continues…..



19

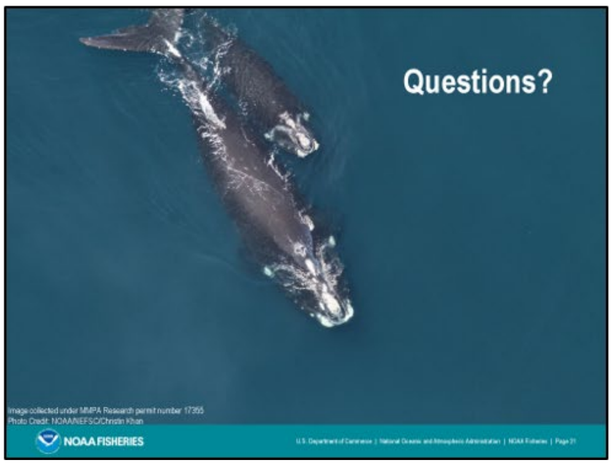


20

Hope- time of great opportunity

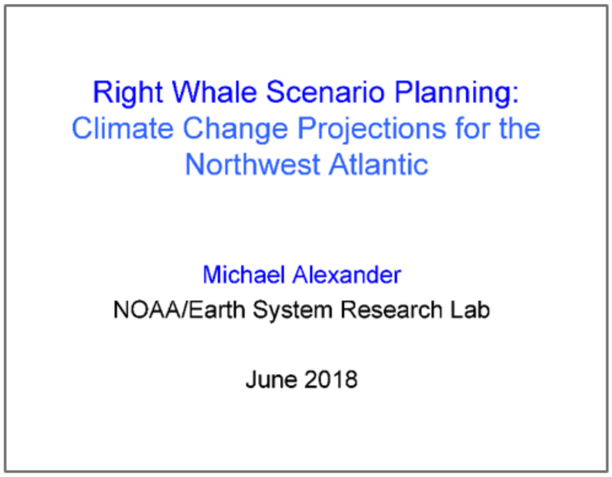
- We are not fighting a black market fishery
- We have the science to inform change
- We have strong international partner
- We have the power and social network support to get the industry to lead the necessary changes

21

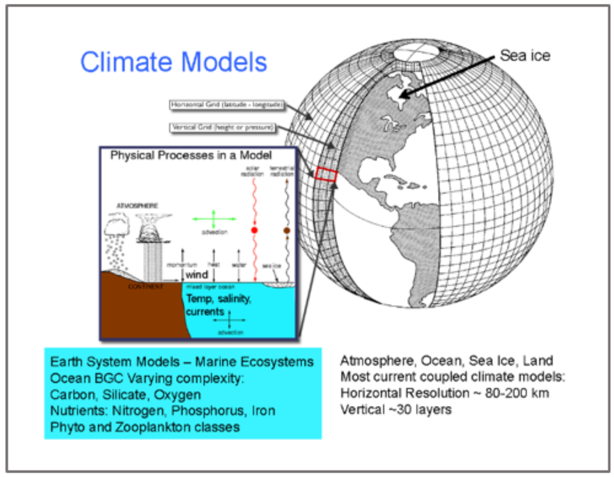


Right Whale Scenario Planning: Climate Change Projections for the Northwest Atlantic, Michael Alexander. Appendix 6. Workshop presentations

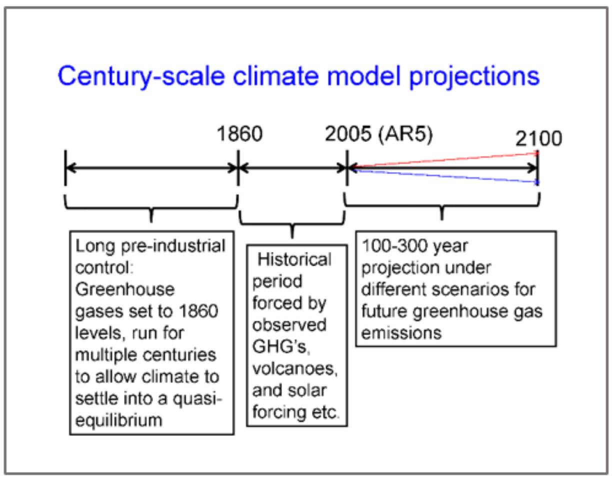
1



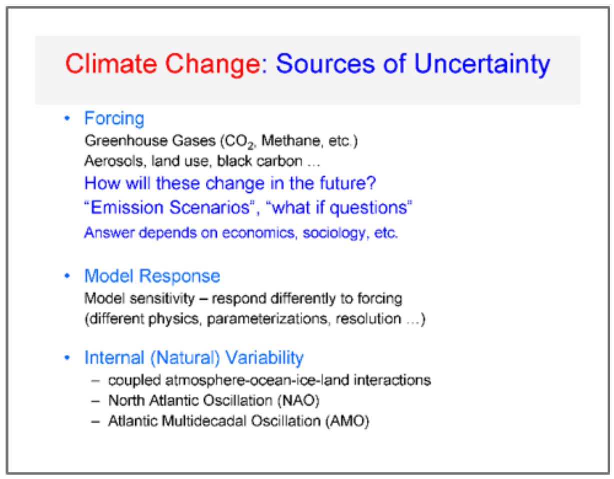
2



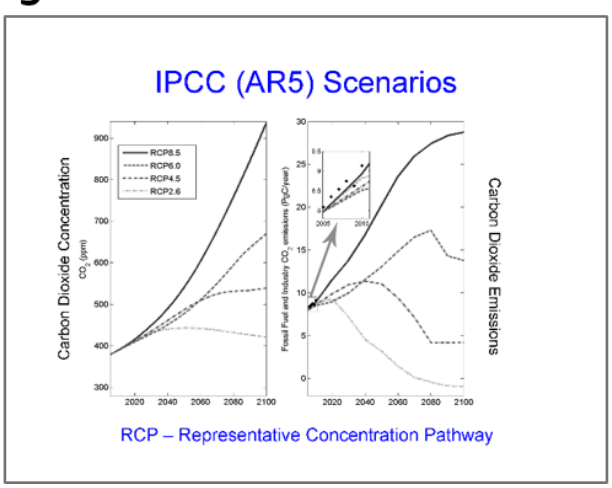
3



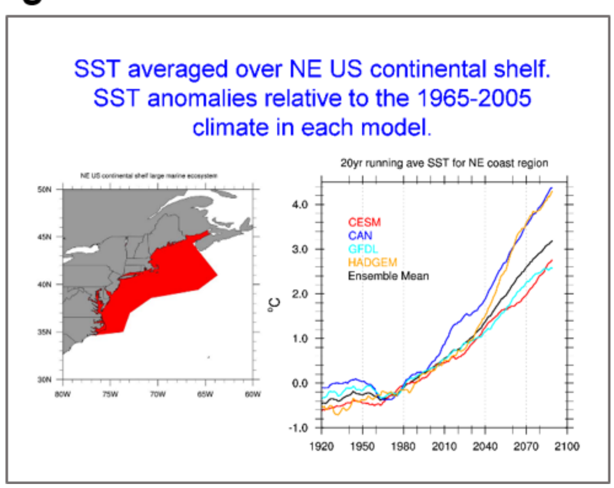
4



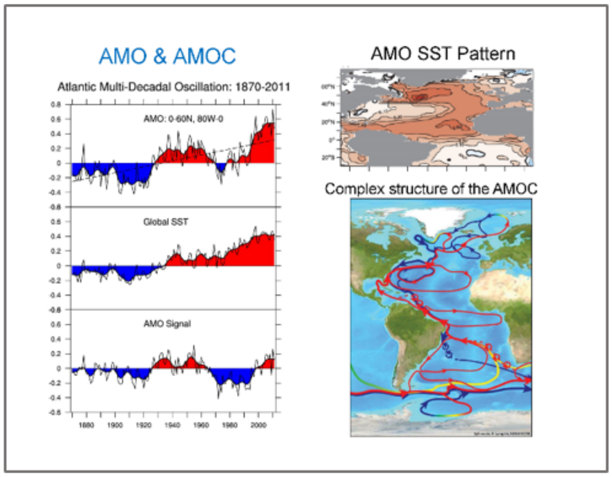
5



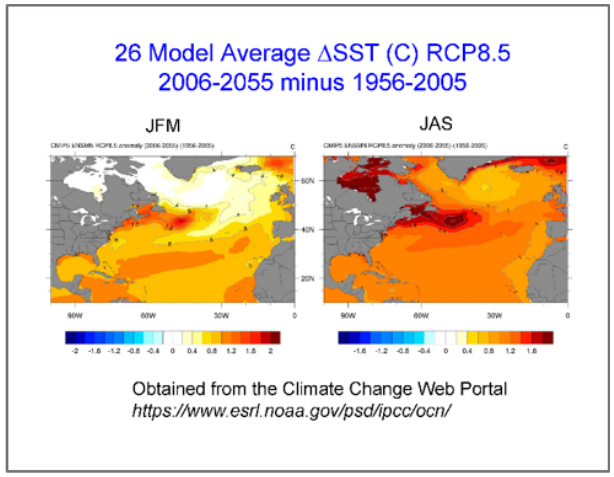
6



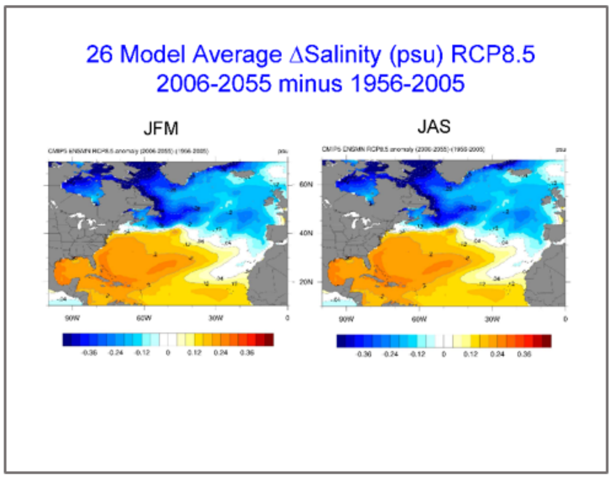
7



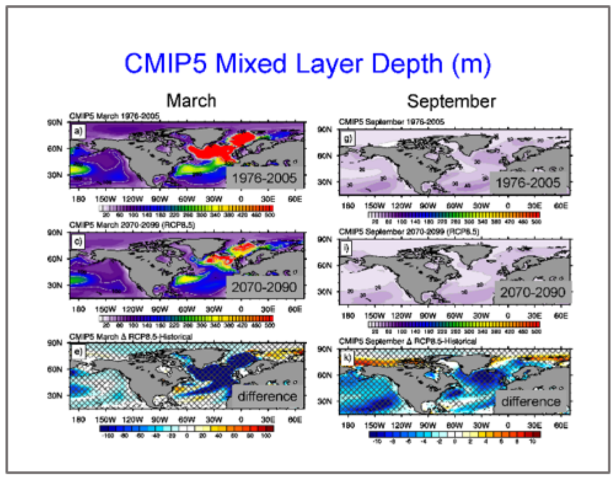
8



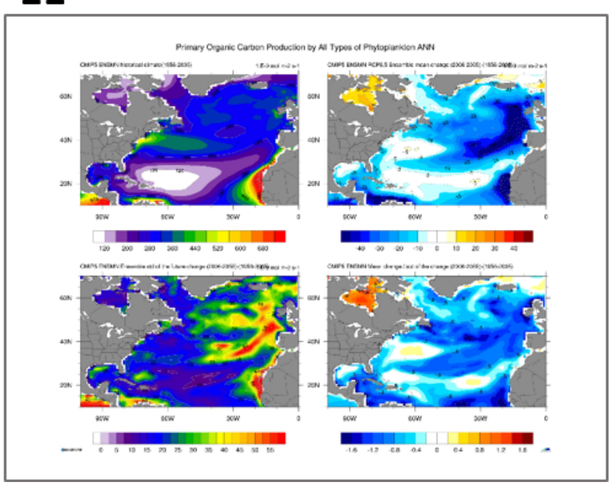
9



10



11



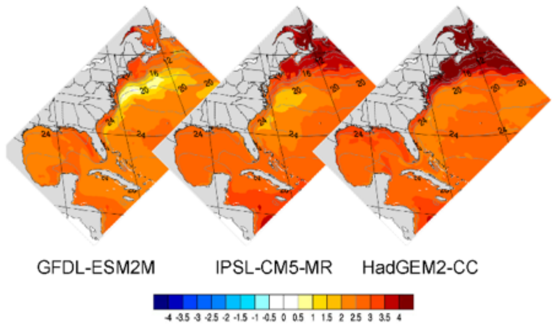
12

Role of Resolution?

- Global high-resolution
  - Vince - GFDL 2.6 with 10 km Ocean Resolution
- Regional Model driven by fields from coarse resolution GCMs
  - US East Coast version of ROMS
    - 7 km resolution
  - Control simulation: 1976-2005 observed BCs
  - RCP8.5 simulations driven by output from three CMIP5 GCMS:
    - GFDL-ESM2M, IPSL-CM5-MR, HADGEM2-CC
  - Mean monthly 30-year average difference (Δ)(2070-2099) minus (1976-2005) added to control
  - Climate change signal: RCP8.5 - Control

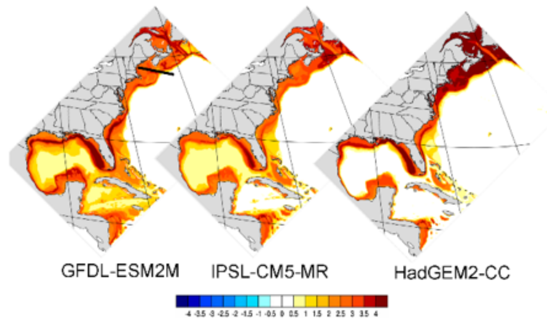
13

ROMS ANN SST (°C)
RCP8.5-CTRL (shaded), CTRL (contour)



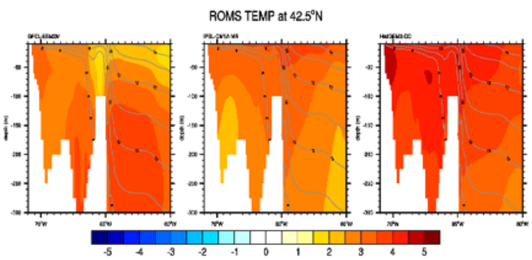
14

ROMS ANN Bottom Temp (°C)
RCP8.5-CTRL (shaded)



15

Cross Section
Annual Mean Temperature 42.5° N
RCP8.5-CTRL (shading) CTRL (contours)



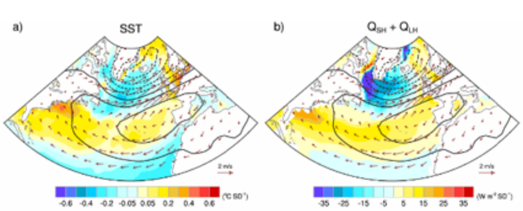
16

Summary/Discussion

- Climate models provide guidance on how climate may change:
  - Strong warming is likely, could be especially strong along Coast
  - Enhanced salinity in subtropics decreased at high latitudes, dividing line around New England
  - Enhanced stratification (Shoaling of mixed layer)
  - decreased nutrients, decrease PP but a lot of model spread
- Difference will arise due to how people use fossil fuels in the future
- Due to different parameterizations models will give different results
- Expect a range of climate change outcomes due to natural variability even for long-term trends

17

Patterns of Surface Fluxes and SSTs:
example North Atlantic Oscillation



Contours are sea level pressure (SLP); vectors - winds
Shading left is SST anomalies, on right is the Flux anomalies
NAO north-south SLP anomaly pattern over the Atlantic

18

Future North Atlantic SST changes across
GFDL CM2.1 Ensemble of simulations

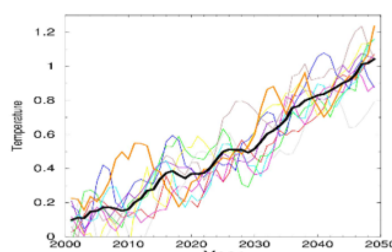
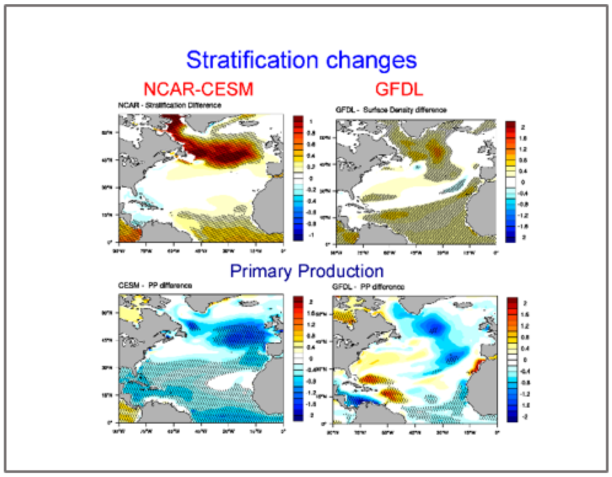
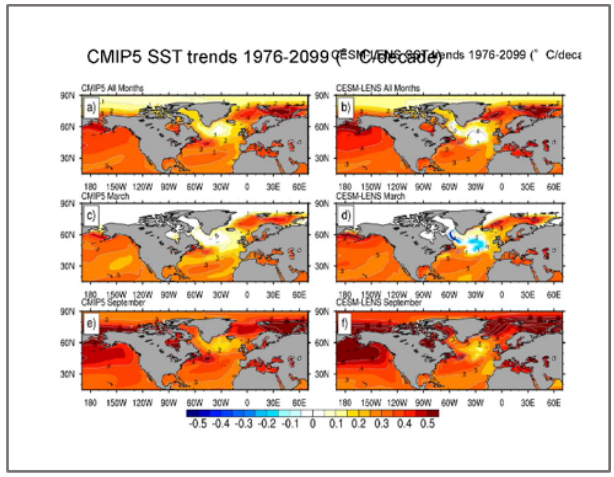


