EXTERNAL PEER REVIEW OF ATLANTIC HERRING MANAGEMENT STRATEGY EVALUATION

March 13-15, 2017
Embassy Suites, Boston Logan Airport
Boston, Massachusetts

Panel Members
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Dr. Gavin Fay
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PEER REVIEW SUMMARY REPORT

EXECUTIVE SUMMARY

The Atlantic Herring Review Panel (hereafter referred to as the "Panel") was convened by the New England Fishery Management Council (NEFMC) on March 13-15, 2017 in Boston, MA to review the Atlantic herring management strategy evaluation (MSE) process. The MSE was carried out by NEFMC and Northeast Fisheries Science Center staff from 2016-2017 and was a collaborative process, involving stakeholder input through two public workshops. The MSE was developed to support the goals of Amendment 8 to the Atlantic Herring Fishery Management Plan which aims to develop and implement a long-term harvest control rule for specifying the acceptable biological catch (ABC) for the Atlantic herring fishery with consideration for the role of herring within the ecosystem. The Panel was composed of four scientists: Dr. Lisa Kerr (Chair, Gulf of Maine Research Institute), Dr. Gavin Fay (University of Massachusetts, Dartmouth), Dr. Douglas Lipton (NOAA), and Dr. John Wiedenmann (Rutgers University).

The Panel reviewed the written materials and presentations on the Atlantic herring MSE process and addressed three terms of reference. The terms of reference required the Panel to: 1) assess the strengths and weaknesses of the MSE methods used to evaluate Atlantic herring ABC control rules, 2) evaluate whether the methods, data, and results of the MSE are sufficient for the NEFMC to use when identifying and analyzing a range of ABC control rule alternatives for the Atlantic Herring Fishery Management Plan, and 3) provide recommendations for future improvements to the process. The Panel recognized that a tremendous amount of work was completed in a rigorous manner under the time and resource constraints of this MSE process. The Panel agreed that the NEFSC technical team constructed a series of models (Atlantic herring, predator, and economic) appropriate for evaluating ABC control rules for the Atlantic herring fishery in the context of herring's role as a forage fish. The Panel detailed areas of strength and areas for improvement in the MSE workshop process, modeling, and synthesis. The Panel concluded that the data, methods, and results of the MSE are sufficient for the Council to use when identifying and analyzing a range of ABC control rule alternatives for the Atlantic Herring Fishery Management Plan. Overall, the Panel concluded that the Atlantic herring MSE represents the *best available science* at this time for evaluating the performance of herring control rules and their potential impact on key predators. The Panel reached consensus regarding their conclusions on all terms of reference.

BACKGROUND

The Atlantic Herring Review Panel (hereafter referred to as the "Panel") was convened by the New England Fishery Management Council (NEFMC) on March 13-15, 2017 in Boston, MA to review the Atlantic herring management strategy evaluation (MSE) process. The MSE was conducted by NEFMC and Northeast Fisheries Science Center (NEFSC) staff from 2016-2017 to evaluate the performance of alternative acceptable biological catch (ABC) control rules for Atlantic herring. The MSE was developed to support the goals of Amendment 8 to the Atlantic Herring Fishery Management Plan which aims to develop and implement a long-term harvest control rule for specifying the ABC for the Atlantic herring fishery that manages herring within an ecosystem context. The MSE process was designed to provide information to evaluate the competing objectives of attaining high and stable yields for the herring fishery with recognition of herring's important role as a forage fish. The NEFMC aimed to use MSE as a collaborative decision making process, involving stakeholder input through two public workshops.

REVIEW PANEL

The Panel consisted of Dr. Lisa Kerr (Chair), Dr. Gavin Fay, Dr. Douglas Lipton, and Dr. John Wiedenmann. Dr. Kerr is currently Vice Chair of the NEFMC Science and Statistical Committee (SSC) and a research scientist with the Gulf of Maine Research Institute. Dr. Gavin Fay is a member of the NEFMC Ecosystem Based Fishery Management Plan Development Team and Assistant Professor in the Department of Fisheries Oceanography at the School for Marine Science and Technology, University of Massachusetts Dartmouth. Dr. Doug Lipton is a member of the Mid Atlantic Fisheries Management Council SSC and a Senior Scientist for Economics at NOAA Fisheries in Silver Spring, Maryland. Dr. John Wiedenmann is a member of the NEFMC SSC and Assistant Professor in the Department of Ecology, Evolution, and Natural Resources at Rutgers University. More information about each panelist's research and scientific expertise can be found at: http://s3.amazonaws.com/nefmc.org/1.Herring-MSE-peer-review-overview_170217_125209.pdf.

As Chair of the Panel, Dr. Kerr facilitated the meeting and made sure that all the terms of reference were reviewed. She also led the preparation of the Peer Review Panel Summary Report. Drs. Fay, Lipton, and Wiedenmann participated in the review and contributed to the Peer Review Panel Summary Report. All panelists submitted Individual Peer Review Reports (Appendix A).

REVIEW ACTIVITIES

During the review, the NEFMC asked the Panel to address three terms of reference (Appendix B). The terms of reference required the Panel to: 1) assess the strengths and weaknesses of the MSE methods used to evaluate Atlantic herring ABC control rules, 2) evaluate whether the methods, data, and results of the MSE are sufficient for the NEFMC to use when identifying and analyzing a range of ABC control rule alternatives for the Atlantic Herring Fishery Management Plan, and 3) provide recommendations for future improvements to the process.

Prior to the in-person meeting, the Panel was provided written materials describing the MSE process and outcomes to review. During the meeting, the NEFSC and NEFMC technical team (including Drs. Jon Deroba, Rachel Feeney, Sarah Gaichas, and Min-Yang Lee) presented on the MSE stakeholder workshops, as well as Atlantic herring, predator, and economic model details and results of model simulations under different harvest control rules (Appendix C). The review was a public meeting that had several designated times on the agenda for public comment and was open for participation through webinar (Appendix D). The Panel appreciated the participation of the NEFMC staff and NEFSC scientists in the review meeting and their role in addressing questions by the Panel.

The following written materials were reviewed by the Panel:

1. Atlantic Herring MSE Peer Review Overview
2. Terms of Reference for the Herring MSE Peer Review
3. Herring MSE Process, February 24, 2017
4. Atlantic Herring MSE Technical Methods and Outcomes, February 24, 2017
5. First Workshop of the Atlantic Herring MSE Summary Report, May 15-16, 2016
6. Herring PDT, AP, and Committee MSE Recommendations, June 10, 2016
7. Second Workshop of the Atlantic Herring MSE Summary Report, December 7-8, 2016
8. Background information on the Atlantic Herring Resource, Management Plan and Fishery, February 17, 2017
9. Correspondence

Presentations covered the following topics were reviewed by the Panel during the in-person meeting: 1) MSE process, 2) herring models, 3) predator models, 4) economic models, and 5) MSE results. All written materials and presentations were made available at the NEFMC website (http://www.nefmc.org/calendar/mar-13-15-2017-herring-mse-peer-review).

EVALUATION OF TERMS OF REFERENCE

ToR 1: Evaluate the strengths and weaknesses of the MSE methods used to evaluate Atlantic herring ABC control rules. Provide suggestions for improvements to the methods where appropriate.

1a. Methods to identify objectives, performance metrics, and control rules for testing (e.g. workshops to solicit stakeholder input)

The Panel reviewed the written materials and presentations on the methods used to identify objectives, performance metrics, and control rules for testing in the Atlantic herring MSE. The objectives, metrics, and control rules were largely based on stakeholder input provided in the forum of two public workshops. The Panel identified several strengths associated with the workshop process, including the outreach to stakeholders and the collaborative, inclusive, and flexible nature of the process that enabled stakeholder input. The Panel also recognized the value of the educational content on MSE presented during the workshop and the benefit of a lead workshop facilitator with expertise in MSE. The Panel identified areas for improvement in this aspect of the MSE and made recommendations relevant to the Atlantic herring MSE, as well as future MSEs conducted by the NEFMC. The Panel recommended additional meetings with stakeholders, expanded education on MSE, expertise in survey design, facilitators with MSE

expertise, more focus on human dimensions, outreach to underrepresented groups, opportunity to modify herring operating models, and further consideration of the approach used to incorporate stakeholder input (public workshop vs. working group). There was consensus among Panel members that although areas for improvement were identified, this aspect of the Atlantic herring MSE was generally conducted in accordance with best practices for MSE. Key areas of strength and areas for improvement are described in further detail below.