Figure courtesy of Tom Delworth/GFDL Climate Change Variability and Prediction Group

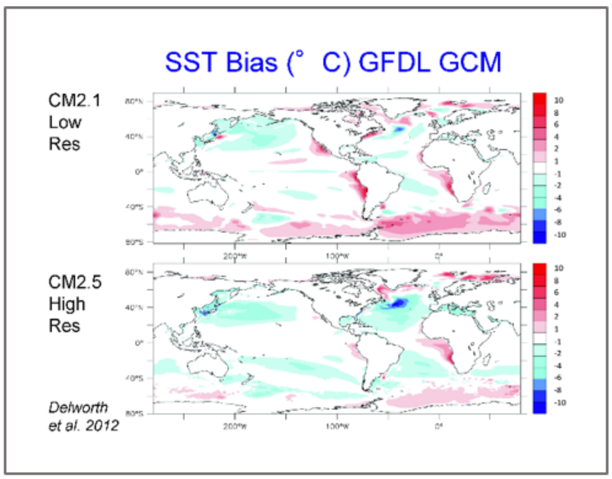
19



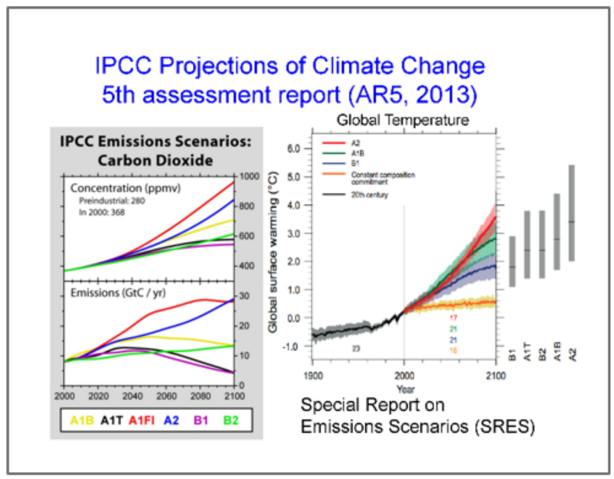
20



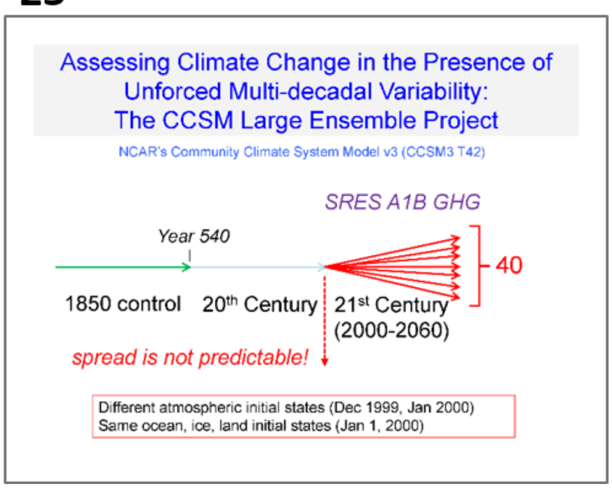
21



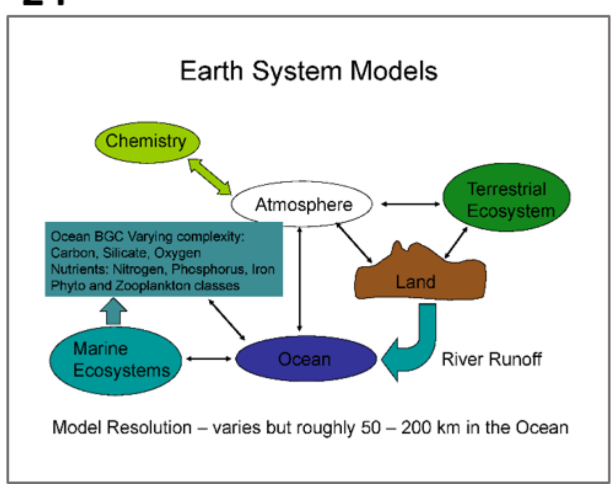
22



23



24

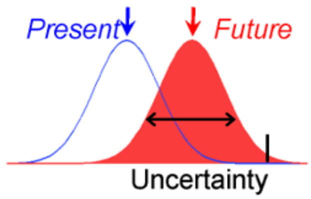


25

Adaptation

Plan for a range of climate changes

Decisions shaped by vulnerability & risk



Signal: Δ Mean/Uncertainty

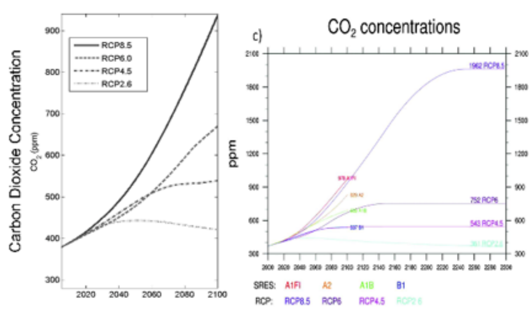
26

Atlantic Multidecadal Oscillation (AMO)

- Slow changes in SSTs over the North Atlantic,
  - cool and warm phases that may last for 20-40 years
  - difference of about 0.6° C between extremes.
  - Index: Detrended 10-year running mean of N Atlantic SST anomalies
  - Named (in off-hand way) by Kerr (writer for *Science* (2000)
  - First "formal" paper Enfield et al. 2001 (Geophys. Res. Let)
- In models, AMO-like variability is associated with changes in the Thermohaline Circulation
- But, historical oceanic observations are not sufficient to associate the AMO index to ocean circulation.
- Phase of AMO *associated* with changes in hurricanes, precipitation in Florida, US droughts

27

IPCC (AR5) Scenarios (Different)

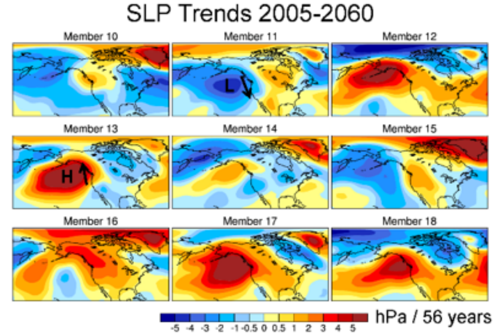


RCP – Radiation Concentration Pathway

28

CCSM3 Large Ensemble

SLP Trends 2005-2060



Internal Variability (in one model)

29

Natural Climate Variability

- Given the nonlinear nature of the climate system very small changes can result in a very different state of the atmosphere ("butterfly effect") after just a few weeks. Extends to the climate system as a whole by ~5-10 years.
- This has surprising consequences
- Won't have skillful (deterministic) forecasts of the atmosphere after ~2-3 weeks
  - Can't forecast the NAO beyond 2 weeks
- Still have lots of natural variability at decadal and longer time scales frequency; e.g
  - Can have 50 year trends in a given location In a "20th century simulation" where climate model is initialized in the 19th century) a given time in the model will NOT match nature
  - Can't directly compare time series from model to nature. Can compare average over a period

30

Implications of Experimental Design

- The statistical properties of climate variability may be captured by a model, but it will not be "in phase" with the historical record.
- Often use "ensembles" a set of simulations with the same forcings that only differ by their initial conditions
  - Spread of ensemble members measure of natural variability)
  - Each ensemble member is equally likely

31

Should I weight models based on skill metrics?

- Active area of research that could reduce uncertainty due to inter-model spread
- No accepted method - many cases where a model's ability to match contemporary regional features was unrelated to a model's ability to match the warming trend (don't like draft a "good hitting" pitcher in the American league)
- Present default is not to weight, though some "culling" of highly aberrant simulations may be necessary (e.g., Overland et al., J. Climate, 24 2011)

Stock et al., 2011, Prog. Oceanogr. 88, 1-27

32

Regional Climate Change

- Regardless of scale can bias correct
  - Simplest is the Delta method
    - Assumes Change not influenced by model bias
- Use current GCMS
  - Lack key features
    - ~2 grid points in gulf of Maine
- Increase resolution of GCMs
    - Starting to happen but very computationally intensive
    - Not all biases improve
- Dynamical Downscaling
  - Use finer scale physical models in a region where boundary conditions are provided by GCMs

33

Projected Changes in Weather Extremes

Table 1: Estimates of confidence in observed and projected changes in extreme weather and climate events.

Confidence in observed changes (latter half of the 20th century)	Changes in Phenomenon	Confidence in projected changes (during the 21st century)
Likely[7]	**Higher maximum temperatures and more hot days over nearly all land areas**	Very likely[7]
Very likely[7]	**Higher minimum temperatures, fewer cold days and frost days over nearly all land areas**	Very likely[7]
Very likely[7]	**Reduced diurnal temperature range over most land areas**	Very likely[7]
Likely[7], over many areas	**Increase of heat index[12] over land areas**	Very likely[7], over most areas
Likely[7], over many Northern Hemisphere mid- to high latitude land areas	**More intense precipitation events[b]**	Very likely[7], over many areas
Likely[7], in a few areas	**Increased summer continental drying and associated risk of drought**	Likely[7], over most mid-latitude continental interiors. (Lack of consistent projections in other areas)
Not observed in the few analyses available	**Increase in tropical cyclone peak wind intensities[c]**	Likely[7], over some areas
Insufficient data for assessment	**Increase in tropical cyclone mean and peak precipitation intensities[c]**	Likely[7], over some areas

34

Internal Variability in Relation to Forcing and Model Sensitivity

Time Scale:

- Forcing - long timescales
- Model Sensitivity – all time scales
- Internal (Natural) Variability – short (< 10-20 years?)
  - Increases as the spatial scale decreases
  - Will differ by variable
    - Larger for precipitation than temperature in most areas

Model Experiments:

- Examine internal variability by using more than one run, i.e. an ensemble of simulations
- Nearly all climate change studies have used one or a very small number of ensemble members

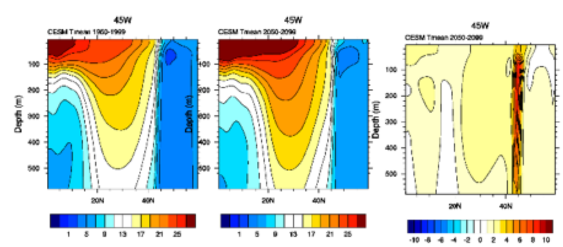
35

Climate variability in century-scale physical climate models

- Many climate models produce realistic representations of prominent modes of climate variability
- Can use climate change projections to study climate variability, but don't expect to be "in phase" with observed variability
- Ensemble means and focusing on differences between multi-decadal averages across century time-scales helps isolate the climate change trend

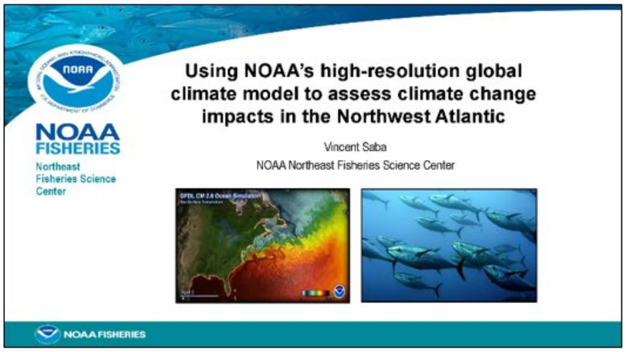
36

Potential temperature (CESM) 45° W

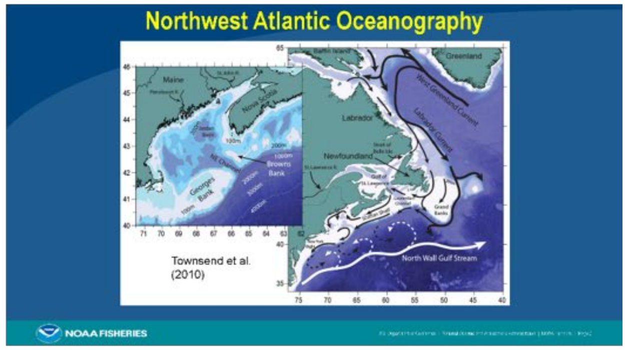


Using NOAA's high-resolution global climate model to assess climate change impacts in the Northwest Atlantic, Vincent Saba.

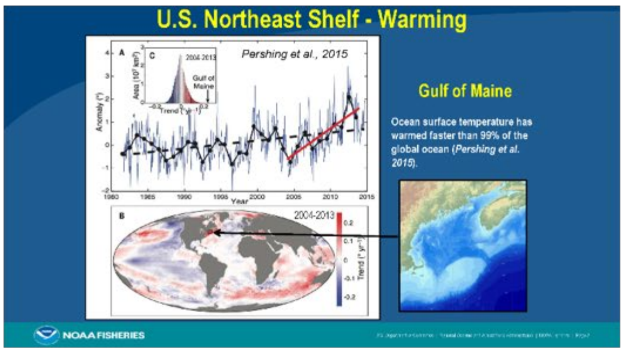
1



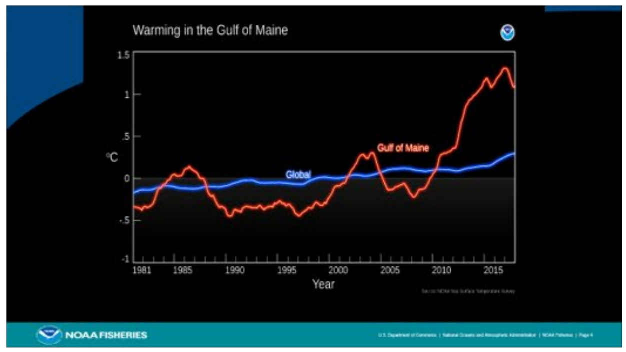
2



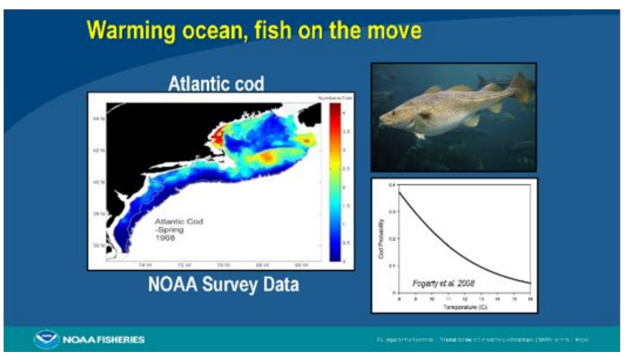
3



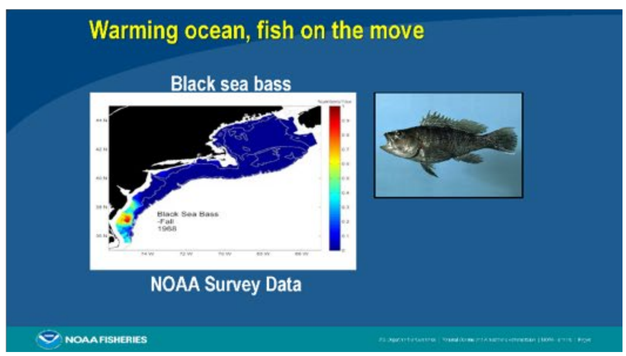
4



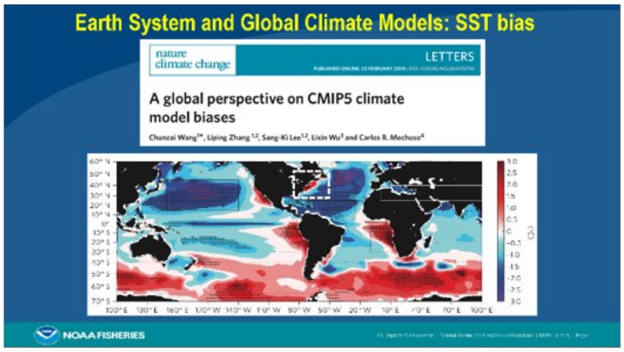
5



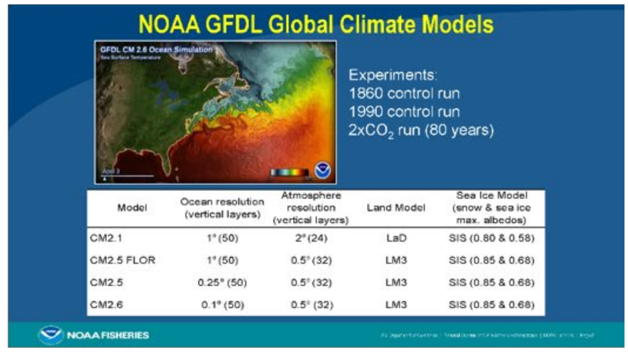
6



7

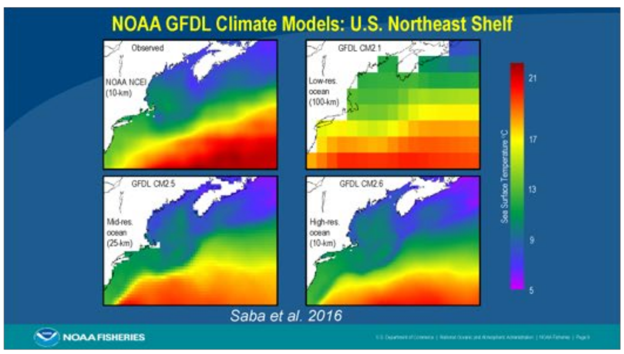


8

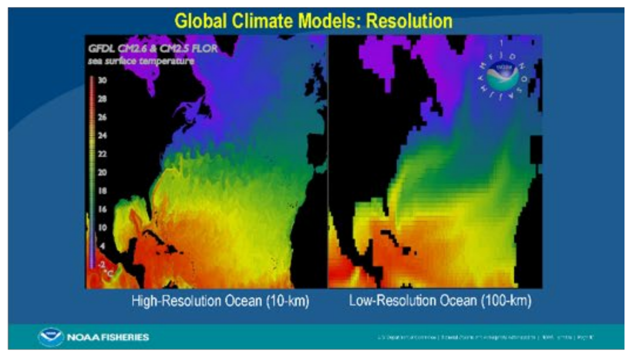


Model	Ocean resolution (vertical layers)	Atmosphere resolution (vertical layers)	Land Model	Sea Ice Model (snow & sea ice max. albedos)
CM2.1	1° (50)	2° (24)	LaD	SIS (0.80 & 0.58)
CM2.5 FLOR	1° (50)	0.5° (32)	LM3	SIS (0.85 & 0.68)
CM2.5	0.25° (50)	0.5° (32)	LM3	SIS (0.85 & 0.68)
CM2.6	0.1° (50)	0.5° (32)	LM3	SIS (0.85 & 0.68)

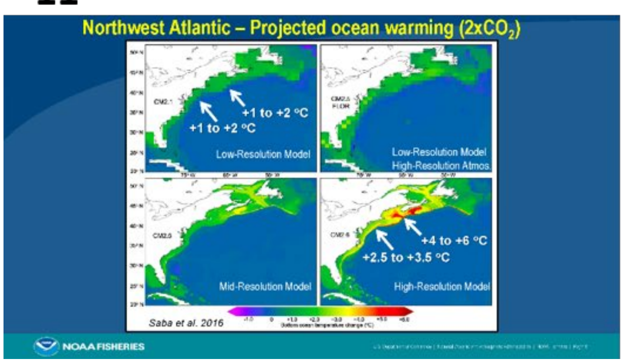
9



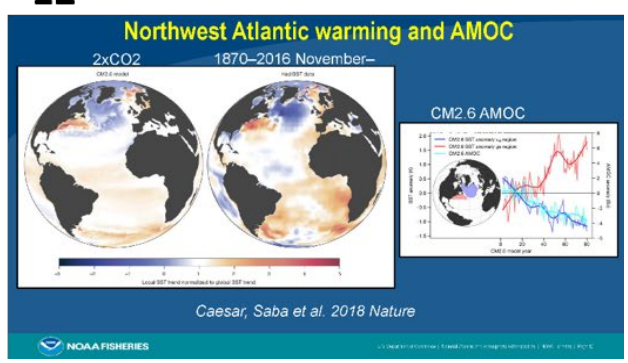
10



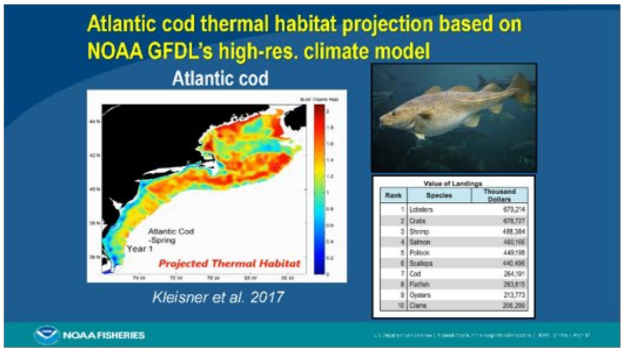
11



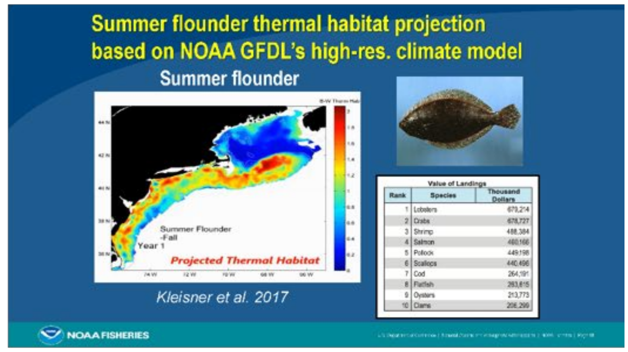
12



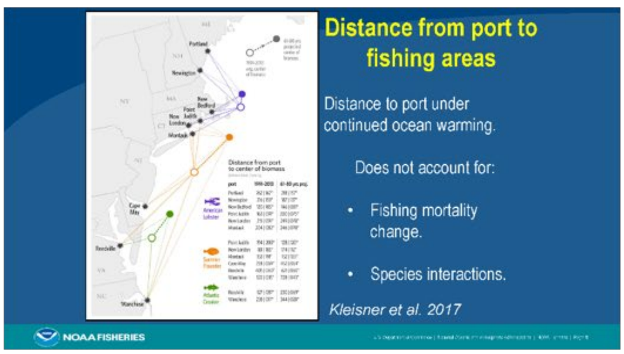
13



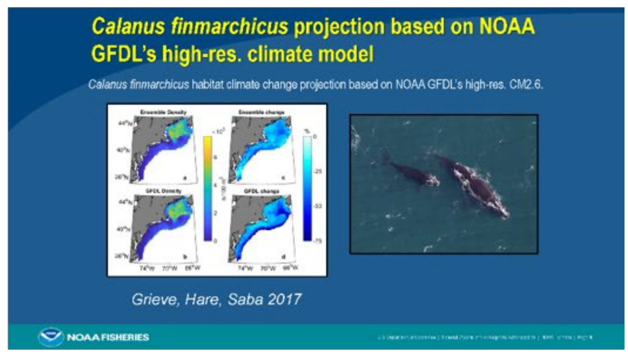
14



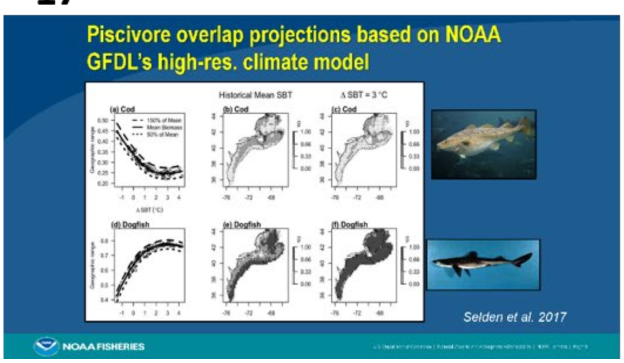
15



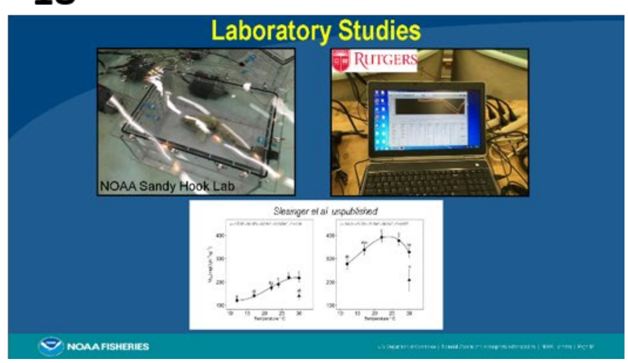
16



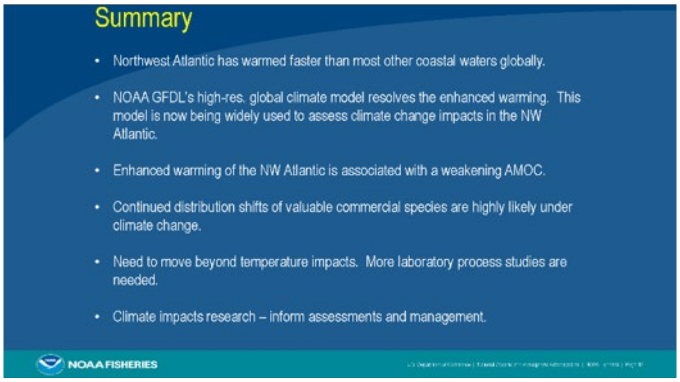
17



18



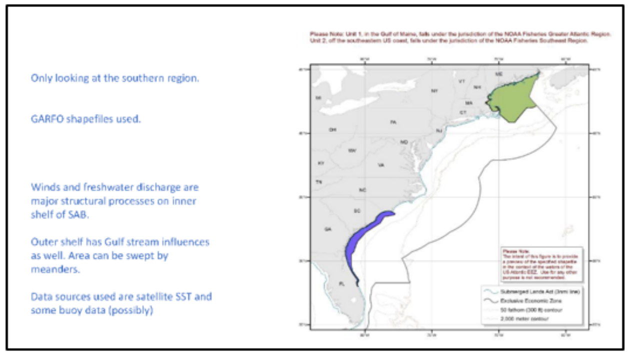
19


Summary
Northwest Atlantic has warmed faster than most other coastal waters globally.
NOAA GFDL's high-res. global climate model resolves the enhanced warming. This model is now being widely used to assess climate change impacts in the NW Atlantic.
Enhanced warming of the NW Atlantic is associated with a weakening AMOC.
Continued distribution shifts of valuable commercial species are highly likely under climate change.
Need to move beyond temperature impacts. More laboratory process studies are needed.
Climate impacts research – inform assessments and management.
NOAA FISHERIES

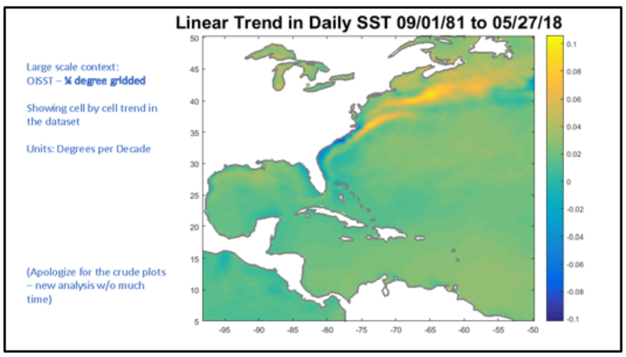
Characterizing some aspects of ‘South Atlantic Bight’ oceanography, John Quinlan.

1

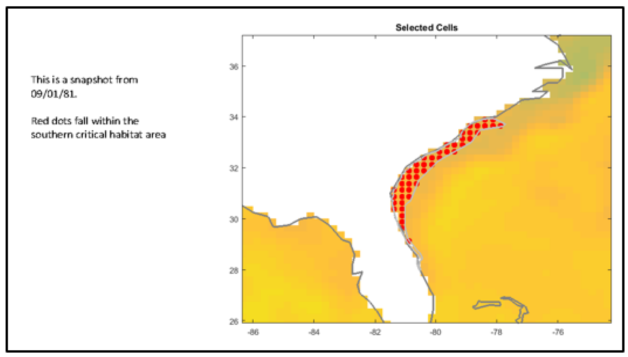
2



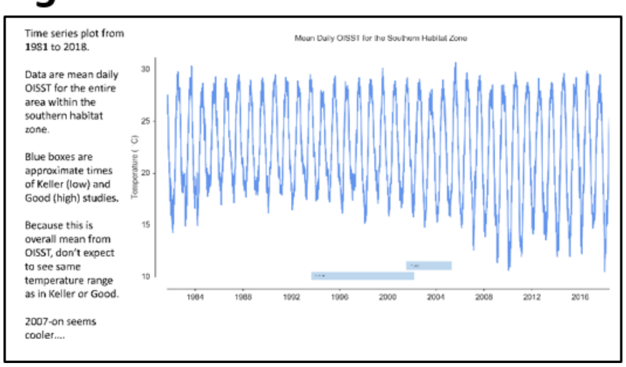
3



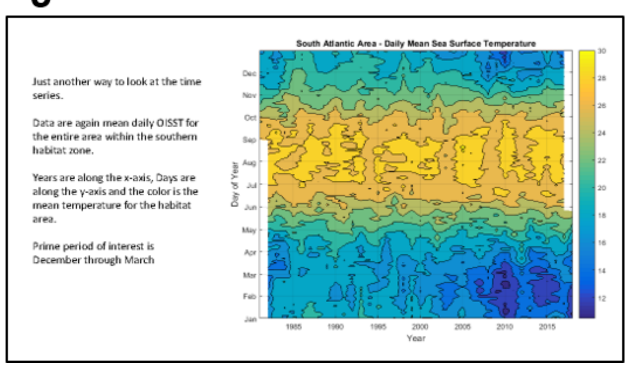
4



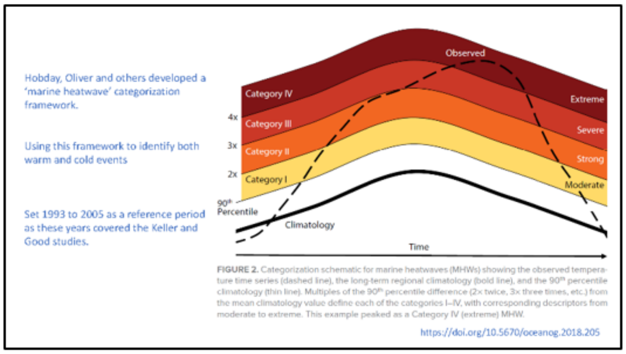
5



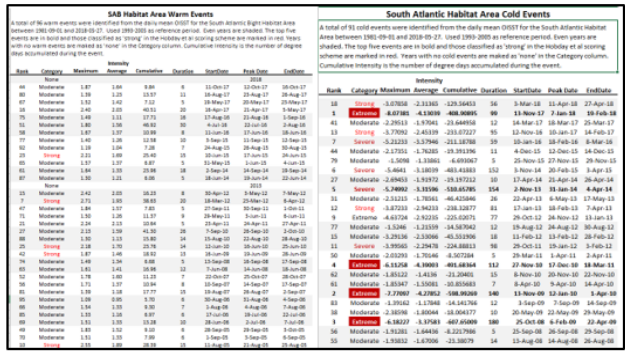
6



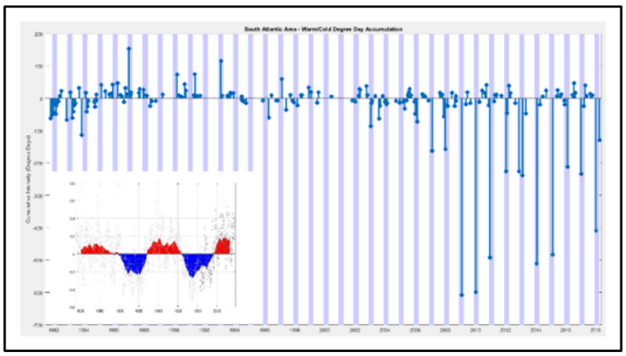
7



8



9



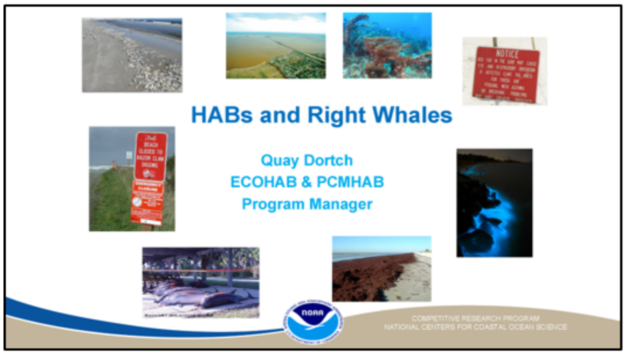
10

Next steps –

- Contrast these data with in situ observations
- Wind stress and storm tracks/met system types
- Get a handle on the wave fields

HABs and right whales, Quay Dortch.