Areas of Strength:

- Timeline Aligned Science with Management Needs: A tremendous amount of work was conducted in one year in order to meet the NEFMC timeline and have the MSE completed for the purpose of selecting an ABC control rule for application in setting Atlantic herring ABCs for 2019-2021.
- Outreach to Stakeholders: The stakeholder workshops associated with the MSE were open to the public. A significant effort went into the notification of potential participants and attempts were made to reach diverse stakeholders for participation in workshops. The inclusion of a diversity of stakeholders (e.g., Atlantic herring industry representatives, bluefin tuna fishery representatives, and other wildlife managers) was a strong aspect of this process. Benefits included increased communication between different stakeholder groups and between these groups and NEFSC and NEFMC staff. In addition, stakeholder interactions led to identification of additional datasets to inform the MSE process and analytical work.
- Collaborative Process: An important aspect of MSE is identifying objectives, performance metrics, and control rules of particular interest to stakeholders. A key strength of the NEFMC Atlantic herring MSE was that these were established with stakeholder involvement through the workshop process. The NEFSC technical team incorporated the range of objectives, metrics, and control rules generated at the workshop into the MSE and, when this was not possible, tried to explain why certain scenarios or outcomes could not be considered. The Panel felt the range of control rules evaluated and performance metrics used was appropriate for the purpose of this MSE. This was not just an academic/desktop MSE, but a collaborative process that allowed stakeholders to provide direct input which has the potential to increase buy-in with respect to the outcomes of the MSE.
- Educational Process: During the workshops held by the NEFMC there was time invested in educating stakeholders on MSE. This was the first MSE conducted by the NEFMC and education was necessary for an efficient and effective process. This was recognized as a positive outcome of the MSE process that should be continued in the future.
- Flexible and Transparent Process: The workshops held by the NEFMC encouraged stakeholders to think broadly about the objectives, metrics, and control rules for Atlantic herring. These aspects of the MSE were not prescribed by the NEFSC technical team or council staff. Rather, there was an open discussion with stakeholders regarding what control rules they would like to see tested.
- Facilitators and Technical Experts: The feedback from stakeholders involved in workshops indicated that having an expert in MSE as the lead facilitator provided useful guidance for the process.

Areas for Improvement and Recommendations:

- Less Constrained Timeline: This MSE was conducted on a very tight timeline (~ 1 year) compared to other MSEs which have typically been conducted over the course of multiple years. It was apparent that time constrained some of the potential scope of modeling and alternative inputs to models that might have otherwise been considered in the MSE.
- Additional Meetings with Stakeholders: There was limited time built into Atlantic herring MSE workshops to iterate through different scenarios and control rule options with stakeholders. An additional meeting with stakeholders would have allowed the NEFSC technical team to present intermediary findings to stakeholders, prior to the final results workshop, and allowed more in-depth evaluation of trade-offs with stakeholders.
- Additional Education on MSE: Additional education on the scope, anticipated benefits, and potential limitations of the Atlantic herring MSE process may have helped in managing stakeholder expectations. For example, some stakeholders were disappointed with questions that could not be addressed due to the goals and timeline of this MSE process. Some of these questions cannot be answered with existing data and would require additional time and resources to collect the information needed. Presentation of a similar case study may have helped get stakeholders up to speed more quickly.
- Public Workshop vs. Working Group: The inclusiveness of the Atlantic herring MSE process was clearly a benefit and aligned with best practices in MSE, however, the large number of people participating at each workshop with diverse backgrounds and understanding of MSE made it challenging to achieve all the desired goals of the workshops. The panel questioned how sensitive the outcome of MSE workshops was to the composition of workshop attendees and the role individual voices played in influencing the direction of the process. The MSE process may have benefitted from a scoping meeting involving all stakeholders and more select involvement of stakeholders in the context of a working group as the MSE moved into more technical considerations.
- Expertise in Survey Design: Surveys of stakeholders were conducted at the workshops to garner input on the acceptable performance of alternative control rules. However, the synthesis of survey responses did not appear to support a clear consensus. This outcome may accurately represent the divergent opinions of stakeholders. However, additional expertise in survey design might have been able to design a survey that would better reveal participant preferences for control rule performance. It was unclear how the NEFMC intended to use the survey responses in the context of decision making on control rules. A clear intention for and design of the survey to achieve specific objectives would have made this aspect of the MSE process more effective.
- Additional Facilitators with MSE Expertise: The breakout groups could have benefited from facilitators with MSE expertise. The Panel recognized the potential for bias in the facilitation process and the reporting out from break-out groups. Experts with experience facilitating an MSE process could effectively limit this bias.
- Additional Focus on Human Dimensions: Social science objectives and metrics did not receive much time or attention during the workshop process and were left to the end of the agenda. This may have compromised the level of stakeholder engagement on this aspect of the MSE. The Panel recommended additional focus on human dimensions in future iteration of the MSE.

- Outreach to Under Represented Groups: Some key stakeholders in fisheries and businesses that rely on herring (e.g., lobster fishery) were under-represented in the MSE stakeholder process. Additional targeted outreach and education of these stakeholders may have facilitated their participation in the process.
- Opportunity to Modify Atlantic Herring Operating Models: Although there was opportunity to comment on the Atlantic herring operating models during public workshops, there was limited ability to modify operating models at that stage. Additional time for iteration of herring operating models with stakeholders would enhance the MSE process and promote better understanding of data limitations.

1b. Methods to construct the Atlantic herring, predator, and economic models (e.g., structure and use of data)

The Panel carefully reviewed the methods used to construct Atlantic herring, predator and economic models that were the foundation of the MSE. The models were constructed by the NEFSC technical team (Drs. Deroba, Gaichas, and Lee) under the direction of the NEFMC and informed by stakeholder input. The Panel recognized that a tremendous amount of work was completed in a rigorous manner under the time constraints of this MSE process. The Panel agreed that the NEFSC technical team constructed models appropriate for considering the NEFMC's goal to simulate population dynamics of Atlantic herring and evaluate the response to alternative control rules as well as consider the role of herring as forage. The methods, assumptions, and caveats of models were clearly described. The Panel made specific suggestions for improvements to each model. Several of the weaknesses identified by the Panel could be addressed through additional time and iteration of the MSE; however, others were related to data limitations. Key areas of strength and areas for improvement are described in further detail below.

Areas of Strength:

- Rigorous Methods: A considerable amount of work was completed in a rigorous manner by the NEFSC technical team, particularly with respect to the timeline of the MSE process.
- Transparent: The NEFSC technical team effectively communicated the technical details of each modeling approach and the caveats and assumptions of methods.
- Responsive to Management Goals: The NEFSC technical team successfully addressed the NEFMC desire to model the response of Atlantic herring to different control rules as well as the impact of changes in herring biomass on key predators in the ecosystem.
- Responsive to Stakeholder Input: Models were built based on stakeholder input to the extent possible.
- Models Informed by Regional Data: The models within the MSE were closely tied to regional data and established relationships supported by data (e.g. predator-prey relationships). There was no drawing from literature on other species and systems to inform models.
- Specification of Atlantic Herring Operating Models: The Panel felt the decision to identify key uncertainties in aspects of Atlantic herring life history and to simulate these alternative realities was a good approach. This generated a small set of alternative

operating models that were intended to bound uncertainty in understanding of Atlantic herring population dynamics.

- Ecosystem Approach: The Panel felt the approach of modeling Atlantic herring biomass/growth impacts on predators was appropriate given the available data, current understanding of predator-prey relationships, and the goal of Amendment 8. This approach allowed for examination of the impacts of alternative control rules on Atlantic herring in isolation, as well as in the context of impacts on key predators.
- Economic Stability Analysis: The use of the net revenue model to look at stationarity and stability of herring fleet revenues was an appropriate approach to developing economic outputs to inform the MSE process. The Panel suggested that the stability analysis might be applicable for looking at some of the biological outcomes from the model.

Areas for Improvement and Recommendations:

Atlantic Herring Operating Models

- Expand Range of Atlantic Herring Operating Model Scenarios: While alternative specifications of several life history parameters were explored, the Panel suggested consideration of an expanded range of operating model scenarios to ensure bounding the full range of uncertainty in Atlantic herring population dynamics as well as potential future states of nature (e.g., climate change impacts or natural mortality scenario considering rebuilt Atlantic cod populations).
- Include Spatial Considerations: Spatial distribution and structure of Atlantic herring was not included in the operating model. The feasibility of a spatially explicit operating model was explored by the NEFSC technical team. However, the analysis/supporting documentation of this exploratory work was not part of the report, so it was not available for review. If the data available will not support a spatially explicit operating model, additional modeling approaches could be conducted to complement the MSE and enable examination of questions related to localized depletion (e.g. species distribution modeling).
- Incorporate Stock Assessment Model: Although assessment error and bias were considered in the Atlantic herring MSE, there was no explicit modeling of a stock assessment. The Panel recommends including a full stock assessment in the future as this would align with best practices in MSE.
- Expanded Modeling of Error: The simulated stock assessment and implementation error incorporated in the MSE were on the low end of values typically considered in MSE. The Panel was concerned that these low values may not fully capture the uncertainty in the assessment process. Future runs with greater assessment error were recommended by the Panel.
- Consideration of Non-Stationarity: The inputs to the Atlantic herring operating model were time invariant (e.g. natural mortality, weight at age). Inclusion of time-varying parameters would enable accounting for non-stationarity of key life history processes. There is the potential for inclusion of density dependent effects on growth and catchability in the MSE. Incorporating time-varying parameters will alter reference points and this will require reevaluation of how to assess the performance of control rules in these scenarios.
- Evaluate Robustness to Misspecification of Reference Points: The Panel suggested switching reference points across alternative operating model scenarios to evaluate the

robustness of control rules to misspecification of reference points. Alternatively, including a stock assessment internal to the MSE would allow for evaluation of the sensitivity of results to misspecification of reference points.

- Evaluate Robustness to Climate Change: There is no direct link to environmental drivers in the Atlantic herring model. The Panel recommends consideration of the impact of climate variability and change on Atlantic herring in the MSE in order to evaluate the robustness of control rules robust to climate variability and change.