1

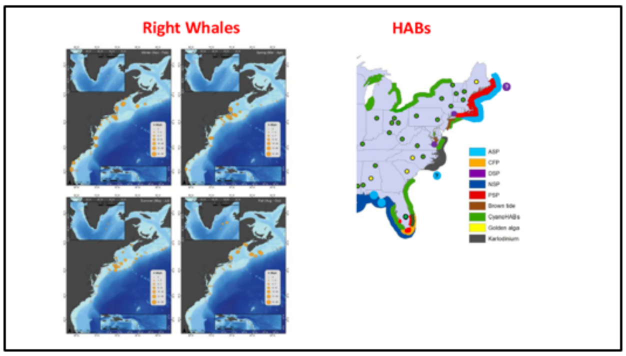


2

Major Caveat
Human Not Whale Centric

Sampling and understanding focused on protecting human health from toxic shellfish/fish. Blooms near shore could be no threat to whales and blooms off shore no threat to humans and missed.

3



4

HAB Threat to Whales

- Toxins accumulate in prey
- Lethal
- Interfere with reproduction
- Sub-lethal effects on behavior
- Examples from this region and other regions

5

Impacts Coastal HABs

		Name	Human & Animal* Poisoning	Fish Kills	Water Discoloration
2	light blue	Amnesic Shellfish Poisoning (ASP)	Yes**	No	No
	orange	Ciguatera Fish Poisoning (CFP)	Yes	No	No
3	purple	Diarrhetic Shellfish Poisoning (DSP)	Yes	No	No
	dark blue	Neurotoxic Shellfish Poisoning (NSP)	Yes**	Yes	Yes
1	red	Paralytic Shellfish Poisoning (PSP)	Yes**	Yes	Yes
?	brown	Brown Tide	No	Yes	Yes
?	green	CyanoHABs	Yes**	Yes	Yes
	yellow	Golden Alga	No	Yes	Yes
?	dark grey	*Karlodinium, Cochlodinium, Karenia mikimotoi, Alexandrium monilatum*	No	Yes	Yes

*Mammals, birds, turtles, often protected species
**Can cause human or animal deaths

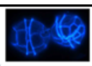
6

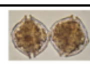
HAB Threat NARW

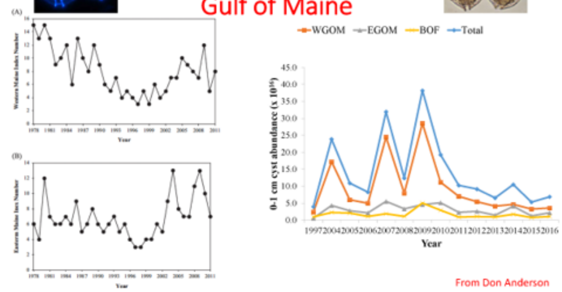
Alexandrium = *Pseudo-nitzschia* > > > >*Dinophysis*
> > > > > > > > > > > > > > All other <u>Known</u> HABS

7

Alexandrium catenella PSTs Gulf of Maine



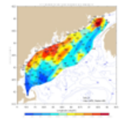




From Don Anderson

8

What controls *Alexandrium* blooms

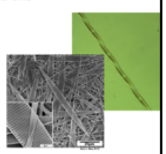


- Cysts
- Interaction of Growth and Loss with oceanographic conditions
  - Changing water masses & Si/N availability
    - Scotia Shelf Water
      - Lower nutrients, Si=N
      - Diatoms use up both, no excess N, no *Alexandrium* bloom
    - Warm Slope Water
      - Higher nutrients, N>SI
      - Diatoms Si limited, N excess, *Alexandrium* bloom
    - Varies months to years (Artic Melt Water role?)
  - Increased "window of opportunity" or not?
    - Cysts germinate over specific bottom water temperature range
    - If bottom waters warm, time they are warm enough increases, earlier bloom, more cysts germinate
    - But if nutrients depleted, maybe earlier bloom but not longer bloom

9

Time Line of *Pseudo-nitzschia* Northwest Atlantic and Gulf of Maine

Nov.-Dec., 1987 PEI Event >100 human illnesses & 3-4 deaths, "*Nitzschia pungens*"
2002 southern Gulf of St. Lawrence Canada—shellfish harvesting closure *P. seriata*
2004, 2005, 2008 Quebec shore Gulf of St. Lawrence sea scallops closure
2008 10 days SW coast NB, Bay of Fundy to US border shellfish harvesting closure
ID 14 species, including toxigenic species, in Gulf of Maine
Sept. 2016 Maine closure shellfish harvesting, shellfish recalls, *P. australis*
Oct. 2016 Bay of Fundy shellfish harvesting closure, *P. australis*
Oct. 2016 MA and RI Precautionary shellfish harvesting closure
Mar 2017 RI Shellfish harvesting closure, *P. australis*
Sept. 2017-Jan 2018, ME shellfish harvesting closures, shellfish recalls



Kate Hubbard, pers. comm.

10

HABs and Climate Change

Environmental Factor

HAB Type	↑ T°C	↑ Stratification	↑ OA	↑ Cultural Eutroph.	Grazing	Hydrography ?????
Diatoms (e.g., *Pseudo-nitzchia* spp.)	↕ +	↓ ++	↕	↓	↕	
Toxic Flagellates (e.g., *Alexandrium, Pyrodinium, Gymnodinium*)	↑	↑ ++	↕	↑	↕	
Benthic (e.g., *Gambierdiscus* spp.)	↕ ++	↑ ++	?	↑	↕	
Fish Killing (e.g., *Heterosigma* spp.)	↓	↑ ++	?	↑ +	↑ +	
High Biomass (e.g., mixed spp.)	↕	↕	↕	↑ ++	↕	
Cyanobacteria (e.g., *Nodularia* spp.)	↑ +	↑ ++	↕	↑ ++	?	
Cell Toxicity	?	?	↑	↕	↕	

From Wells et al. 2015

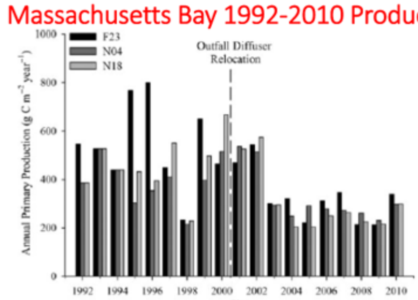
11

Long-Term Changes in Gulf of Maine Productivity

- **Changes in water masses providing nutrients (Townsend)**
  - **Reductions in inflow of deep, nutrient-rich Slope waters?????**
  - **Lead to less productivity**
- **Increased DOC (POC) in rivers (Balch 2012, 2016)**
  - **Yellowing of Gulf of Maine over last 100 yrs**
  - **Lead to lower productivity**
- **Increased T and stratification in some areas**
  - **Earlier spring bloom**
  - **Faster growth rates**
  - **Nutrient limitation**
  - **Net effect on productivity unclear**

12

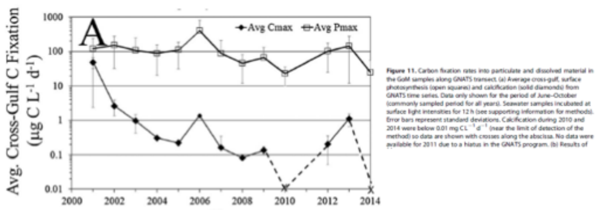
Massachusetts Bay 1992-2010 Productivity



From McManus et al. 2014

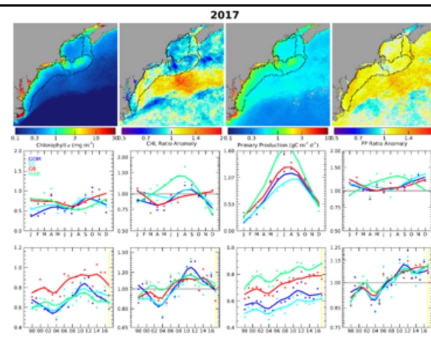
13

Productivity Gulf of Maine N Atlantic Transect



Balch et al. 2016

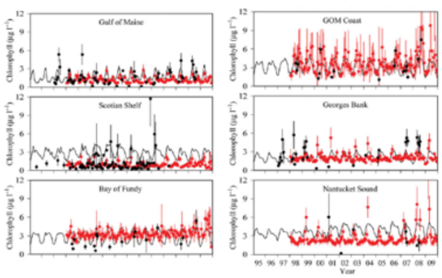
14



Personal communication
Kim Hyde

15

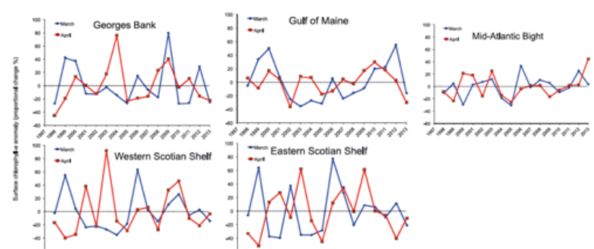
Gulf of Maine Chlorophyll



Tian et al. 2015
Black line Model
Red Dot SeaWIFS
Black Dot Water Sample

16

NE Continental Shelf Spring Chl Anomaly



Saba et al. 2015

17

Future Projections 8 Earth Systems Model Northwest Atlantic

- **Projected 50 yrs**
- **"large spatial and inter-model variability in future trends as well as in the historical mean depth-integrated primary production"**
- **"no conclusion can be reached regarding future primary production in the northwest Atlantic using these results"**

CanESM2
IPSL–CM5A–LR
GFDL–ESM2M
MPI–ESM–LR
HadGEM2–ES
NorESM1–ME
CNRM–CM5
CESM1–BGC

Laboie et al. 2017

18

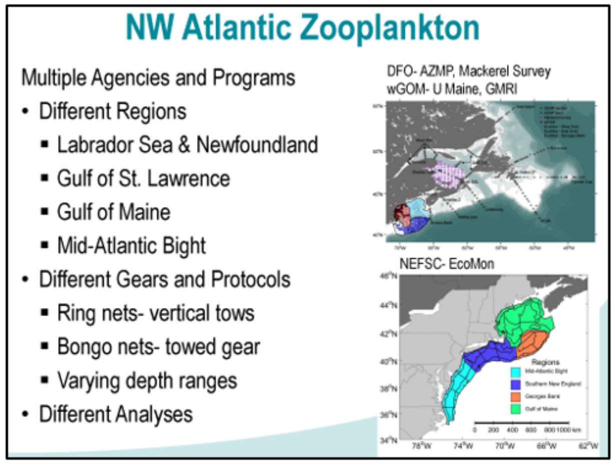
Conclusion

Uncertainty

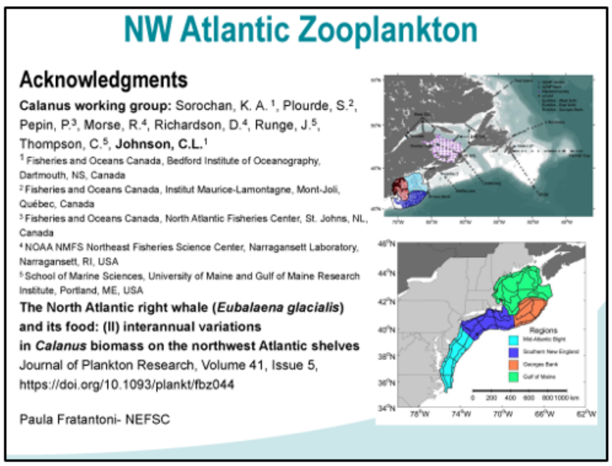
Zooplankton Distribution in the Northwestern Atlantic, Harvey Walsh and Catherine Johnson.

1

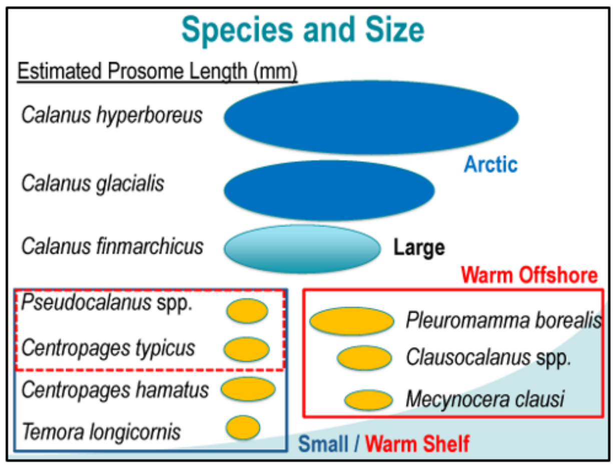
2



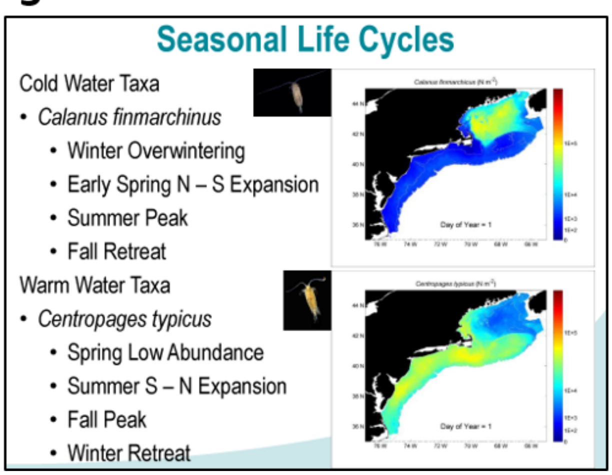
3



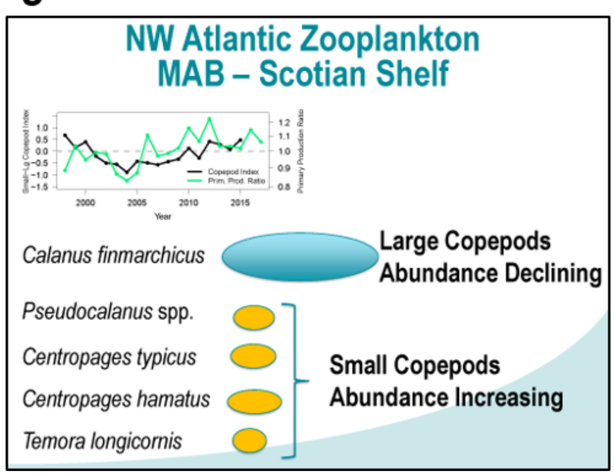
4



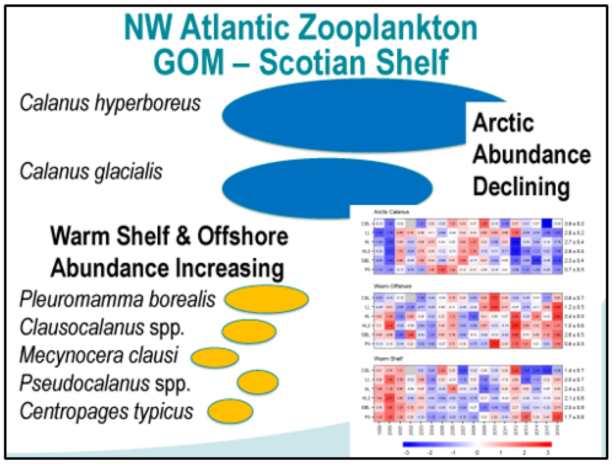
5



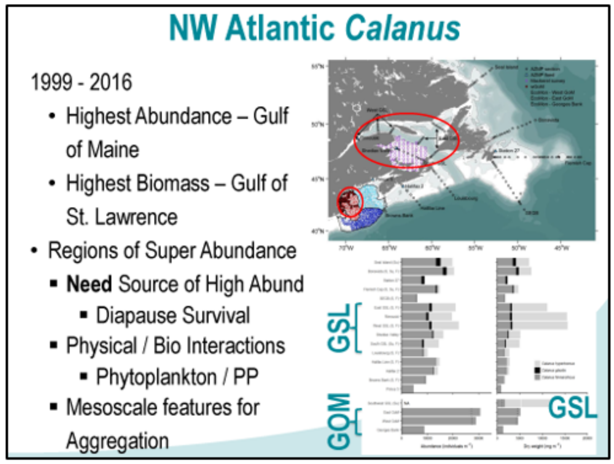
6



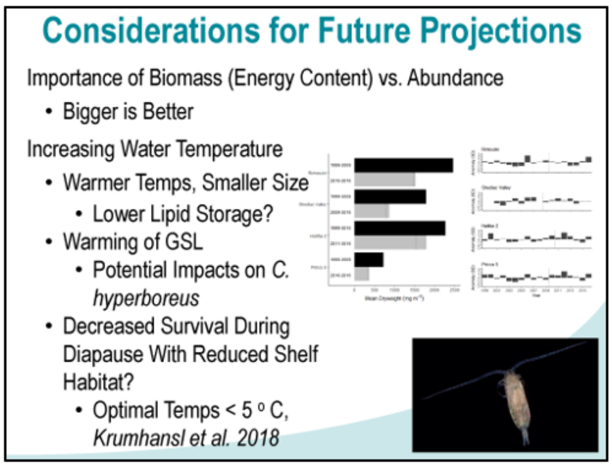
7


NW Atlantic Zooplankton
GOM – Scotian Shelf
Calanus hyperboreus
Calanus glacialis
Arctic
Abundance
Declining
Warm Shelf & Offshore
Abundance Increasing
Pleuromamma borealis
Clausocalanus spp.
Mecynocera clausi
Pseudocalanus spp.
Centropages typicus