Predator models:

- Further Development of Predator Models: The Panel felt the focus on modeling the impact of herring on a suite of individual species was a reasonable first approach and responsive to NEFMC objectives. However, modeling the impact of herring biomass on predators is a complex challenge and it is unclear whether these models, which are relatively simple, are able to emulate the impact of changes in herring biomass/growth on predators in the system.
- The Panel reviewed the food web modeling that was not included in the final MSE and suggested further exploration of this work. Ultimately, a combination of approaches, with ecosystem/food web modeling providing a broader system-wide view of the importance of herring as forage, and individual species models providing information on the specific impacts on key predators, may provide a more holistic evaluation of ecosystem impacts.
- Consideration of the Impact of Predators on Herring: There was no explicit link modeling the impact of predators on Atlantic herring in the models (i.e., no top-down effects on Atlantic herring). The Panel suggested integration of a feedback between predator biomass and Atlantic herring as a long-term goal in model development, noting however that the data requirements to do so are substantial.
- Dependence of Predators on Herring: The models focused on the direct link between herring and predators, but did not consider the capacity for and impacts of availability of alternative prey. In future iterations of predator models, it will be important to consider how to capture the dependence of predators on prey and their capacity to shift to alternative prey.
- Expanded Consideration of Predator-Prey Relationships: The predator-prey relationships were somewhat simplistic (i.e., one type of isolated impact was captured for each species). Time and data availability constrained the ability to explore additional potential mechanistic relationships.
- Consideration of Natural Variability: Consideration of the natural variability of predator dynamics (e.g., the probability of predator biomass decreasing below B_{MSY} with and without a change in herring biomass) is needed to put the potential impact of herring on predators in context. In addition, process error should be incorporated in predator models.

Economic Model:

- Further Development of Economic Model: The economic model was not as developed as the other models in the MSE. For practical and appropriate purposes, it was limited to an examination of herring ex-vessel price demand that feeds into a net revenue model of the fishery. The Panel felt that this work could be expanded upon with additional time.
- Improve Herring Demand Model: The direct herring demand model that was attempted did not perform well econometrically and, therefore, expert opinion was used to select an elasticity of -0.5 as a proxy until better estimates can be determined from the statistical

model. The Panel felt that this was a reasonable and appropriate course of action, but that work should continue to improve the demand model estimate.

- Incorporation of Interactions: The demand model is challenging because of the rapidly changing lobster fishery that relies on herring for bait, and the availability (or lack thereof) of menhaden as a substitute bait. Attempts have been made to account for these interactions and these should continue to be refined.
- Develop Derived Demand Models: Modeling of derived demand for herring as an input in the production of economically valuable prey species such as tuna, groundfish, or seabirds is data and time intensive. These types of analyses should be pursued in the future when comprehensive production relationships are developed that can predict absolute changes in predator abundance that can potentially be valued in an economic model.

1c. Methods to evaluate the control rules and performance metrics

The Panel evaluated the methods used to evaluate control rules and performance metrics. The Panel identified several areas of strength and areas for improvement, including:

Areas of Strength:

- Presentation of MSE results: The presentation of MSE results provided an effective, high-level view of the performance of alternative control rules. From these graphs it was apparent which control rule types (i.e., biomass based, constant, and conditional constant) were suboptimal and didn't perform well for specific tradeoffs (e.g., yield vs. SSB). Additionally, the outcome of predator models in the form of box plots aggregated over simulations provided insight regarding what aspect of the MSE was driving particular outcomes (i.e. was it the influence of the operating model or control rule).
- Range of Control Rules Considered: The Panel agreed there was sufficient coverage of a range of harvest control rules evaluated in the MSE. There were no suggestions for additional control rules that needed to be tested based on the goals of the MSE.
- Performance Metrics to Consider: Given the time-frame for the MSE work, the suite of performance metrics considered was sufficient. There are other socio-economic metrics that could be developed in the future such as those developed at the NEFSC related to fishing community vulnerability.

Areas for Improvement and Recommendations:

- Presentation of MSE Results: A tremendous amount of output was generated from the Atlantic herring MSE. It is a recognized challenge to communicate the results of MSE, but further consideration should be given as to how to do this most effectively for the intended audiences. It was noted that stakeholders had difficulty interpreting figures and understanding results. The Panel recognized that there is not a single presentation approach that would be appropriate for interpretation by all stakeholders involved given their varied experience with MSE. However, the Panel suggested presenting results in a variety of different ways to aid interpretation of results, more specific input is provided below.
    - There was little text associated with figures. The addition of written text describing results and guidance on the interpretation of figures and how to view overall outcomes across metrics would aid understanding of the MSE results.

    - Medians of simulation output were reported, however percentiles or quartiles could also be reported to provide insight on variability. This could be accomplished in the short term.
    - The current presentation of results makes it very challenging to compare tradeoffs across a single ABC control rule.
    - Boxplots, spider and rose plots were suggested as a good visualization approaches that could be applied.
    - Additional figures plotting control rules across all operating models would enable simultaneous comparison.
    - Another option in presenting results would be optimizing for one aspect and plotting outcomes for other objectives.
    - A brief summary of results with infographics could help communicate this information to a general audience.
- Selection of Control Rules: A large number of control rules were evaluated which may make narrowing in on a single option challenging. Initial removal of illegal/suboptimal outcomes for all performance metrics would be a straight-forward approach to begin narrowing down control rule options. Development of a scoring system that weights control rules based on performance across a range of measures could help in vetting options.
- It is clear to see how the outcomes of herring tradeoffs could inform current decision-making (i.e., yield vs. SSB plots). However, it is more challenging to understand how predator impacts will be viewed in the decision-making process. The purpose of this MSE was to evaluate the impact of desirable control rules for herring on predators. There may be challenges in how to weight the impact on predators and managers will be required to make decisions regarding the level of impact on predators that is acceptable.
- Model parameters: The panel suggested inclusion of analysis to understand how control rule parameters influence the performance of control rules (e.g. GLM analysis of outcomes).

ToR 2: Evaluate whether the methods, data, and results of the MSE are sufficient for the New England Fishery Management Council to use when identifying and analyzing a range of ABC control rule alternatives for the Atlantic Herring Fishery Management Plan. Comment on any constraints that may hinder use of the MSE in the development of management alternatives.

The Panel agreed that the MSE represents the *best available science* at this time for evaluating alternative ABC control rules for Atlantic herring. The MSE provides a strong basis for evaluating the performance of control rules over a range of possible states of nature for Atlantic herring (i.e., alternative operating model scenarios). A suite of independent predator models enable evaluation of the impact of changes in herring biomass/growth on key predators in the ecosystem. Economic considerations are included in the form of a net revenue model of the fishery. The Panel agreed that this represented a strong first iteration of a MSE for Atlantic herring, and while more development could be done to improve different aspects of the MSE, the methods and results of the current iteration are sufficient for the NEFMC to evaluate ABC control rule alternatives for the Atlantic Herring Fishery Management Plan. The Panel concluded that the Atlantic herring MSE represents a marked advancement in the information available for decision-making on Atlantic herring catch advice.

The Panel identified several areas for improvement of the MSE; however, none were viewed as a constraint that would prevent application of the MSE for evaluating management alternatives. For example, the Panel made several suggestions for improvements to Atlantic herring operating models, but the current operating models are considered a good approximation of herring dynamics and not considered a constraint. There was discussion by the Panel regarding the biological realism of the herring—predator relationships used to inform predator models. Given the time constraints and data availability, the Panel felt this was an appropriate treatment of the impact of Atlantic herring on predators. The Panel recognized that more could have been done with economic considerations, but no major issues were identified that would constrain developing management alternatives. Thus, while improvements to these models were suggested, the Panel agreed that the MSE addressed the specific objectives of the NEFMC to the extent possible given time constraints and data availability.

The Panel strongly suggested that the NEFMC consider the need to revisit the MSE for several possible reasons related to the implementation and monitoring of ABC control rules. These suggestions are drawn from best practices for MSE and include:

1. Retrospective evaluation of the performance of the selected ABC control rule against expectation from MSE. In particular, if the ABC control rule is performing very poorly there may be a need to reconsider the outcomes of the MSE (e.g., the International Whaling Commission considered poor performance of the control rule as "exceptional circumstances" that would require reconsideration of harvest control rules and revisiting MSE).
2. If there are considerable improvements/changes made to operating models, predator-prey relationships, or economic models, there would be a need reevaluate the robustness of the current control rule or a small number of preferred ABC control rules.
3. If there is a shift in the ecosystem that is outside of expectations based on the historical view of the system, there may be a need to revisit the performance of ABC control rules under this new state.

ToR 3: Provide any recommendations for future improvements. Comments should include the following:

3a. How to address any data limitations or needs

There is a need for additional data to inform an MSE for Atlantic herring with full consideration of Atlantic herring dynamics (e.g., mechanistic links between life history processes and environment), as well as herring's role as forage (e.g., marine mammal abundance and consumption data). In some cases, these data gaps would require more data collection; however, resources may be limited and require choices as to where it would be best to invest time and effort. One important application of MSE is to identify data gaps that can impede informed decision-making. The Panel suggests further examination of the key uncertainties in the Atlantic herring MSE and application of this information to inform prioritization of future data collection to support this work.

In some cases, suggested improvements to the MSE recommended by the Panel are beyond the scope of the currently available data. In other cases, additional time and technical capabilities would have permitted addressing an area of weakness.

3b. How to conduct future Atlantic Herring MSEs

The Panel highlighted specific areas for improvement that should be considered as work proceeds on the Atlantic herring MSE. The Panel categorized its recommendations as either short-term activities that could be accomplished with limited time and effort or long-term endeavors that would require significant time and effort. The Panel also provided more general advice that is both relevant to the Atlantic herring MSE as well as to future MSEs conducted in the region. For more detailed descriptions of these suggested improvements see the full description under *ToR 1*.