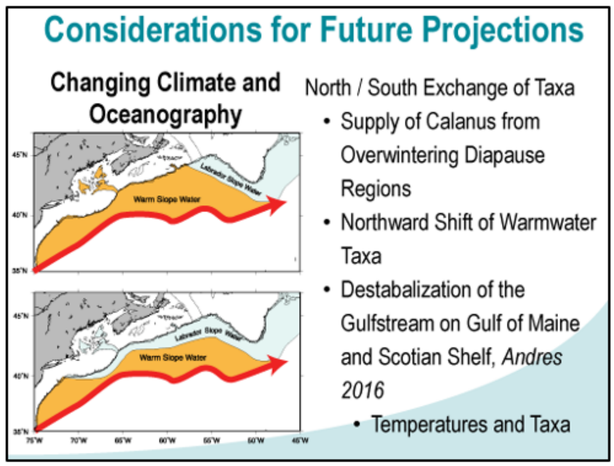
8


NW Atlantic Calanus
1999 - 2016
• Highest Abundance – Gulf of Maine
• Highest Biomass – Gulf of St. Lawrence
• Regions of Super Abundance
▪ Need Source of High Abund
▪ Diapause Survival
▪ Physical / Bio Interactions
▪ Phytoplankton / PP
▪ Mesoscale features for Aggregation
GSL
GOM
GSL

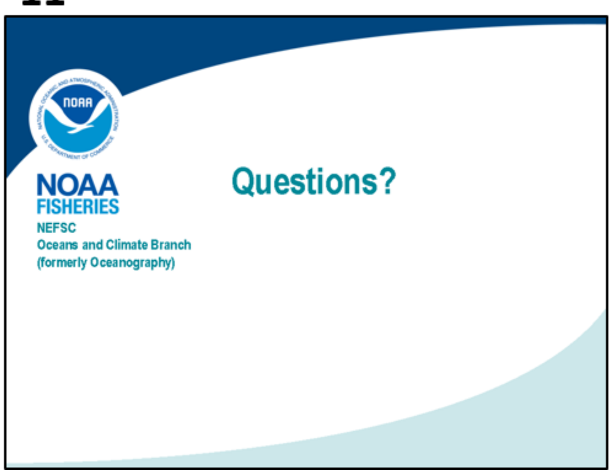
9


Considerations for Future Projections
Importance of Biomass (Energy Content) vs. Abundance
• Bigger is Better
Increasing Water Temperature
• Warmer Temps, Smaller Size
• Lower Lipid Storage?
• Warming of GSL
• Potential Impacts on C. hyperboreus
• Decreased Survival During Diapause With Reduced Shelf Habitat?
• Optimal Temps < 5 ° C, Krumhansl et al. 2018

10

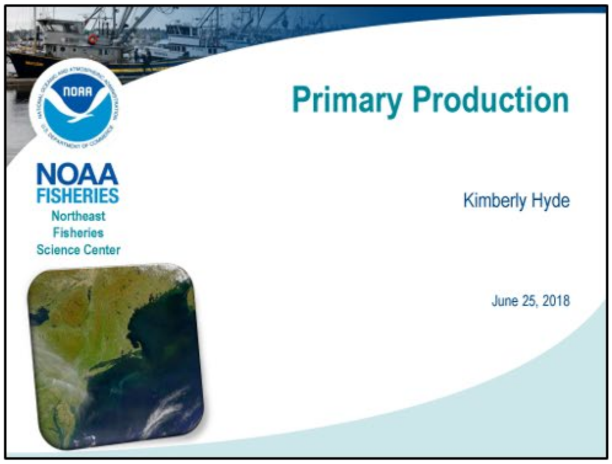

Considerations for Future Projections
Changing Climate and Oceanography
North / South Exchange of Taxa
• Supply of Calanus from Overwintering Diapause Regions
• Northward Shift of Warmwater Taxa
• Destabalization of the Gulfstream on Gulf of Maine and Scotian Shelf, Andres 2016
• Temperatures and Taxa
Warm Slope Water
Labrador Slope Water
Warm Slope Water
Labrador Slope Water

11

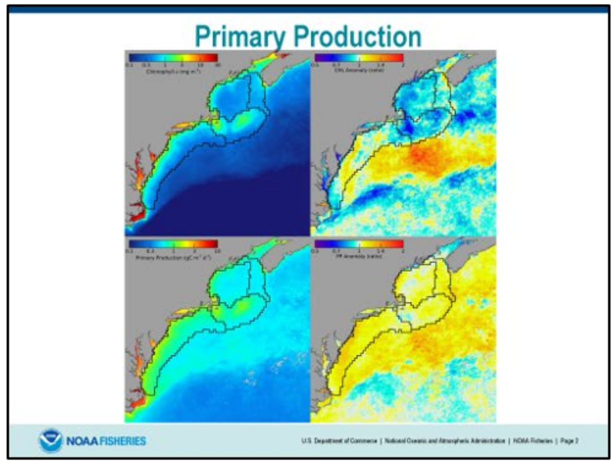

NOAA
FISHERIES
NEFSC
Oceans and Climate Branch
(formerly Oceanography)
Questions?

Primary productivity, Kimberly Hyde.

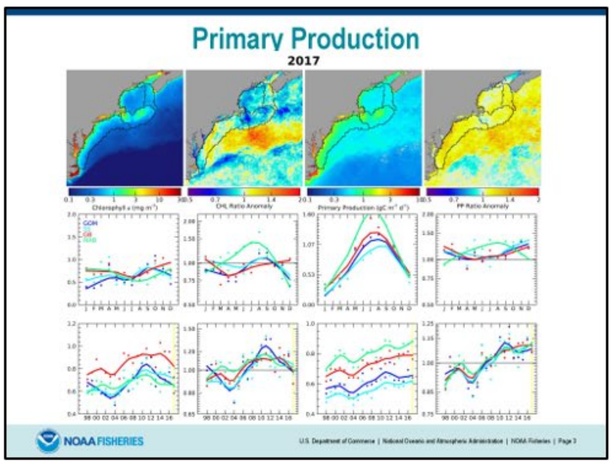
1



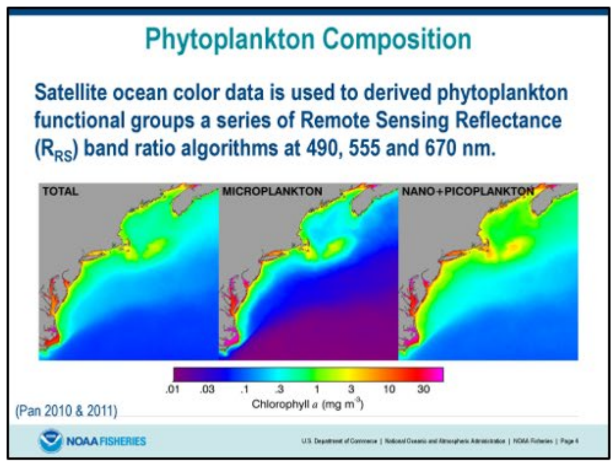
2



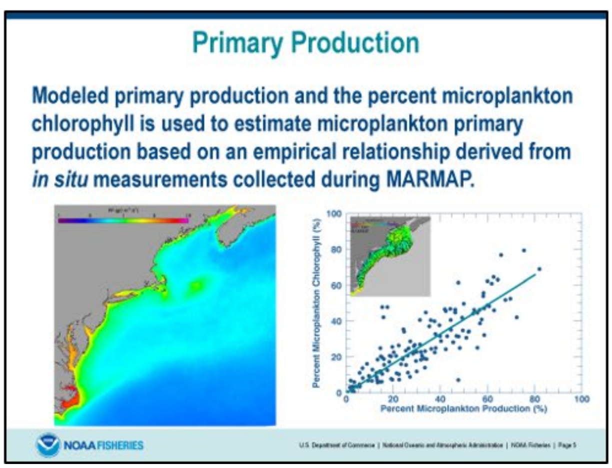
3



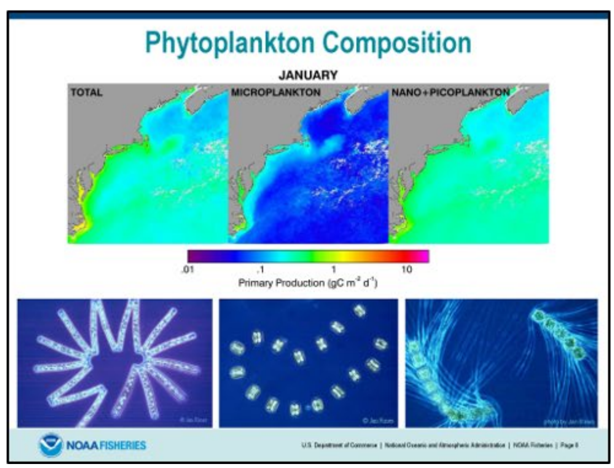
4



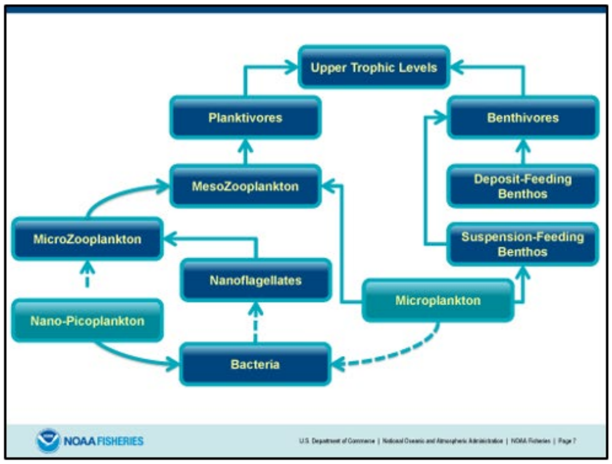
5



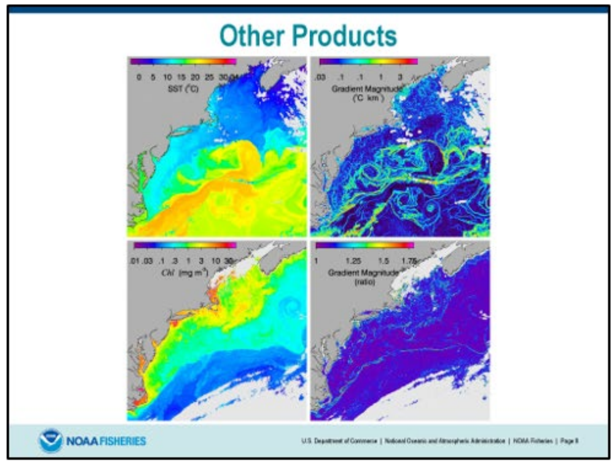
6



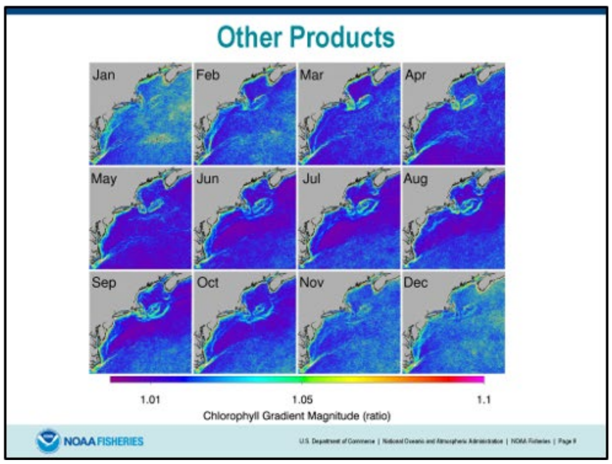
7


Upper Trophic Levels
Planktivores
Benthivores
MesoZooplankton
Deposit-Feeding Benthos
MicroZooplankton
Suspension-Feeding Benthos
Nanoflagellates
Microplankton
Nano-Picoplankton
Bacteria
NOAA FISHERIES

8

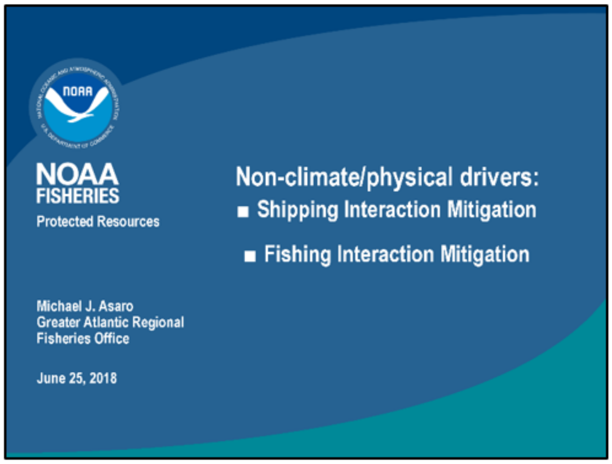

Other Products
NOAA FISHERIES

9

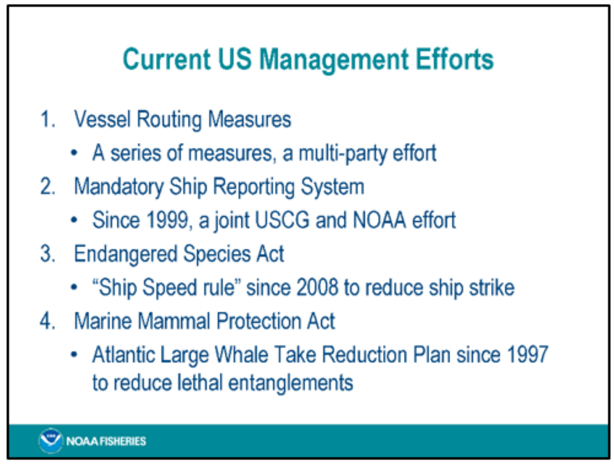

Other Products
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1.01
1.05
1.1
Chlorophyll Gradient Magnitude (ratio)
NOAA FISHERIES

Non-climate/physical drivers: Shipping Interaction and Fishing Interaction Mitigation, Mike Asaro.

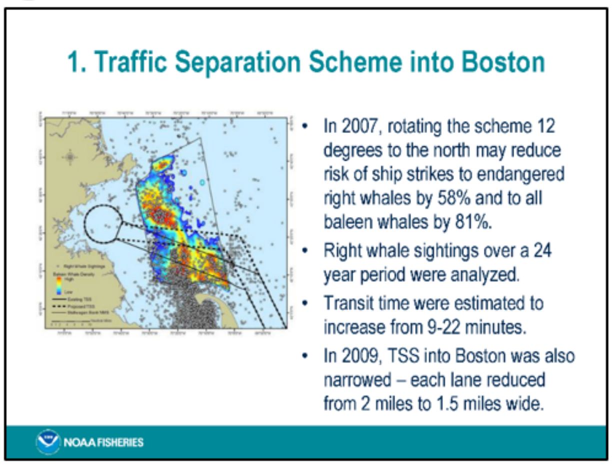
1



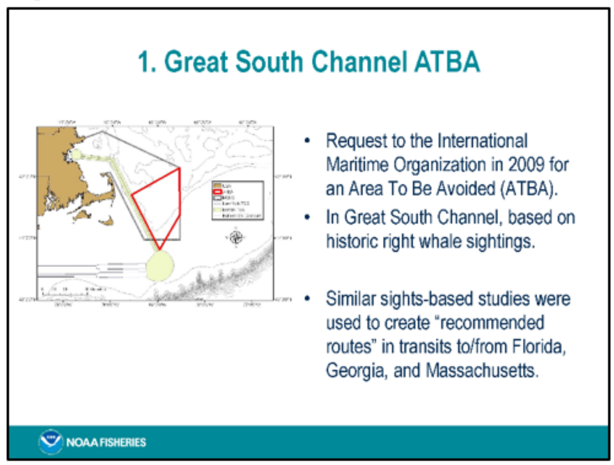
2



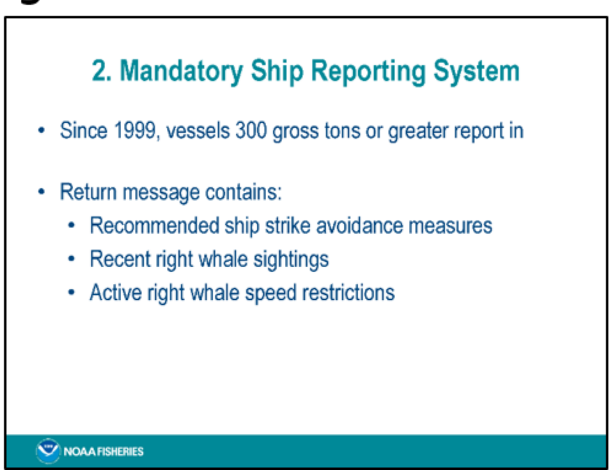
3



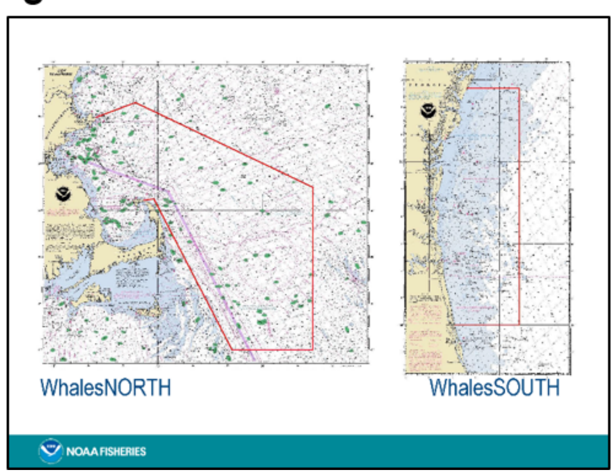
4



5



6



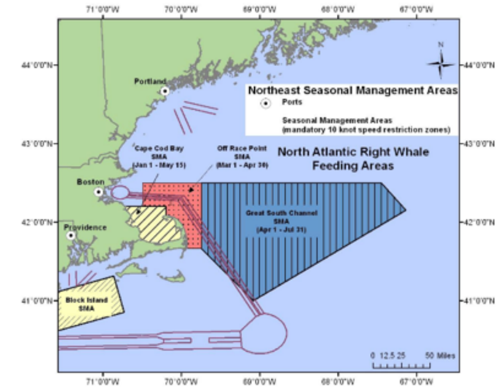
7

3. ESA - Ship Speed Rule

- Since 2008, a two-part strategy of Seasonal Management Areas (SMAs) and Dynamic Management Areas (DMAs)
- Seasonal Management Areas:
  - Mandatory 10-knot speed restrictions for vessels 65 feet in length or greater on the US East Coast
- Dynamic Management Areas:
  - Voluntary, 15-day speed restriction areas triggered by 3 or more right whales