Suggested Future Improvements to the Atlantic Herring MSE:

Atlantic Herring Model

Short term:

1. Expand the range of stock assessment error and implementation error informing the MSE.
2. Incorporate density dependent impacts in operating model.
3. Evaluate robustness of control rules to misspecification of reference points.

Long term:

1. Expand the range of Atlantic herring operating model scenarios.
2. Include spatial considerations in Atlantic herring operating model.
3. Incorporate a stock assessment of Atlantic herring in the MSE.
4. Include non-stationarity in life history processes (beyond density-dependent effects listed above).
5. Evaluate robustness of control rules to climate change.

Predator Models

Short term:

1. Expand the analysis and integration of food web modeling in the MSE.
2. Expand the consideration of predator-prey relationships (some of this work is ongoing at the NEFSC).

Long term:

1. Model feedback of predators on Atlantic herring through consumption.
2. Address spatial concerns regarding predator-prey interactions (i.e. local depletion). This may require parallel modeling outside of the framework of the MSE (e.g. species distribution modeling).
3. Incorporate consideration of the dependence of predators on Atlantic herring in the context of availability of alternative prey.
4. Include consideration of natural variability in predator biomass.

Economic model

Short term:

1. Improve the demand model for Atlantic herring.
2. Incorporate interaction with menhaden and changes in the lobster fishery.
3. Model entry and exit for the herring fleets.

Long term:

1. Develop derived demand models (economic valuation of herring impacts on predators).

2. Include non-economic social science evaluating the impact of control rules on fishing communities (e.g. social well-being of resource users).
3. Develop values/weights for ecosystem aspects (stated preference choice experiments) from regional survey.

Considerations for Future MSEs by the NEFMC:

- Longer Timeline: It was clear that the MSE process would have benefited from more time. Changing the expectations for the time-frame over which MSEs can be completed is necessary to maximize the potential of the MSE process. If tighter timelines are needed to address management objectives, expanded partnerships with others who work on MSE within the region could provide additional capability to achieve goals more quickly.
- Technical Capacity in Region: Additional training of students and post-doctoral researchers in MSE is needed, as well as collaboration among experts in the region. Increased technical capacity could expand the application of MSE within New England.
- More Education on MSE: Additional education on MSE for fisheries stakeholders in the region could have helped the Atlantic herring process and would make future applications more efficient and effective. This education could happen through council sponsored meetings or possibly through the MREP training program.
- Workshop Facilitation with Expertise in MSE: The Panel recognized that additional people with expertise in MSE would aid in the facilitation of stakeholder meetings.
- Approach to Stakeholder Involvement: There were recognized benefits to holding public meetings, but also drawbacks due to the different composition of attendees between the first and second workshop. There may be a role for both large, public scoping meetings to generate objectives, metrics, and control rules, and a smaller working group that addresses technical details of the MSE.
- Expanded Social Science Expertise: The addition of a MSE team member with expertise in social science (non-economist) would expand the scope of the MSE.
- Improved Communication of MSE Results: Effective communication of results is a recognized challenge in the field of MSE. The Atlantic herring MSE would benefit from additional time spent on synthesis and graphical display of data, with the aim of translating MSE results to different audiences. The Panel suggested the potential for development of interactive web-based tools (e.g. R Shiny App.) that would allow for broad accessibility of the output of MSE. Providing an interface for stakeholders to "play" with output would help them evaluate and understand tradeoffs.
- Lessons learned: The Panel suggested that best practices should be summarized from the Atlantic herring MSE to inform future MSE work within the region.
- Where does MSE fit in future fishery management process?: A plan should be developed by the NEFMC for future iteration and application of the Atlantic herring MSE. The Panel recommends continued research to inform the Atlantic herring MSE. There was a suggestion that MSE be conducted in a benchmark/update structure similar to the stock assessment process or that evaluation of the performance of control rules using the MSE could be conducted within the context of stock assessments.

3c. How to clarify the current and future MSE final reports, including input on best practices for translating MSE results for a general audience

In general, the discussion of modeling methods were clear and concise in MSE reports, however, the results were more difficult to interpret. The Panel made recommendations for clarifying current and future MSE final reports and categorized its recommendations as either short-term activities that could be accomplished with limited time and effort or long-term endeavors that would require significant time and effort. Below are suggestions by the Panel for effectively communicating MSE results to a broad range of stakeholders.

Short term:

- The Panel suggested that summary text synthesizing results be added to the report and text that guides readers on how to interpret figures (i.e. trade-off evaluation) be included in the report.
- The Panel suggested more user friendly figure display and more descriptive figure captions.
- The Panel suggested that the workshop recordings and slides be made available for those who would like to review this information online.
- The Panel suggested that the NEFMC produce a web-based summary report with infographics that could help communicate the content of reports to stakeholders.

Long term:

- The Panel suggested that the NEFSC and NEFMC staff work with experts in data visualization to communicate MSE findings more effectively.
- The Panel suggested presenting data in multiple formats in order to reach a broader audience (e.g. reports, website, video).
- The Panel suggested that NEFMC staff conduct focus groups with stakeholders to understand how this data can be best translated to the intended audiences.

CONCLUSIONS

The Panel reviewed the written materials and presentations on the Atlantic herring MSE and addressed three terms of reference. The terms of reference required the Panel to: 1) assess the strengths and weaknesses of the MSE methods used to evaluate Atlantic herring ABC control rules, 2) evaluate whether the methods, data, and results of the MSE are sufficient for the NEFMC to use when identifying and analyzing a range of ABC control rule alternatives for the Atlantic Herring Fishery Management Plan, and 3) provide recommendations for future improvements to the process. The Panel recognized the tremendous amount of work that was completed in a rigorous manner under the time constraints of this MSE process. The Panel detailed areas of strength and areas for improvement in the MSE workshop process, modeling, and synthesis. The involvement of stakeholders in identifying objectives, metrics, and control rules was a strong aspect of the MSE process and aligned with best practices for MSE. The Panel agreed that the NEFSC team constructed models appropriate for considering the NEFMC's goal to develop and implement a long-term harvest control rule for specifying ABC for the Atlantic herring fishery that manages herring within an ecosystem context. The Panel concluded that the data, methods, and results of the MSE are sufficient for the Council to use when identifying and

analyzing a range of ABC control rule alternatives for the Atlantic Herring Fishery Management Plan. The Atlantic herring MSE provides the NEFMC with a structured decision making approach for setting Atlantic herring catch advice. Overall, the Panel concluded that the Atlantic herring MSE represents the *best available science* at this time for evaluating the performance of herring control rules and their potential impact on key predators. The Panel reached consensus regarding their conclusions on all terms of reference.

APPENDIX A: Individual panelist reviews

Atlantic Herring MSE Individual Panelist Report: Dr. Lisa Kerr

EXECUTIVE SUMMARY

The Atlantic herring management strategy evaluation (MSE) was conducted to evaluate the performance of alternative acceptable biological catch (ABC) control rules for the Atlantic herring fishery that consider the role of herring as forage. The Northeast Fisheries Management Council (NEFMC) convened a Review Panel to evaluate the Atlantic herring MSE, including stakeholder involvement through the workshop process, models, and the synthesis of results. The MSE conducted by the NEFSC technical team represents a considerable amount of work, conducted within a relatively short time-line. The Atlantic herring MSE was a collaborative process that included stakeholders in the establishment of objectives, performance metrics and control rules. The methods used to construct the Atlantic herring, predator, and economic models were appropriate and the data limits, caveats and assumptions associated with these models were described in a clear manner. Overall, I find that the MSE is sufficient for use by the NEFMC to identify and analyze a range of ABC control rule alternatives for the Atlantic Herring Fishery Management Plan. No major constraints were identified in the current MSE that would hinder its use in the development of management alternatives; however, recommendations were made regarding areas for improvement in the Atlantic herring MSE. The Panel summary reflects the consensus of the entire panel and this reviewer.

BACKGROUND

The Northeast Fisheries Management Council (NEFMC) is developing Amendment 8 to establish a long-term control rule for specifying the acceptable biological catch (ABC) for the Atlantic herring fishery. The goal of Amendment 8 is to develop and implement a control rule that manages herring within an ecosystem context. A management strategy evaluation (MSE) was conducted 2016-2017 to evaluate the performance of alternative ABC control rules. The MSE process was aimed at resolving control rules that address the competing objectives of attaining high and stable yields for the fishery and the role of herring as a forage fish. The NEFMC aimed to use MSE as a collaborative decision making process, involving public input.

The NEFMC convened a Review Panel in Boston, MA on March 13-15 to evaluate the Atlantic herring MSE process. The panel reviewed both written materials as well as in-person presentations by the NEFSC team. The Panel was charged with providing feedback on three terms of reference, including: 1) evaluate the strengths and weaknesses of the MSE methods used to evaluate Atlantic herring ABC control rules, 2) evaluate whether the methods, data, and results of the MSE are sufficient for the NEFMC to use when identifying and analyzing a range of ABC control rule alternatives for the Atlantic Herring Fishery Management Plan, and 3) provide recommendations for future improvements to the process. Each panelist was asked to summarize their independent findings, identifying points of agreement with the panel consensus and where the view of the individual panelists differs from the rest of the panel.

FINDINGS

Terms of Reference

Evaluate the strengths and weaknesses of the MSE methods used to evaluate Atlantic herring ABC control rules. Provide suggestions for improvements to the methods where appropriate.

a. Methods to identify objectives, performance metrics, and control rules for testing (e.g. workshops to solicit stakeholder input)

A key aspect of MSE is determining fishery objectives, performance metrics and relevant uncertainties. In the NEFMC Atlantic herring MSE, these were established with stakeholder involvement through the workshop process. The NEFSC team was responsive to the suggestions of workshop participants and directly incorporated their input into the MSE process. This was not just an academic MSE, but a truly inclusive and collaborative process. This inclusion of stakeholders in the MSE process should be recognized as a key area of strength. Overall, the range of performance metrics and control rules considered was appropriate given the objective of the NEFMC, however, consideration of economic metrics was limited.

The Atlantic herring MSE was completed on a very tight timeline (~ 1 year) and this constrained the extent to which stakeholders could be involved in understanding the results and weighing tradeoffs. With only two public workshops, there wasn't a lot of time built into the process to iterate through initial results with stakeholders and discuss alternative scenarios they would like to see simulated in the MSE. For example, there was limited opportunity during workshop meeting to provide input on operating model structure of Atlantic herring. Given that this was the first MSE conducted in the region, additional meetings may have helped in navigating both the education and application of MSE with stakeholders.

b. Methods to construct the Atlantic herring, predator, and economic models (e.g., structure and use of data)

The MSE conducted by the NEFSC technical team represents a considerable amount of work, conducted within a relatively short time-line. Overall, the methods used to construct the Atlantic herring, predator, and economic models were appropriate and the data limits, caveats and assumptions associated with these models were described in a clear manner. The NEFSC team effectively structured models to allow both a fishery and ecosystem focus, enabling consideration of changes in herring harvest on the fishery as well as key predators in the ecosystem. Below I have highlighted several areas for improvement within Atlantic herring, predator, and economic models that could be considered in future iteration of the MSE.

Atlantic herring model:

- Single stock area: There was no consideration of spatial structure of Atlantic herring in the operating model. Atlantic herring are heterogeneous in distribution and known to exhibit complex population structure. Future work should include exploration of whether the data available could support a spatially explicit operating model.
- Stationarity of Parameters: The inputs to operating model were time invariant (M, WAA). Incorporation of time-varying parameters would likely increase the biological realism of the model and allow for consideration of potential links to environmental forcing.

- No environmental influence: There was not explicit modeling of environmentally driven processes in the MSE. Evidence of environmental impacts on recruitment, growth, or distribution of Atlantic herring may warrant inclusion in future iteration of the MSE. This would enable evaluation of potential impacts of climate change on management performance.
- No stock assessment: There was no explicit modeling of a stock assessment within the MSE. Future work should include incorporation of a stock assessment to accurately represent the fishery management process for Atlantic herring. Currently, assessment error was modeled over a limited range, however, a broader range of error should be considered. MSE outcomes were sensitive to assessment bias and additional modeling incorporating different levels of bias (i.e. beyond rho = 0.6) should be pursued.
- Reference points without error: The MSE assumes reference points are known without error. Incorporation of error should be pursued in future iterations of the MSE.

Predator-prey model:

- Predator models: Modeling the impact of herring harvest on predators is a complex challenge. It is unclear how accurately these models capture the reality of predator dynamics in the way they consider the herring-predator relationship in isolation (i.e. absence of other forage). Future collaboration with stock assessment scientists who work on the assessments of predators modeled in the herring MSE (e.g. Bluefin tuna, spiny dogfish) could improve these models.
- Top Down Impacts: No top-down effects of predator biomass on herring were included in the model.
- Predator-prey relationships: The predator-prey relationships were relatively simplistic. Additional time to explore data for further evidence of these complex interactions could lead to better informed models.
- Bluefin tuna model: Exploration of the impact of herring availability on bluefin tuna availability to the fishery would be valuable. This could not be accomplished within the current structure the MSE, but could be explored through parallel modeling efforts (i.e. joint species distribution modeling).

Economic model:

- Economic model: Overall the description of the economic model was less detailed and the modeling seemed less developed than other aspects of the MSE. Limited results were provided.
- Valuation of herring to predators: It is difficult to fully assess tradeoffs when no value is put on in-situ herring for predators. Future work should consider including valuation of herring to predators.
- Impact on other fisheries: The lobster fishery is reliant on the herring fishery for bait. Future modeling should incorporate this relationship and simulate economic impacts on the lobster fishery.

c. Methods to evaluate the control rules and performance metrics

Overall, the performance measures applied to evaluate the outcome of alternative ABC control rules were appropriate. In the reporting of results, more focus was given to herring and predator resource and herring yield metrics and consideration of economic metrics was limited (ie. net revenue). Trade-offs were evaluated through two dimensional plots that displayed different

performance metrics on each axis. The presentation of results in plots of Atlantic herring yield versus SSB was effective for visualizing which control rules performed well for this specific tradeoff. In general, figures provided insight regarding harvest strategy options to rule out and those that performed well. As the number of control rules considered is narrowed down, trade-off plots across a single harvest control rule would enable in-depth look at their performance across metrics**.**

2. Evaluate whether the methods, data, and results of the MSE are sufficient for the New England Fishery Management Council to use when identifying and analyzing a range of ABC control rule alternatives for the Atlantic Herring Fishery Management Plan. Comment on any constraints that may hinder use of the MSE in the development of management alternatives.

The Atlantic herring MSE represents the *best available science* for setting catch advice. This was a strong first iteration of MSE for Atlantic herring and, although more development could be done to improve different aspects of the MSE, the current iteration provides insight regarding the performance of alternative harvest control rules for Atlantic herring and their impact on key predators. Overall, I find that the MSE is sufficient for use by the NEFMC to identify and analyze a range of ABC control rule alternatives for the Atlantic Herring Fishery Management Plan. No major constraints were identified in the current MSE that would hinder its use in the development of management alternatives. There is room for improvement in Atlantic herring operating models, however, the current models do address major uncertainties and likely are good approximations of reality. We have suggested improvements to predator models and the herring—predator relationships, however, these models are able to provide perspective on potential impacts of herring control rules on predators. The current approach to modeling economic impacts is appropriate, but more could be done to develop this aspect of the MSE. Proposed improvements are described in further detail in ToR 1 and 3.

3. Provide any recommendations for future improvements.

a. How to address any data limitations or needs

There were data needs that influenced the scope of Atlantic herring, predator, and economic models. For example, Atlantic herring are not sampled well by the trawl survey and this could limit development of a spatially explicit model. In addition, marine mammals are key predators on Atlantic herring; however, there is not a robust time series of marine mammal data in our region. Furthermore, inclusion of social science data on the Atlantic herring fishery, as well as associated fisheries that rely on herring, could have enhanced the MSE and enabled modeling of fishing community impacts. MSE is a useful tool in identifying key uncertainties in understanding a system and can be helpful in prioritizing which data gaps can be addressed with limited resources. Some of the limitations of the current MSE are associated with the constrained time-line and resources dedicated to this process. Future MSE processes should consider the need for additional time and/or staff for workshops with stakeholders, model development and simulation, and synthesis and communication of results.

b. How to conduct future Atlantic Herring MSEs

There were lessons learned during the Atlantic herring MSE process that can inform future iterations of the Atlantic herring MSE, as well as future MSEs conducted in this region. The outreach to stakeholders through workshops was a strong aspect of the Atlantic herring MSE and

as the MSE process continues to evolve there should be continued outreach and communication with stakeholders. Feedback to workshop participants in the form of a clear synthesis of MSE results and how results will be used in decision making is needed to make the process fully transparent. The MSE was completed on a very tight timeline which allowed this effort to keep pace with management needs. However, the timescale did limit the scope of the Atlantic herring, predator and economic models that could be considered in the MSE (e.g. alternative operating model scenarios). Outreach to stock assessment scientists who lead assessments on predators modeled in the MSE (e.g. bluefin tuna, spiny dogfish) could help inform these models. The economic modeling did not receive the time and attention needed for such an important aspect of the study and should be expanded upon. This effort represents the first MSE conducted through the NEFMC and future MSEs are anticipated. Additional, education on MSE is needed in the region to allow stakeholders to effectively engage in the process. The NEFMC should establish a clear plan for future iteration and improvement of the MSE.

c. How to clarify the current and future MSE final reports, including input on best practices for translating MSE results for a general audience

It is a challenge to communicate the large number of results produced from a MSE; however, further consideration should be given to the best approach for synthesis of the tremendous amount of work completed through the Atlantic herring MSE process. The synthesis of findings in final reports was done mainly through figures with little associated text. In their current format, I don't find the reports to be easily understandable for a broad audience. Additional effort is needed to produce summary documents appropriate for council members and the broad range of stakeholders who contributed to the MSE process. Future synthesis of the MSE could be conducted through development of a web-based tool (such as a Shiny App. similar to IPHC MSE). A web-based tool would allow for broad accessibility of the output of the MSE and the ability to "play" with model settings to understand their impact. I highly recommend more effort to communicate MSE outcomes at different levels (e.g. brief summary documents, more in-depth reports, web-based tools).

CONCLUSIONS AND RECOMMENDATIONS

The MSE conducted by the NEFSC technical team represents a considerable amount of work, conducted within a relatively short time-line. The Atlantic herring MSE was a collaborative process that included stakeholders in the establishment of objectives, performance metrics and control rules. The methods used to construct the Atlantic herring, predator, and economic models were appropriate and the data limits, caveats and assumptions associated with these models were described in a clear manner. Overall, I find that the MSE is sufficient for use by the NEFMC to identify and analyze a range of ABC control rule alternatives for the Atlantic Herring Fishery Management Plan. No major constraints were identified in the current MSE that would hinder its use in the development of management alternatives. However, recommendations were made regarding areas for improvement in future iteration of the Atlantic herring MSE. The Panel summary reflects the consensus of the entire panel and this reviewer.