NOAA FISHERIES

8

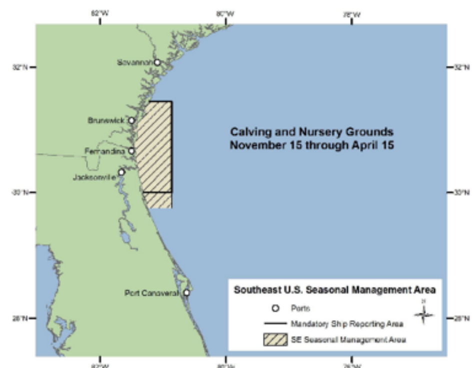


NOAA FISHERIES

9

NOAA FISHERIES

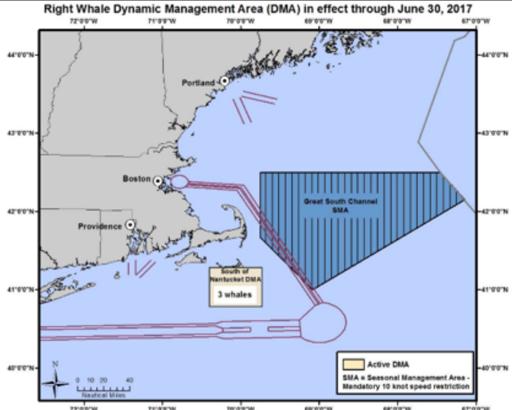
10



NOAA FISHERIES

11

Right Whale Dynamic Management Area (DMA) in effect through June 30, 2017



NOAA FISHERIES

12

4. Atlantic Large Whale Take Reduction Team

- Established in 1996 under MMPA
  - **Purpose**: to develop a take reduction plan for reducing the incidental take of right whales, humpback whales, fin whales and minke whales in commercial trap/pot and gillnet gear in U.S. waters from Maine to Florida
  - **Goal**: reduce serious injuries and mortalities to < PBR (PBR=0 for Right Whales at that time)

NOAA FISHERIES

13

Team Membership

Group	Number
Trap/Pot Industry	18
Gillnet Industry	5*
Conservation/Environmental	6
Academic/Scientific	9
State Managers	14
Federal Managers	5
Fishery Mgmt Organizations	4
Total	61

* Some trap/pot members represent gillnet as well

NOAA FISHERIES

14

July 22, 1997
- Establish TRP
- Weak link requirements
- Effective November 15,1997

December 2000
- Gear marking requirements
- Effective February 2001

January 9, 2002
- Establish SAM and DAM program
- DAM effective February 8, 2002
- SAM effective March 2002

June 25, 2007
- Seasonal gillnet closures in Southeast
- Effective July 2007

October 5, 2007
- Expand weak link requirements
- Implement sinking groundline requirements
- Effective April 2009
- Replaced SAM and DAM program

June 27, 2014
- Vertical line rule
- Additional gear marking requirements
- Effective June 2015

December 12, 2014
- Modification to time/area of closure area
- Effective immediately

May 28, 2015
- Modification to vertical line rule. Effective immediately
- Additional gear marking requirements

NOAA FISHERIES

15

Weak Links and Gear Marking

- Weak links are required coastwide

- Gear marking is required coastwide
  - Including two areas of importance for right whales with specific marks (Jordan Basin and Jeffreys Ledge)
  - 4,008 vessels are required to gear mark with three 12" marks

NOAA FISHERIES

16

Sinking Groundline Rule

- At the 2003 ALWTRT meeting, by consensus, the ALWTRT agreed to two overarching principles associated with reducing large whale entanglement risks:
  - Reducing groundlines in commercial trap/pot gear; and
  - Reducing vertical lines (endlines or buoy lines) in commercial trap/pot and gillnet gear.
- The ALWTRT agreed to focus first on addressing the groundline entanglement risk.
- Lengthy rule development process that ultimately led to the implementation of sinking groundline requirements for all trap/pot fisheries throughout the entire east coast.
  - NMFS finalized in October 2007 and it became effective in April 2009.

NOAA FISHERIES

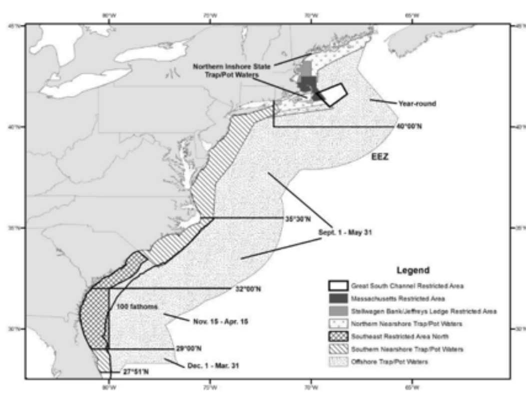
17

Vertical Line Rule

- **Final Rule Published in June 2014**
  - Increase the number of traps per trawl based on area fished and miles fished from shore [(0-3), (3-12), (12+)] and [(0-3), (3-6), (6-12)(12+)]
  - Closure: Created the MA Bay Restricted Area to be closed February 1 – April 30 to trap/pot fisheries (Amended December 2014)
  - Some exemptions to the minimum number of traps per trawl
    - ¼ mile buffer from shore around islands (Monhegan, Matinicus, Ragged Islands).
    - New Hampshire state waters
  - In SER require single pots/traps, weaker weak links and breaking strength of vertical lines
  - More robust gear marking program coast wide and monitoring in the Mid-Atlantic.

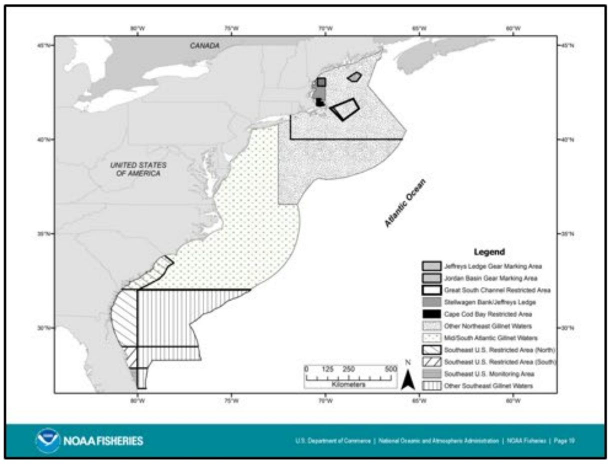
NOAA FISHERIES

18

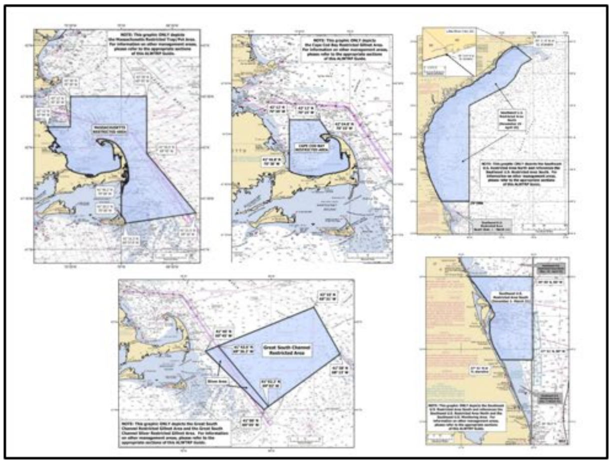


NOAA FISHERIES

19



20



21

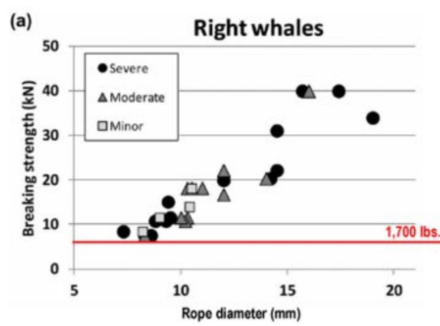
TRT Activities in 2018

- **Planned:** October 2018 TRT meeting to consider measures that necessary to reduce the effects of gillnet and trap/pot gear entanglements on right whales
- **Ongoing:** Two TRT Subgroups investigating the feasibility of:
  1. Ropeless fishing
  2. Whale release rope & gear marking

NOAA FISHERIES

22

1,700 lb. Breaking Strength Rope

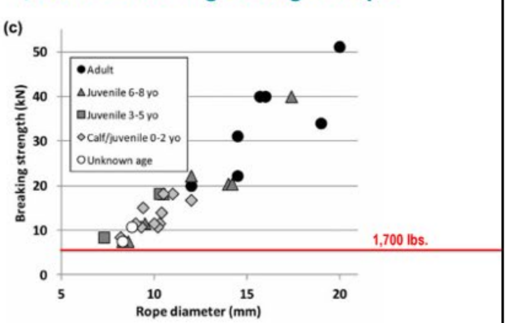


Source: Knowlton *et al.* 2016

NOAA FISHERIES

23

1,700 lb. Breaking Strength Rope

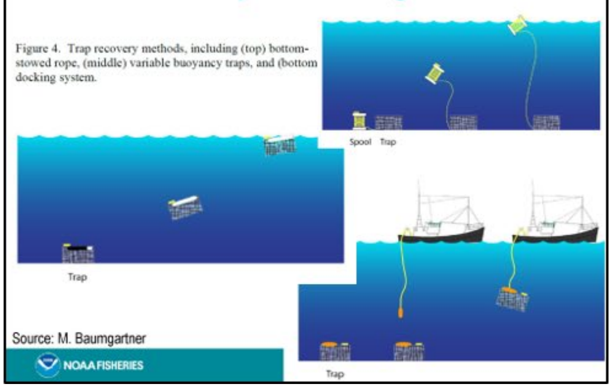


Source: Knowlton *et al.* 2016

NOAA FISHERIES

24

Ropeless Fishing



Source: M. Baumgartner

NOAA FISHERIES

25

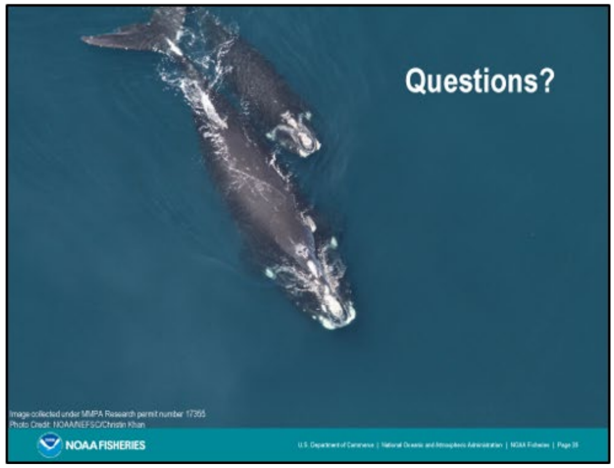
TRT Subgroups

Focused on feasibility

1. Technological feasibility: Does the tech exist?
2. Functional feasibility: Will it work?
3. Economic feasibility: Is it cost-effective?

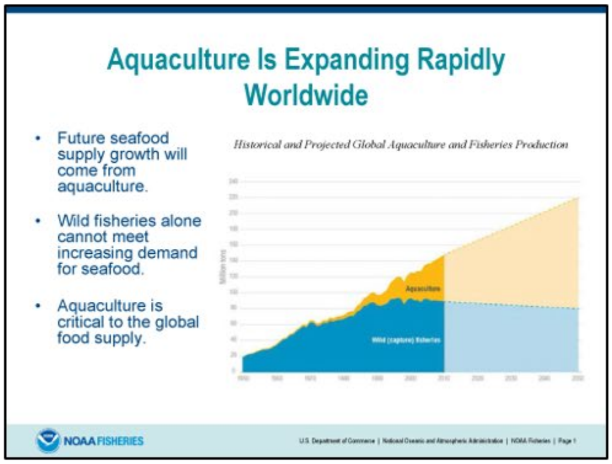
NOAA FISHERIES

26

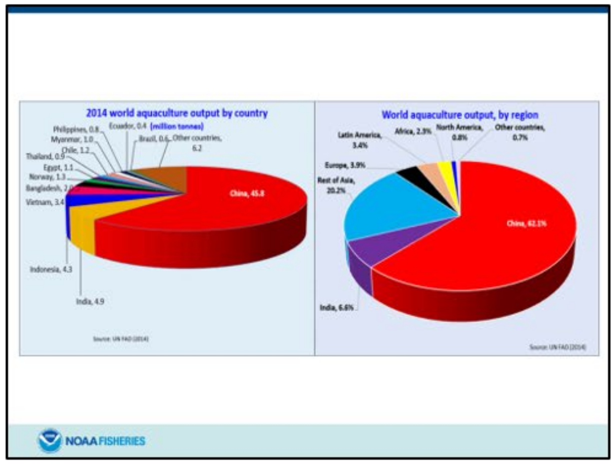


Aquaculture, Kevin Madley.