Atlantic Herring MSE Individual Panelist Report: Dr. Douglas Lipton

Executive Summary

The Atlantic herring management strategy evaluation (MSE) conducted by the Northeast Fisheries Science Center and the New England Fisheries Management Council was an ambitious undertaking to develop recommendations for harvest control rules for Atlantic herring that account for its role as a prey species. An attempt was made to use extensive stakeholder input in developing candidate harvest control rules and performance metrics. The peer review panel examined the MSE process including two stakeholder workshops, herring operating models, simulations under different harvest control rules and output performance related to the herring fishery, effects on predators and economic performance. Given the limited time and resources available to conduct the MSE, the panel felt that the project was a success and would provide useful information for the Management Council to use in setting Atlantic herring total allowable catch that is informed by the ecosystem considerations included in the analysis. Although the panel identified numerous areas for improvement, some that could be applied in the short run, and many that will require more time and resources to complete, these were not seen as constraining to the use of the MSE by the Council. The chairs report reflects the consensus of the entire panel and this reviewer.

Background

The purpose of the peer review was to examine both the process of performing the herring MSE as well as the underlying models to determine their appropriateness in achieving the goals of the task as well as evaluating their scientific rigor. The panel also reviewed the outputs from the analysis to determine if they reflected the underlying science, were appropriately communicated and, ultimately, whether they would be useful for management decisions.

The panel was presented with background materials and presentations on the overall MSE process, including stakeholder workshops, a range of operating models of Atlantic herring, simulations of different harvest control rules, predator models and an economic model. These models were used to evaluate performance against a number of metrics that were developed at the stakeholder workshops.

Findings

1. Evaluate the strengths and weaknesses of the MSE methods used to evaluate Atlantic herring ABC control rules. Provide suggestions for improvements to the methods where appropriate. Evaluation should include the following:
    a. Methods to identify objectives, performance metrics, and control rules for testing (e.g. workshops to solicit stakeholder input)

The MSE project entailed holding two stakeholder workshops to identify the management objectives, performance metrics and control rules that would be included in the MSE. A description and results of the individual workshops were provided to the panel, and a presentation about the workshops was given to the panel. The workshops which had about 60 attendees at each were a major undertaking. With limited resources and time to plan and conduct the workshops, the organizers did an excellent job in getting broad stakeholder

involvement and driving the meeting to the results needed for the next step in the process. Some of the strengths were:

- Able to reach a diverse set of stakeholders, not all of whom are regularly engaged in fisheries management council activities.
- Leveraged a diverse, talented and knowledgeable set of workshop facilitators and organizers.
- Served as an educational opportunity for stakeholders (and the technical team), particularly to learn about the concerns and interests of other stakeholder groups

There is always room for improvement in these types of activities. Some of the weaknesses or concerns about the approach were:

- Workshop participants may not be representative of the true stakeholder community, with some groups over-represented and others under-represented
- There was a lot of material to cover in just two workshops, so there was probably some information overload.
- Large turnover of participants between workshops.
- Some stakeholders may have had greater expectations for the final product than was communicated and may have come away disappointed that the analysis did not go further than they would have liked.

b. Methods to construct the Atlantic herring, predator, and economic models (e.g., structure and use of data)

The panel was provided background materials and presentations on the underlying operating models for the Atlantic herring fishery, predator-prey interactions and the economic model. Justifications were given for the approaches taken which included data limitations, and time and resource constraints. It is my judgement that the decisions made by the modeling team were appropriate and the best that could be accomplished at this time.

Specifically for the economic model, the study was limited to the economic performance of the herring fishery in terms of net revenues and stability of performance over time. Effort was made to develop a suitable demand model for herring, and although initial success was lacking, it appears that a reasonable model will be developed in the near future with a proxy value for demand elasticity being used in the current analysis. Many of the suggestions made by the panel and in public comments about improvement for the demand model were already considered or are being explored.

This panelist agrees with the decision to not pursue some of the more advanced economic analyses that would inform a future MSE, such as calculating indirect demands for herring (as prey for directly valued species such as tuna or groundfish) or for other ecosystem components such as the health of seabird populations. These analyses have heavy data requirements or the data may not be readily available, and thus, should only be attempted when the time and resource are sufficiently allocated to the effort to ensure success.

c. Methods to evaluate the control rules and performance metrics

As captured in the panel recommendations, the use of the net revenue model to look at stationarity and stability of herring fleet revenues was an excellent approach to developing economic outputs to inform the MSE process. It was suggested that the stability analysis might be useful in looking at some of the biological outcomes from the model. The notion being that multi-year patterns of all low (or high) net revenue have different impacts on entry-exit behavior of the fleet than the same variability with completely random annual fluctuations.

2. Evaluate whether the methods, data, and results of the MSE are sufficient for the New England Fishery Management Council to use when identifying and analyzing a range of ABC control rule alternatives for the Atlantic Herring Fishery Management Plan. Comment on any constraints that may hinder use of the MSE in the development of management alternatives.

As an individual, and the panel as a whole, felt that the package of materials that constitute the MSE to this point are sufficient to inform the process of setting ABC control rules for Atlantic herring and will provide improved guidance as compared to the status quo. The major challenge in utilizing this information will be maintaining all the caveats, and limiting the interpretation of the findings to the level they are intended. This is a communications challenge to the MSE team, and one that they recognize as evidenced by the interests in examining different graphic representation of results, among other communication challenges.

3. Provide any recommendations for future improvements. Comments should include the following:
    a. How to address any data limitations or needs
        - Continue working on improvement of herring demand model.
        - Develop model of entry-exit in the herring fleet.
        - Develop derived demand model for herring in relation to predator species (long term)
        - Consider development of a region-specific stated preference choice experiment for valuation of trade-offs across multiple objectives (long-term).
    b. How to conduct future Atlantic Herring MSEs
        - Track and monitor implementation of current MSE and use that analysis as the launching point for any new MSE or MSE update.
        - Work on “closing the loop” on a few key species which would entail full production analysis of the predators as well as their feedback on herring populations

    c. How to clarify the current and future MSE final reports, including input on best practices for translating MSE results for a general audience

        - Look to related “communities of practice” for best practices such as the IEA community

Conclusions and Recommendations

The MSE for Atlantic herring represents the best scientific information available, and the data, models and outputs should be used by the New England Fisheries Management Council in setting herring catch specifications. This reviewer and the committee made many recommendations for improvements on all aspects of the project, but these should be construed as needed for future improvements in implementation and not an impediment for utilizing the MSE in current deliberations. This is a complex and challenging task, and the MSE team has done an excellent job in advancing the scientific basis for herring management.

Atlantic Herring MSE Individual Panelist Report: Dr. John Wiedenmann

A management strategy evaluation (MSE) was conducted to test a range of control rules for setting the acceptable biological catch (ABC) for Atlantic herring, accounting for the role of herring as forage. The MSE included two stakeholder workshops to obtain input on the control rules and performance measures of interest, as well as key predators to consider in the model. The MSE model contained a single-species herring model that quantified the responses of the herring population to control rules, accounting for uncertainty in herring population dynamics (natural mortality, growth, and reproductive success at low stock size). The biomass estimates of herring from each model run were used in population models for select herring predators and in an economic model to understand the broader impacts that changes in herring biomass may have on the ecosystem and the fishery. The review panel concluded that the MSE was appropriate for use by the New England Fishery Management Council (NEFMC) to select an ABC control rule for herring. The panel identified a number of key strengths of the whole MSE process, as well as some areas for improvement, both short and long term. The report by the chair captures the consensus of the review panel, and some individual thoughts on each Term of Reference (ToR) are provided here, with an emphasis on the herring and predator operating models.

1. Evaluate the strengths and weaknesses of the MSE methods used to evaluate Atlantic herring ABC control rules. Provide suggestions for improvements to the methods where appropriate. Evaluation should include the following:

a. Methods to identify objectives, performance metrics, and control rules for testing (e.g. workshops to solicit stakeholder input)

Through two workshops, stakeholder input was obtained to identify 1) ABC controls to be tested, 2) important herring predators for consideration in the model, and 3) desirable outcomes to be used as performance measures in the MSE to evaluate control rule performance. Having stakeholder input is an essential component for a MSE addressing an issue with divergent stakeholder interests, as is the case with herring. The workshops had a large number of attendees (60+) representing herring, tuna, groundfish, and lobster fisheries, as well as NGOs with interests in sea bird and marine mammal conservation, among others. The workshops were successful in engaging stakeholders, and were very effective at addressing objectives 1-3 listed above. Some issues identified with the workshop process were that not all groups were equally represented and that participation was not consistent at both workshops, that some voices may have been more dominant than others, and some individuals may have biased their answers on questionnaires to counter opposing viewpoints in the workshop. However, none of these issues take away from the overall utility of the workshops.

b. Methods to construct the Atlantic herring, predator, and economic models (e.g., structure and use of data)

The herring, predator, and economic models were rigorously developed given the logistical constraints (i.e., time and data availability) facing the analysts. The herring model consisted of multiple operating models representing different observed states of nature for the population dynamics of herring. Having the population dynamics based on observed changes in herring is a key strength of the model, although consideration of some more extreme changes would have

evaluated control rule robustness across scenarios outside the realm of what has been observed for herring. In addition, there appeared to be a negative correlation between the total biomass of herring and size at age of herring, suggesting possible density-dependent growth. Inclusion of such a mechanism is warranted in future model runs, as there may be some interesting interactions with the performance of particular control rules. The herring model used a "simple" assessment approach that mimicked a full assessment by generating assessment estimates of abundance as an autocorrelated error process about the true herring abundance. This simple assessment approach is an effective alternative to including a full assessment model, particularly when it is not feasible to do so, and it also allows for the inclusion of bias in estimates (as was done for herring) without explicit knowledge of the potential sources of that bias. In the case of herring, time constraints and the large number of control rules being tested prevented the inclusion of a full assessment model. However, the level of error assumed in the simple assessment approach was low compared to some other studies, and additional exploration of the greater assessment error is suggested.