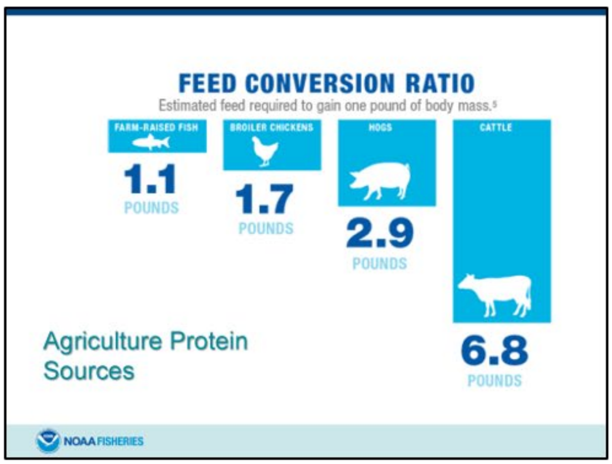
1



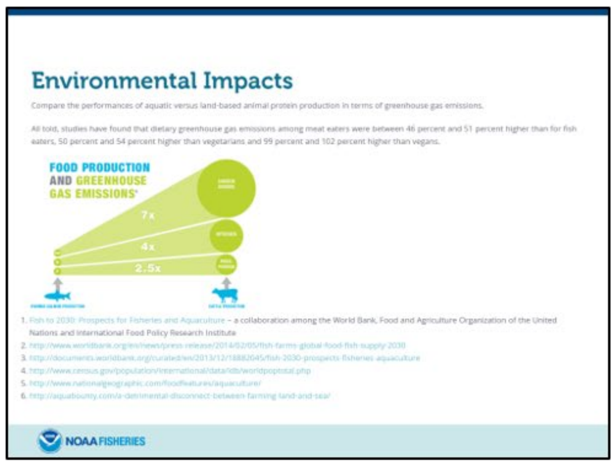
2



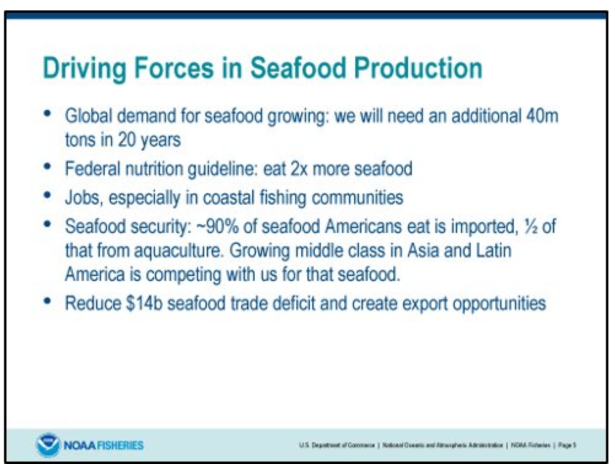
3



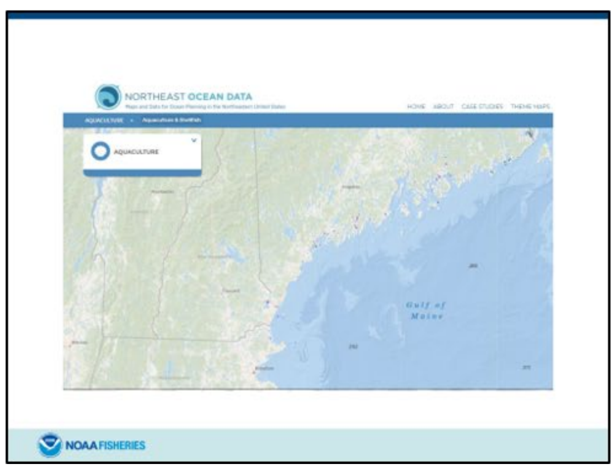
4



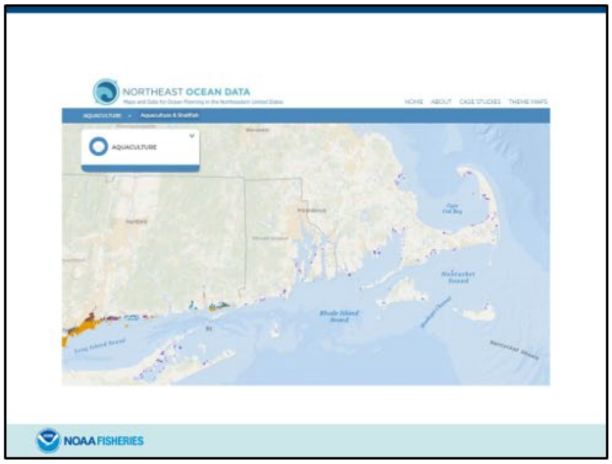
5



6



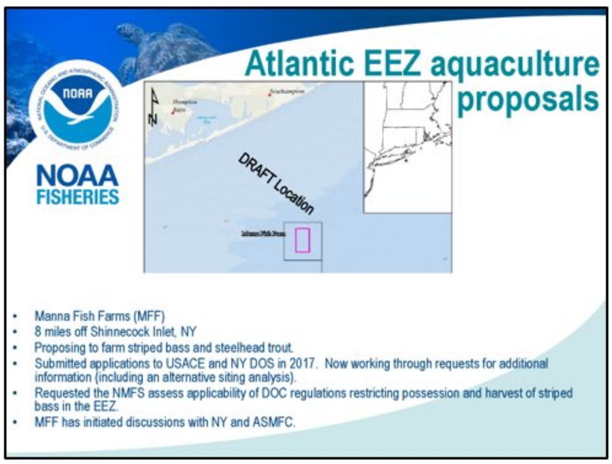
7


NORTHEAST OCEAN DATA
AQUACULTURE
NOAA FISHERIES

8


NOAA FISHERIES
Atlantic EEZ aquaculture operations
Two USACE permits have been provided for current Atlantic EEZ aquaculture operations (pilot scale). Both are blue mussel operations.
Approx. 8 miles off Cape Ann is an blue mussel longline operated by Salem State U.
The second is in Nantucket Sound but as of yet has placed no gear in the water.
Boston
Massachusetts Bay
Cape Cod Bay
Nantucket Sound

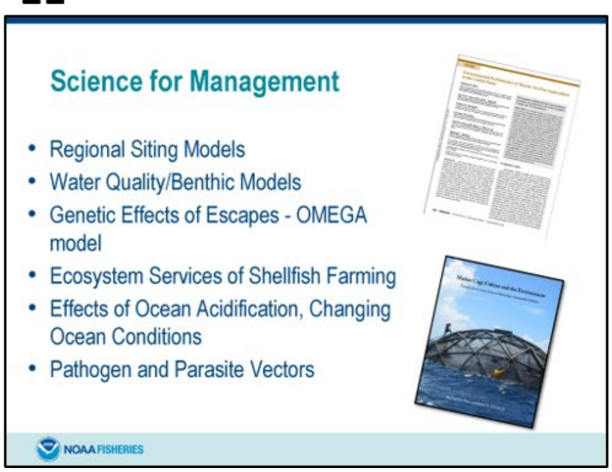
9


NOAA FISHERIES
Atlantic EEZ aquaculture proposals
DRAFT Location
Manna Fish Farms (MFF)
8 miles off Shinnecock Inlet, NY
Proposing to farm striped bass and steelhead trout.
Submitted applications to USACE and NY DOS in 2017. Now working through requests for additional information (including an alternative siting analysis).
Requested the NMFS assess applicability of DOC regulations restricting possession and harvest of striped bass in the EEZ.
MFF has initiated discussions with NY and ASMFC.

10


NOAA FISHERIES
Atlantic EEZ aquaculture proposals
Stakeholders have also contacted NMFS over the past two years seeking guidance on processes to permit EEZ operations, such as:
Tuna farming off NJ and NY
Steelhead trout farming off New England
Blue mussel farming off RI and MA
Oyster farming off RI, MA and ME
Kelp farming off RI, MA and ME
Additionally:
NC has requested NOAA, MAFMC, and SAFMC develop a permit process for aquaculture in the EEZ
SAFMC has expressed interest and begun plans for an aquaculture FMP in the future

11


Science for Management
Regional Siting Models
Water Quality/Benthic Models
Genetic Effects of Escapes - OMEGA model
Ecosystem Services of Shellfish Farming
Effects of Ocean Acidification, Changing Ocean Conditions
Pathogen and Parasite Vectors
NOAA FISHERIES

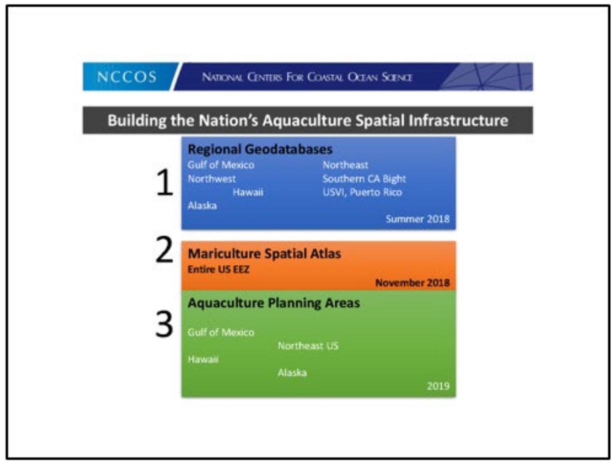
12


NCCOS
National Centers For Coastal Ocean Science
Coastal Aquaculture Siting
Location, Location, Location!

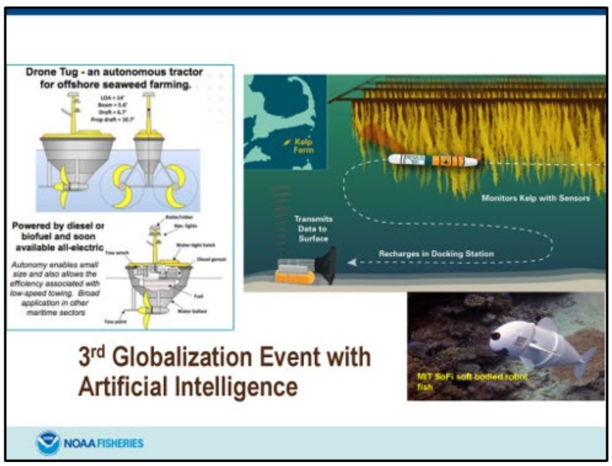
13


NCCOS
NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE
ABOUT RESEARCH PRODUCTS NEWS
A screenshot of the Gulf AquaMapper tool's online interface, which provides data to help with permitting and siting of potential offshore aquaculture ventures.
Credit: NOAA.
This product was developed in partnership with marinecadastre.gov, and similar products are in development for other regions across the United States.
The Gulf AquaMapper is one of many coastal planning tools designed to assist managers, planners, and industry with sustainable aquaculture development, all of which can be found on NCCOS's Coastal Aquaculture Planning Portal.
For more information, contact James.Morris@noaa.gov.

14


NCCOS
National Centers For Coastal Ocean Science
Building the Nation's Aquaculture Spatial Infrastructure
1
Regional Geodatabases
Gulf of Mexico
Northwest
Hawaii
Alaska
Northeast
Southern CA Bight
USVI, Puerto Rico
Summer 2018
2
Mariculture Spatial Atlas
Entire US EEZ
November 2018
3
Aquaculture Planning Areas
Gulf of Mexico
Northeast US
Hawaii
Alaska
2019

15


Drone Tug - an autonomous tractor for offshore seaweed farming.
Powered by diesel or biofuel and soon available all-electric
Autonomy enables small size and also allows the efficiency associated with low-speed towing. Broad application in other maritime sectors
Kelp Farm
Monitors Kelp with Sensors
Transmits Data to Surface
Recharges in Docking Station
3rd Globalization Event with Artificial Intelligence
MIT SoFi soft bodied robot fish
NOAA FISHERIES

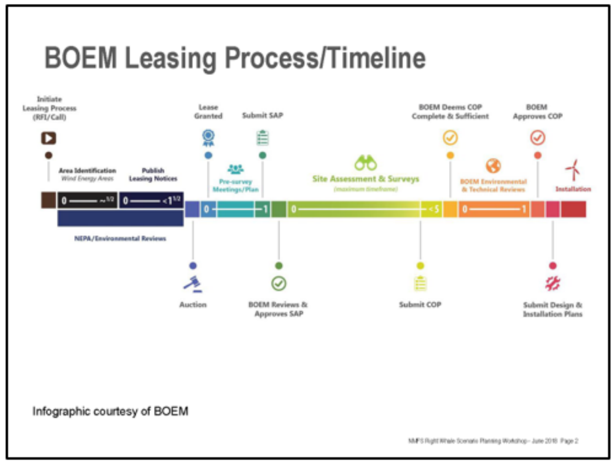
16


Questions?
Kevin Madley
NMFS Greater Atlantic Region
Aquaculture Coordinator
kevin.madley@noaa.gov

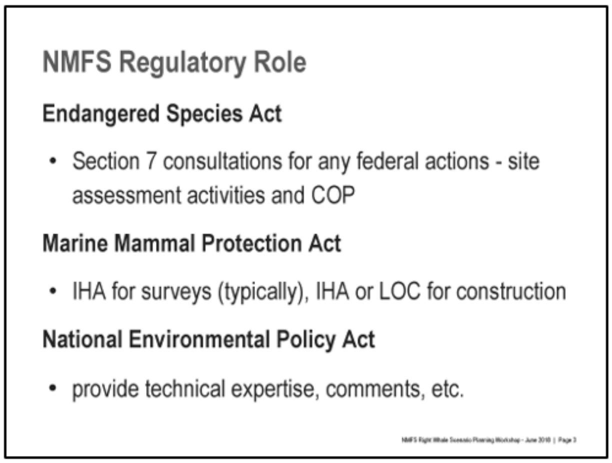
Offshore wind – U. S. Atlantic Coast, Julie Crocker.

1

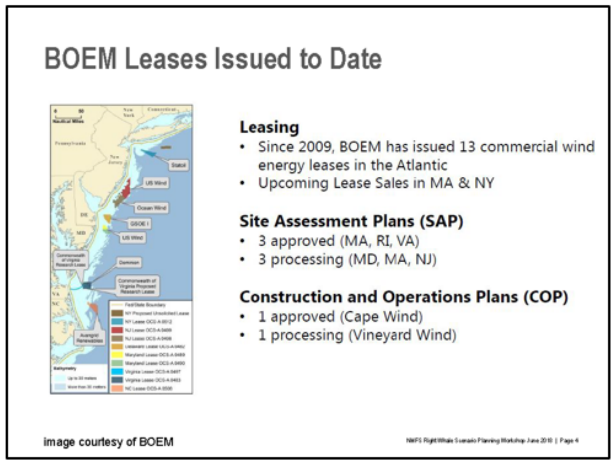
2



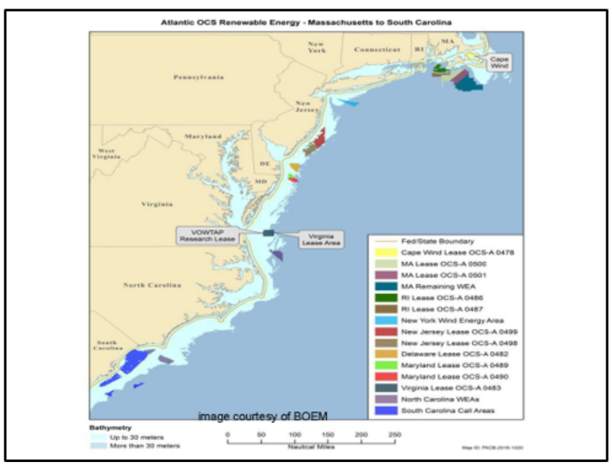
3



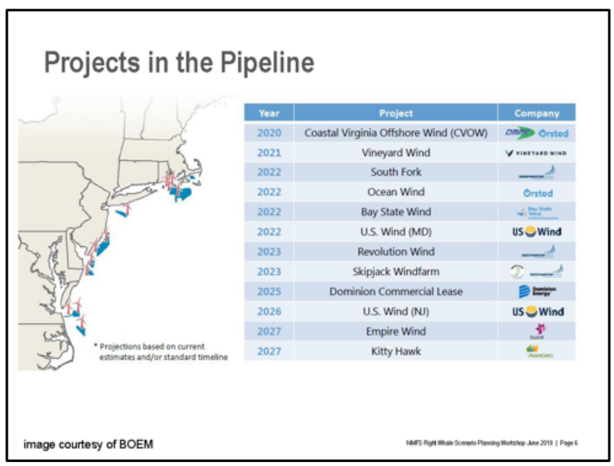
4



5



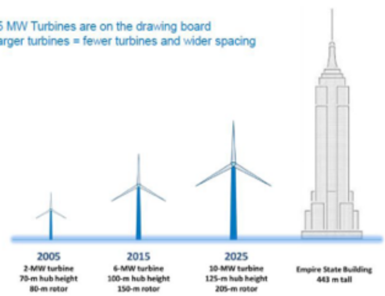
6



7

What Does a Wind Farm Look Like?

15 MW Turbines are on the drawing board
Larger turbines = fewer turbines and wider spacing

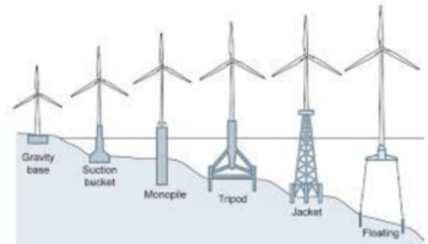


images: National Renewable Energy Laboratory

NMFS Right Whale Scenario Planning Workshop June 2018 | Page 7

8

Foundations and Construction

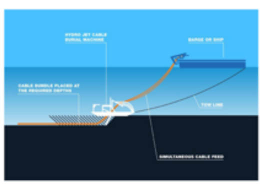


- Depths of 0-50m currently considered viable for existing foundation technology
- "floating" turbine for potential deeper water use being tested at U. Maine
- Spacing between turbines depends on turbine size, site conditions and other concerns
- Piles need to be driven into the seabed with specialized equipment
- Likely no more than one foundation installed per day, with pile driving up to a few hours

NMFS Right Whale Scenario Planning Workshop June 2018 | Page 8

9

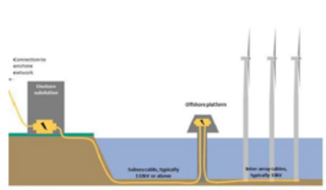
Construction/Installation



Images: GE, Deepwater Wind, doi ts.org Page 9

10

Getting the Electricity to Land



Offshore Wind Electric Cable Schematic from Turbines to On-shore Grid Connection

Offshore Wind Electric Service Platform (Substation)

- Cables are typically buried 6 feet below the sea bed - likely with a jet plow or similar equipment
- There are likely to be "'inter-array' and 'export' cables and may be more than one electric platform

images: National Renewable Energy Laboratory

NMFS Right Whale Scenario Planning Workshop June 2018 | Page 10

11

Considering Right Whales and Offshore Wind

Pre-Construction

- noise exposure during shallow hazards surveys
- increased vessel traffic during surveys

During Construction

- noise exposure - pile driving
- habitat disturbance - foundations and cable laying
- increased vessel traffic
- displacement from area?
- effects to prey?

NMFS Right Whale Scenario Planning Workshop June 2018 | Page 11

12

Long Term/Post-Construction Considerations

Displacement/Avoidance of the area?

Changes in fishing effort/distribution?

Shifts in vessel traffic?

Operational noise (likely not a concern)

Prey/Oceanographic changes?

image: USCG

13


Lots of Information Available Online!
https://www.boem.gov/Renewable-Energy/
https://www.boem.gov/Offshore-Wind-and-Maritime-Industry-Knowledge-Exchange/
http://dwwind.com/
https://www.vineyardwind.com/
https://www.equinor.com/en/what-we-do/empirewind.html
https://baystatewind.com/
https://www.4coffshore.com/windfarms/maryland---us-wind-inc-united-states-us4x.html
Image: deepwater wind | Page 13

APPENDIX 7. Full transcripts of workgroup Scenario Deepening worksheets Note: Participants were encouraged to think as broadly and unrestrained as possible, therefore, what is recorded here includes thoughts that are not fully formed and do not represent agency policy.