Time series' of biomass estimates from the herring model were then used in models of predator population dynamics to understand the potential impacts of changes in herring abundance on the predators. Thus, the link between herring and predators was unidirectional, i.e., changes predator abundance did not impact the natural mortality rate of herring. Although such an inclusion would be more biologically realistic, all herring predators would need to be included (not just the select ones that were chosen), and the data and time to do so were not available. Predators were selected with input from stakeholders at the workshop (Bluefin tuna, common terns, and spiny dogfish), and were treated as representative of other predators in region, and different mechanisms were explored to try to link predator success with herring abundance. This assumption is useful for the purposes of the MSE and necessary given the limited information for many species in the region. A key strength of the approach used is that the analyses for selected predators were limited the available data for each predator, such that assumptions were not borrowed from other species / regions when information was lacking. However, in some cases additional analyses could have been conducted to identify links between predators and herring. For example, growth anomalies were considered for tuna but not groundfish. Rather than using abundance of predators as a dependent variable to identify relationships with herring, it may be more useful to consider deviations in surplus production of a predator population in response to herring biomass or proportion of herring in the diet.

Overall the herring and predator models were developed rigorously with sufficient consideration given to the available species, datasets and predator-prey linkages. Although there is room for improvement in both models, the current limitations identified do not prevent the use of this model in making decisions about ABC control rules for herring.

c. Methods to evaluate the control rules and performance metrics

The methods in the MSE to evaluate control rule performance were robust, and the performance measures were an effective means of summarizing results. A large number of control rules were tested and many performance measures were calculated for each run of the model. As such, it was not feasible to review all performance measures across each control rule from each operating model, and the panel was only presented a subset of performance measures with control rules grouped into broad categories. From this sample of results some of the tradeoffs were apparent, and some general patterns emerged of performance across the broad control rule groupings. For

the predator models the results were grouped by broad control rule category and by operating model, making it clear when results were more sensitive to the herring operating model or to the different control rules being evaluated. Although performance measures were clear to the review panel, they may not be clear to managers and stakeholders, and how the model results can be best presented to a broader audience should be given considerable thought. Effectively summarizing output from a complex MSE model is a common challenge, and this will likely be a very useful exercise in learning how to best translate model results to a broader audience.

2. Evaluate whether the methods, data, and results of the MSE are sufficient for the New England Fishery Management Council to use when identifying and analyzing a range of ABC control rule alternatives for the Atlantic Herring Fishery Management Plan. Comment on any constraints that may hinder use of the MSE in the development of management alternatives.

The panel agreed that the entire MSE process was sufficient for the Council to evaluate ABC control rules options for the herring fishery. However, the primary caveat associated with the MSE is that control rule performance is sensitive to the many assumptions in the herring and predator models. These assumptions must be carefully articulated to managers and stakeholders so that model results are not over-interpreted. For example, herring population dynamics may deviate dramatically from various operating models considered (which were based on the observed dynamics), or certain predator populations not considered due to data limitations may be more sensitive to herring abundance. This caveat does not hinder the use of the MSE, but it does highlight the need for careful and consistent evaluation of the MSE predictions against reality.

3. Provide any recommendations for future improvements. Comments should include the following:

a. How to address any data limitations or needs

There were many data limitations identified throughout the review process, including limited spatial / seasonal information on herring distribution and predator overlap, and more generally on the abundance and diets of other herring predators. In most cases new data would need to be collected to expand the herring and predator models, but it may be possible to find existing datasets and incorporate them into the model. The dataset on common tern abundance and foraging habits in the Gulf of Maine was identified in the workshop process, and efforts to find similar datasets could be fruitful.

b. How to conduct future Atlantic Herring MSEs

The panel felt that MSEs (for herring or future stocks) should be viewed as an iterative process. This first attempt for herring was successful in the creation of the model, and also in the learning that occurred throughout the process for Council staff, the analysts, and stakeholders. It is essential for the MSE to be updated with new information as it becomes available so that control rule performance can be tested with the new information. Large stakeholder meetings may not be necessary for future herring updates, and it might be useful to establish a working group with representatives of various stakeholder groups to discuss future model revisions and results. More generally, any future MSEs undertaken by the Council should be given sufficient time, as many

of the issues identified in the herring MSE review were the result of the short timeframe. In cases where short timeframes are unavoidable, it may be necessary to partner with outside researchers to ensure sufficient effort can be devoted to complete the task .

c. How to clarify the current and future MSE final reports, including input on best practices for translating MSE results for a general audience

The current and future reports would benefit from detailed description of the results and what the implication are of those results, particularly in the figure captions. Captions in the current report are brief, making it difficult to interpret results, particularly for someone without any background in MSE or other fisheries models. Creation of some info-graphic to aid stakeholders and managers in how the MSE works would also be very helpful, and could be included in all future MSE reports or on the Council's website. In addition, an interactive web tool that allows users to visualize the performance measures calculated for particular control rules across operating models would be very helpful.

Atlantic Herring MSE Individual Panelist Report: Dr. Gavin Fay

The New England Fishery Management Council (NEFMC) conducted a Management Strategy Evaluation (MSE) of Atlantic herring to evaluate the performance of acceptable biological catch (ABC) control rules for Atlantic herring, accounting for the role of herring as forage. As part of the MSE, two large stakeholder workshops were convened to identify objectives, performance measures, and alternative control rules. The NEFSC technical team conducted a considerable amount of work, performing a rigorous set of analyses. Configurations of a single-species operating model of herring population dynamics model considered uncertainty in herring productivity and natural mortality. The stock assessment process was approximated in the MSE by considering bias and imprecision in biomass estimates from the operating model, with control rules using these biomass estimates to specify ABC within the model projections. Outputs from the herring model were used in models for herring predators given linkages between herring dynamics and predator productivity to quantify possible impacts of changes in herring population on the ecosystem. Herring operating model output was also linked to an economic analysis to understand consequences for the fishery. Results from the MSE analyses were presented in the form of tradeoff plots against the performance measures identified during the stakeholder workshops.

The review panel concluded that the MSE was appropriate for use by the New England Fishery Management Council (NEFMC) to select an ABC control rule for herring, with strengths of the process and areas for improvement. The Chair report reflects the consensus of the review panel, with additional individual comments on each term of reference below.

1. Evaluate the strengths and weaknesses of the MSE methods used to evaluate Atlantic herring ABC control rules. Provide suggestions for improvements to the methods where appropriate. Evaluation should include the following:

1a. Methods to identify objectives, performance metrics, and control rules for testing (e.g. workshops to solicit stakeholder input)

The participatory approach taken during the MSE (public workshops) provided a platform for engaging a large range of stakeholders in identifying objectives and performance metrics, and is considered best practice for MSEs. There was considerable investment in education on MSE during the process and this will pay off in terms of building capability in stakeholders, scientists, and managers understanding of MSE in the region. It was noted that the technical team and facilitators at the workshops were very responsive to questions about the MSE process and the specifics of the models for herring and the predators. Having a lead facilitator at the workshops that was well-versed in MSE seemed successful.

A lot was accomplished in a single year in a successful and rigorous fashion, however the timeline certainly constrained the analyses and process. In other instances where MSE has incorporated public workshops the MSEs have typically been a multi year process, including sometimes not even with as extensive stakeholder participation. Conducting MSEs with large public involvement is a resource-heavy process and efforts that could be made to streamline the process might be helpful. Consideration of additional workshops (perhaps with smaller groups) or training opportunities, coupled with a refinement of the information gathering procedure, might help. In part, the investment in to MSE training as part of this initial herring MSE should go a long way towards improving process in future MSEs. Presentation of the technical analyses at the 2nd workshop seemed to be a lot, it is possible that an additional intermediate workshop, whether with the full group or smaller sessions (or even through an alternative venue – online?) might provide an opportunity for participants to digest the information more fully. No input was requested at the public workshops about the specifications for the operating model scenarios. This was due to the specific objectives of the MSE and the constrained timeframe. Scoping of the scenarios to be considered might have improved buy-in to the process, but this is unclear. Even if a refinement of the public process is undertaken, it is important to stress the value of a large range of engagement at the scoping phase. A benefit stressed by stakeholders was that the process allowed some a chance to participate in the Council process who felt like they don't normally have an opportunity to participate. In general, holding public workshops as part of MSE can have/achieve multiple goals: education, buy-in to process, engagement, as well as garnering information in a participatory approach. That this appears to have occurred during the herring MSE process should be recognized as a success.

It was not clear how the information gathered through surveys at the workshop is going to be used. The technical team seemed disappointed with a lack of consensus in responses on values for performance metrics, etc. and there was indication that the results may have been the result of people misunderstanding the usage of these information, or based on expectation of other's responses to questions (e.g. trying to game the result). Some additional investment in expertise in survey methodology, with regard to structuring worksheet questions that reveal preferences may be useful, depending on how the Council wishes to use these information when choosing among options. Consultation of literature or experts on methods for expert elicitation might be useful.