In your scenario: **Scenario Name: Limited Options But Alive**

Main region climate features:		
• Weakening AMOC • Increased nutrients • Change in prey field	• Change in competitors (fish on the move) • Unknown change in residence time in old and novel habitats	
Notable non-climate features and developments:		
• Increase in HAB episodic events • Changes in fishery targets and practices • Energy exploration (wind, oil, gas) increases		
Significant events and developments:		
2020-2030	2030-2050	2050-2075 • Economic viability of fossil fuel driven activities decrease • Decrease in wild caught lobster • Increase in black sea bass and aquaculture
What are the main changes in conditions/impacts on right whales:		
Region 1? • Increase in cold snaps/ short, cold winters • Increase in poor calving conditions or increase in variability	Region 2? • Prey abundance increases but prey size and prey quality decreases → feeding rates increase • Increased residence time to feed in region	Region 3? • Prey abundance increases but prey size and prey quality decreases → feeding rates increase

In your scenario: **Scenario Name: Thrive**

Main region climate features:		
• Foraging = dense prey patches • AMOC = more slope water, increased productivity, zooplankton, phytoplankton? • Need to understand relationship between AMOC and primary production		
Notable non-climate features and developments:		
• Increased societal value → increased awareness → increased economic activity → increased funding → political will • Adoption of ropeless fishing (fishery may be different, i.e. no lobsters but crabs) • Whale safe aquaculture, shipping renewables	• Remediation of human activities happens quickly • Improved surveillance → better understanding of distribution/demographics (acoustics, tagging, drones) • Improved ability to predict episodic events and to respond • Ability to detect prey aggregations and to manage preemptively	
Significant events and developments:		
2020-2030 • Ropeless → experimentation prototype development • Whale safe lobster campaign • Quieting ships → prototype of quiet ships	2030-2050 • Mass production/reduced costs for ropeless technology • Mass production of quiet ships	2050-2075 • Phased implementation of ropeless fishing • Implementation of quiet shipping
What are the main changes in conditions/impacts on right whales:		
Region 1? • Conditions for calving are favorable (e.g., warm and calm) • Full utilization of range • Improved socialization/communication • Improved ability to find mate	Region 2? • Expansion of calving into this region • Full utilization of range • Improved socialization/communication • Increased awareness of value for protecting RWs	Region 3? • *Calanus* moving north, optimal feeding moves north • Full utilization of range

In your scenario: **Scenario Name: Dive**

Main region climate features:

- Reduced Scotian Shelf water in the Gulf of Maine
- Increased salinity in Gulf of Maine
- Warming
- Silica limitation → Fewer diatoms → Fewer copepods
- Potential poor survival of copepods during winter
- More frequent cold snaps in south
- Shifting copepod phenology and increased match/mis-match
- Distance between calving and foraging grounds increases → increased migratory cost
- Sea level rise → societal disruption → conflict

Notable non-climate features and developments:

- Shifting budgets to deal with weather and natural disasters
- Change in fishing – Less lobster? More sea bass pots? More aquaculture? More entanglement… RW lost the conflict, no political will to force change in fisheries
- More windfarms and whales totally displaced
- Disease
- Bigger, faster, louder vessels
- Oil and gas development along coast
- Repeal of ocean monuments
- Increasing global conflicts and RW at the bottom the list of concerns

Significant events and developments: In the DIVE scenario we assumed there was a continuous 5% pop decline

2020-2030	2030-2050	2050-2075
• ~ 361 (2020) RW left • First commercial scale wind farm • Election • Black sea bass, Jonah crab fisheries increase	• ~ 216 (2030), ~129 (2040) RW left • Oil exploration, seismic surveys ramp up • Human population reaches 9 billion • Lobster collapse in Gulf of Maine • Black sea bass, Jonah crab fisheries increase	• ~ 77 (2050), ~ 21 (2075) RW left • First oil well off Gulf of Maine • Black sea bass, Jonah crab fisheries increase • 10.8 billion humans by 2075

What are the main changes in conditions/impacts on right whales:

Region 1?	Region 2?	Region 3?
• Stop visiting SEUS calving grounds or increased migratory cost • Industrialization of ocean (oil & gas, wind, vessels/shipping) • Decreased ocean protections (fishing closures, protected areas) • Increased sea bass & Jonah crab out without concern for entanglement • Increased aquaculture without concern for entanglement & habitat loss • Poor water quality/increased coastal runoff • Decreased genetic diversity • Decreased health • Increased stress/risk of disease	• Calving grounds shift north into Region 2, leads to gillnet risks – new conflict • Lose foraging habitat (copepods move north) • Industrialization of ocean (oil & gas, wind, vessels/shipping) • Decreased ocean protections (fishing closures, protected areas) • Increased sea bass & Jonah crab out without concern for entanglement • Increased aquaculture without concern for entanglement & habitat loss • Poor water quality/increased coastal runoff • Decreased genetic diversity • Decreased health • Increased stress/risk of disease	• Warm….lobsters also dive. Less lobster fishing effort/less pot gear in the water • Industrialization of ocean (oil & gas, wind, vessels/shipping) • Decreased ocean protections (fishing closures, protected areas) • Increased sea bass & Jonah crab out without concern for entanglement • Failure to collaborate with Canada • More whale watching, more stress • Increased human population due to climate shifts • Decreased genetic diversity • Decreased health • Increased stress/risk of disease

In your scenario:		Scenario Name: Support and Survive
Main region climate features:		
• Temporal mismatch between phytoplankton bloom/production, zooplankton production and whale feeding • Suboptimal zooplankton composition and quality • Region scale warming above long term climate trends • Increased frequency of HABs		
Notable non-climate features and developments:		
• Slow, quiet, reactive vessels • Dynamic/responsive management • Effective surveillance of whales • Whale friendly fishing/aquaculture • Strong marketing →social, political support for conservation		
Significant events and developments:		
2020-2030 • Improved whale & climate science • Maintain current ship-strike regulations • Reduction of fishery mortality/entanglement • Implementation of whale-friendly fishing	2030-2050 • Recognition of anthropogenic climate impacts	2050-2075 • Degraded/ing climate conditions • Senescent/Low reproduction whale population • Implementation of sustainable fishing/commercial practices
What are the main changes in conditions/impacts on right whales:		
Region 1? • Poor calving conditions • Poor perinatal survival (related to episodic events) • Continuing and improving ship-strike risk management • No additional aquaculture/fisheries threats • "Whale safe" offshore energy development	Region 2? • Calving? • Feeding habitats? (poor zooplankton composition) • Continuing and improving ship-strike risk management • No additional aquaculture/fisheries threats • "Whale safe" offshore energy development • Whale safe fishing	Region 3? • Suboptimal feeding • More occurrence in Canadian waters • Strong bilateral cooperation • Continuing and improving ship-strike risk management • No additional aquaculture/fisheries threats • "Whale safe" offshore energy development • Whale safe fishing

APPENDIX 8. Full transcripts of workgroup Generating Options worksheets. Items below the dashed line includes factors/actions that could be taken under consideration to help us prepare for the next 30-50 years. Note: Participants were encouraged to think as broadly and unrestrained as possible, therefore, what is recorded here includes thoughts that are not fully formed and do not represent agency policy.

Scenario Name: Limited Options But Alive

If you knew this scenario was the future, what actions would you take now / within 5 years to prepare for/achieve/avoid this?

Science/Research	**Management – Vessels**	**Relationships/Collaboration**
• Understand feeding: can we farm copepods? • Improvements in carcass detection and tracking and recovery • Understand habitat in future • Better forensic analysis to determine cause of death & other biological info (reduce 50% non-ID mortality) • Technology to tag & track safely • Passive acoustics, real time, satellite, drones • Improved health assessments, especially relative to fecundity, calf health -- • Changing oceanographic conditions, right whale biology (i.e. what are thermal limits?) • Technology improvements for expanded enforcement • Cumulative effects of multiple stressors	• Better understand avoidance behavior • Expand speed restrictions to MA and add smaller vessels -- • Hovercraft	• Consumer driven efforts are key • Grassroots awareness and activism • Partner with organizations on outreach and awareness • National HAB program coordination • Ship designers • Socioeconomics -- • Oprah, Ellen, Amazon, Google
Management - Fishing	**Management – Other (e.g., aquaculture, wind energy, noise)**	**Other**
• Ropeless fishing paramount • Proactive engagement for whale smart fishery developments and planning with changing climate and ocean conditions --	• Whale safe and industry safe approach • Dynamic management for important places, threats (mobile protected areas) • Expansion to Region 4 • Enforcement – flexible as management • Aquaculture – change farms/methods to whale safe now -- • Whatever industry may develop e.g., autonomous vessels	• Incentive programs for positive behavior • Buy local can be positive to reduced ship traffic • Understand ramifications of RW measures to other species • Information technology for decision making -- • War • Implement decisions quickly

Scenario Name: Thrive

If you knew this scenario was the future, what actions would you take now / within 5 years to prepare for/achieve/avoid this?

Science/Research	**Management – Vessels**	**Relationships/Collaboration**

• Ropeless traps – engineering → improve catchability
• Grappling – need way to mark trawl (acoustic?) refine techniques
• Economic research on desirability of whale-safe lobsters
• Improved modeling of *Calanus* aggregations
• Improve inputs to dynamic management
  o Non-invasive, long-term tags
  o Passive acoustics
  o Aerial surveillance
-- 	
• Vessel detection of whales e.g. sonar
• Aquaculture/wind farm: whale behavior/avoidance
• Episodic events: develop techniques to avoid impacts to whales
	• Improved dynamic management – slow speed and avoid aggregations
	• Electric vessels?
	• Assess/modify ship-strike rule
	-- 	
	• Electrify whale watch vessels as first step of outreach tool (whale sense)
		• Involving industry in ropeless trap development
		• Involving engineering community in developing technologies – connect engineers with fishermen
		• Involve philanthropic community
		• Involve aquaculture/wind industry with whale awareness
		• Involve economists to research incentives/profitability
		-- 	
		• Need X prize for ropeless technology

Management - Fishing	**Management – Other (e.g., aquaculture, wind energy, noise)**	**Other**
• Ropeless traps – prioritization of funding/grants • Grappling • Subsidy program • Mandate weak rope with buyback of old rope • Incentive to use ropeless in order to access a closed area --	• Designate zones for no activity • Need best practices and monitoring of impacts • Effects of displacement of fishermen --	• Promote whale-safe marketing • Create a market for whale-safe lobsters as an incentive for fishermen to adopt new technology • Promotion of RW – social science, media, communication • Need infrastructure to monitor/assess/ predict episodic events → management response --

Scenario Name: Dive

If you knew this scenario was the future, what actions would you take now / within 5 years to prepare for/achieve/avoid this?

Science/Research	**Management – Vessels**	**Relationships/Collaboration**
• Ability to study/quantify the effectiveness of management actions • Gear technology • Forecasting future distribution – zooplankton and whales • Enhance observation capability through new technology • Multiple stressor problem -- • Long term tags for RWs	• Understanding how increased ocean infrastructure will shift vessel patterns and change risk • Adaptive ship/whale co-occurrence plan • Change "speed limit" areas to required rather than voluntary and broaden (reduce) vessel size below 65 feet -- • Noise reduction / quieting technology	• States (esp. MA and ME) and Canada • Continued data sharing • NGOs → consumer awareness campaign to push industry changes ("whale safe lobster") • Private investment in technology • "neutral" party to push change/ increase awareness, maybe University of Maine or Lobster Institute • "Whale safe aquaculture" --

Management - Fishing	**Management – Other (e.g., aquaculture, wind energy, noise)**	**Other**

• Flexibility for short term management actions/dynamic management
• Politically & economically viable solutions
  o Weak rope
  o Incentivized access to closed areas (ropeless)
  o Temporal management of lines
• Trap number reductions – drop overhead $, maintain revenue
• Funding
  o Emergency relief plan coupled with contingency closure plan
  o Subsidy for ropeless and/or marking
-- 	
• Goal of ropeless by 2030 with milestones along the way
• Traps for technology
	• Active design engagement for aquaculture technology to reduce entanglement risk
	• Ability to apply lessons learned to the next project (wind and aquaculture)
	• Siting – to minimize conflict with whales
	• Keeping oil & gas development out of Atlantic
	-- 	
		• Funding – more dedicated staff
		• Stronger engagement with ocean planning processes at national, local and regional level
		• Community resiliency
		  o Marketing programs
		  o Alternatives to fishing
		  o Diversify lobster fishery portfolios
		• Balanced approach across industries
		• Public and industry buy-in
		-- 	

Scenario Name: Support And Survive

If you knew this scenario was the future, what actions would you take now / within 5 years to prepare for/achieve/avoid this?

Science/Research	**Management – Vessels**	**Relationships/Collaboration**
• Better understanding of noise effects related to offshore energy development • Improve methods for understanding spatial & temporal movement of whales (finer scale) – tagging, prey distribution • Better understanding fine scale whale behavior around gear, ships – tagging, prey distribution • Higher resolution climate modeling • Gear research • Better understanding of sources of mortality, reproductive failure, and factors affecting reproduction • Better understanding of fishing effort ------------------------------ • Vessel traffic changes related to offshore energy? • Connection between aquaculture, HABs, disease	• Maintain/strengthen ship strike measures • Maintain/strengthen enforcement of ship-strike rule • Evaluate effectiveness of ship-strike measures ------------------------------ • Address vessels <65 foot LOA • Vessel quieting technology development	• Collaborate with Canada & expand collaboration • Work with fishing industry to develop whale-safe gear and gear marking • Incorporate social science into management • Liaison with constituents (NGOs, industry etc.) • Congressional relations • Maintain/strengthen relationship with federal and state partners • Internal relationships ------------------------------ • Dynamic response as S.O.P. – need buy-in
Management - Fishing	**Management – Other (e.g., aquaculture, wind energy, noise)**	**Other**
• Begin development/implement whale-safe fishing gear including gear marking, ropeless • Maintain/strengthen enforcement of gear regulations • Respond to lawsuits • Evaluate effectiveness of fishing regulations • Improve gear identification when removed from animals ------------------------------ • Increase reporting of fishing effort/activity	• Maintain & implement MMPA import rule, ESA section 7 consultation etc. ------------------------------ • Aquaculture planning, permitting etc. • Improve adaptive management structure	• Social, marketing, political support for conservation • Continued/expanded support for stranding response to evaluate effectiveness of measures • Recognizing effects of climate change ------------------------------

APPENDIX 9. Full transcripts of priorities (includes top two for each category (science and research, fishing, shipping, relationships, and other) plus two wildcards that can include any category) for the four breakout groups on generating priorities. Note: Participants were encouraged to think as broadly and unrestrained as possible, therefore, what is recorded here includes thoughts that are not fully formed and do not necessarily represent agency policy.

Group 1

Science & Research

- Tag development and testing
- Climate modeling/monitoring (phyto/zooplankton)

Fishing

- Ropeless gear development and testing
- Initiate management rulemaking for use (exp. open closed areas)

Shipping

- Reevaluate (maintain) effectiveness of ship strike rule(s)
- Incentives to shippers (small and large) to slow/avoid

Relationships

- Oh, Canada!
- Public awareness: partner with past successful NGOs/PR/Marketing

Other

- Aquaculture (proactive and whale safe)
- Maintain current regulatory framework

Wildcard

- Maintain current monitoring/detection/response programs
- Investigate whale response to vessels

Group 2

Science & Research

- Gear technology
- Distribution, reproduction, behavior

Fishing

- Ropeless fishing
- Gear enhancement

Shipping

- Evaluate effectiveness of current rule
- Enforcement

Relationships

- Consumer awareness: social media
- Industry engagement and incentives

Other

- Proactive whale safe measures
- Flexible, nimble

Wildcard

- X-prize
- Consumer driven efforts

Group 3

Science & Research

- Spatial/temporal whale/copepod movement
- Climate/habitat modeling

Fishing

- Gear research / Technology development
- Reduce line in water column e.g., trap limits, grappling

Shipping

- Analyze vessel traffic relative to whale distribution and planned activities to inform ship strike rule
- Address vessels less than 65 feet

Relationships

- Protect/maintain current measures
- Industry engagement in problem solving

Other

- Social science/marketing
- Incentivizing innovation/non-traditional

Wildcard

- Telemetry development
- Understanding whale sensing/reaction

Group 4

Science & Research

- Where are they now and where are they going to be
- Cumulative stressors
- Acoustics – hearing thresholds and impacts of sound sources and soundscape

Fishing

- Ropeless gear
- Proactive emerging fisheries management

Shipping

- Expand measures to smaller boats, other geographies
- Whale safe ships of the future

Relationships

- Industries and federal agencies
- NGOs, public support, and social science

Other

- Aquaculture and blue economy industries (renewables)
- Dynamic/flexible management including enforcement
- Emergency response for episodic events