There was less time devoted to societal and economic indicators and models at the workshop than for the ecological components and objectives. Additional focus here would not only have increased the holistic nature of the analyses but may have been more aligned with stakeholder interests.

1b. Methods to construct the Atlantic herring, predator, and economic models (e.g., structure and use of data)

The details of model development and use of data was clearly articulated; the technical team did an excellent job of explaining model assumptions and caveats. In addition to presenting the

models and results to the Panel, the importance of effective messengers in MSE should be recognized, the technical team, Council staff, and facilitators involved in this process were very good and committed to lead people through the technical details of the MSE. The technical team took a rigorous and practical approach to including key uncertainties and creating models that allowed the control rules to be evaluated against the objectives, given the constraints (time and data availability).

Atlantic herring models:

The technical team created alternative operating models for herring dynamics that bracketed values for key uncertainties, rather than developing population dynamics models with complex time-varying dynamics of growth and mortality. This approach to considering uncertainty via extreme scenarios allows for clear treatment of the effect of the uncertainties in herring productivity on the model results and was an effective, practical choice that allowed the technical team to achieve a large amount of work within the project period. Robustness of control rules to extremes may not however be the same as robustness to time-varying dynamics. When identifying candidate control rules it will be important to consider performance of alternatives across the full range of operating models, and a control rule chosen based on its performance in a given 'regime' of herring productivity may need to be revisited if information suggests that the system has changed.

The stock assessment process within the MSE was represented by generating (possibly biased) abundance estimates, that were combined with knowledge of the fishing mortality rate at maximum sustainable yield in the harvest control rules. This simple approach to approximating a stock assessment was practical, and is frequently done. Inclusion of a full stock assessment model into the MSE simulations would be more representative of the process of assessing herring status, better integrate uncertainty with the estimation process, and would be a clear avenue for future applications of MSE for herring.

Mis-specification of reference points in the assessment was not considered; the control rules were applied using the known true value for the fishing mortality rate at maximum sustainable yield. An important advantage of frameworks like MSE is that it can evaluate how methods (assessments and control rules) may perform when the assumptions made are wrong. The technical team did consider this in terms of the abundance estimates, with scenarios considering the effects of bias in the abundance estimate. This might be an important thing to consider for the value of the fishing mortality rate reference point used too. A relatively simple option that might be able to be explored in the near term could be to use the reference points from the wrong operating model (rather than model bias and imprecision), a simple swap of reference points between operating model scenarios. This would be an extreme version of likely candidates for estimates of the reference points but may provide some insight into possible implications. Such a check could be done once a set of candidate control rules are identified. The technical team and panel noted that there could be a plausibility inconsistency between the information coming from

the operating model and assuming the wrong reference points, which might suggest that in practice one wouldn't use the extreme values for the wrong reference points because the data from the system would be informative about system productivity. The values for F_{MSY} from the high and low production operating models are substantially different from eachother.

Note that including an assessment model within the MSE as mentioned above could provide an alternative to having to pre-define estimates for fishing mortality reference points (as they may be estimated within the model).

Predator models:

Models for herring predators were created based on evaluating the impacts of changes in herring dynamics on a set of predator species for which data were available, with these species being used as representations for the likelihood of impacts of herring ABC control rules on predators. The technical team took a data-driven approach to modeling and hypothesis creation, and models and scenarios were built off of what people asked for during the workshops. Data for the three predator species models (bluefin tuna, common terns, and spiny dogfish) and the mechanistic links between herring and predators were then based on regional information rather than using assumptions from other areas or species. The linkages between the herring and predator models were limited to the effect of herring on the predators, rather than including effects of predators on herring mortality in the herring operating models. This predator model approach was appropriate to the goal – identifying how ABC control rules for herring might impact predators. While two-way predator-prey modeling is more realistic, the data (needed for all predators) and time to develop such models was not available.

Preliminary explorations using a food web model (EwE) were done to explore systemic effects of changes in herring biomass, but the technical team emphasized that these analyses would need additional attention to develop to a comparable level for the other herring models. Nevertheless, this approach could provide some context for the detailed MSE analyses, by providing guidance on possible system response given a small subset of scenarios for herring fishing (that might approximate alternative ABC control rules). An intermediate level of ecosystem model (MICE model) that included feedbacks would be different from these models and require data for different species because the predators causing mortality on herring are not necessarily those that are most dependent on herring.

The predator models used available data to quantify mechanistic links between herring and predators, but did not consider the effects of availability of alternative prey. Capturing the dependence of predators on herring given variability in the presence or otherwise of other prey might be important in future versions of predator models for a herring MSE. Including variability (process error) in predator population dynamics models would also allow for the potential impact of herring on predator dynamics to be placed in context – predator populations may drop below reference points due to variability not associated with changes in herring abundance.

Overall the herring and predator models were well-developed with appropriate consideration of uncertainty in dynamics, links, and data availability for the species. While the panel identified some caveats, these do not prevent the use of these models for making decisions among alternative ABC control rules for herring.

1c. Methods to evaluate the control rules and performance metrics

The control rules and performance metrics were developed through stakeholder input at the public workshops; the panel agreed this was a good approach. The range of performance metrics for evaluating the MSE results that were considered covered the normal range of metrics that are typically used, although these focused (by objective) on long-term performance rather than short-term effects. The metrics used for the predators were appropriate. The 'streakiness' metric seems useful and could be applied to quantities besides the economic component of the analyses (e.g. quantifying the number of years in a row that overfishing occurs, or number of years in a row that tern productivity is less than 1). Reflective of the workshop process, the control rule shapes investigated were the types of control rules that stakeholders said they were interested in.

A challenge common to all MSEs is how to effectively summarize and evaluate the quantity of output – a large number of control rules were tested for each scenario, and many performance metrics were calculated for each. The methods used to evaluate the results and tradeoffs among performance metrics were effective, but the large number of options meant that the panel was not presented with opportunity to evaluate the performance of individual control rules across all scenarios and metrics. Pre-filtering options before a final workshop may be appropriate in terms of reducing the number of candidates, and this can probably be done to some degree without making value judgements about preferred values for performance metrics (some options will produce unviable or illegal outcomes).

Boxplots were used effectively to show how performance of control rules varied across the different factors in the analyses, and more use of these could be made to present the results across additional factors (e.g. shape of control rule, location and magnitude of breakpoints, etc.). The technical team also presented results in terms of trade off plots for the average behavior (medians of performance metrics) of individual control rules for particular shapes, as well as 'window' plots that show the variability in performance within a particular control rule. These window plots were shown for a arbitrary set of control rule shapes, however they could be useful in exploring tradeoffs once the number of candidate control rules has been narrowed down significantly (it may be difficult to view more than 5 of these at once). An additional way of presenting the sensitivity of control rules could be to display additional quantiles, or the interquartile range, for performance metrics, rather than the median. A strength of the presentation of results is that the technical team showed the performance of the status quo control rule along with the many alternatives. This allows the performance of alternative ABC

control rules for herring to be viewed in the context of how the current management approach could be expected to perform.

When choosing among options, care should be taken to not disregard individual control rules that may meet objectives but are presented with others that do not – for example, viewing the output solely by control rule type may lead to removal of candidate control rules that perform well if the control rules as a whole are judged on the apparent aggregate behavior of the group.

How the model results can be communicated effectively to broader audiences will require some thought and additional time. A scoring procedure for control rules could be applied to help evaluate options – if the responses from workshop surveys about the preferences for metrics stated at the workshop are deemed representative, then it would be possible to summarize performance of control rules with respect to the degree to which they meet these preferences. In general, multiple media may work best in presenting information and evaluating control rules.

2. Evaluate whether the methods, data, and results of the MSE are sufficient for the New England Fishery Management Council to use when identifying and analyzing a range of ABC control rule alternatives for the Atlantic Herring Fishery Management Plan. Comment on any constraints that may hinder use of the MSE in the development of management alternatives.

The structured approach to decision-making provided by the MSE analyses provides a better means for weighing options than currently exists. The panel agreed that the MSE methods, data, and results were sufficient for the Council to evaluate ABC control rule alternatives for the herring fishery. Many of the above suggestions and improvements would require additional time, and none of the constraints above should prevent the NEFMC from using the results to select/choose among ABC control rule alternatives. However, it is important that control rules are evaluated in the context of the assumptions against which they were tested. Decisions could be made about how to identify when to iterate or revisit the operating model dynamics, perhaps when observations are made that lie outside the realm of what was tested in the MSE. One approach for identifying these could be to obtain the predictive distribution for the range of biomasses that were observed in the MSE.

A possible constraint could be the ability to weight objectives and state preferences for particular values for the performance measures when trying to choose among alternatives. Evaluation of performance should be against stated objectives, so as a filtering step in identifying alternatives it may be OK to remove options that don't do well in any of the cases for any metric. When choosing among options, a potential difficulty may arise when a given control rule might not be robust to operating model uncertainty but perform well in some cases. Once a small set of candidate control rules are chosen, there may be value in testing these against a set of additional uncertainties (identified by the panel in the Chair report) to evaluate sensitivity of performance.

3. Provide any recommendations for future improvements. Comments should include the following:

3a. How to address any data limitations or needs

The panel recognized that there were several data limitations and needs for further development of the models and MSE analyses. Some of these were linked to the time constraints of the process, but in some cases additional data may need to be collected. Some data may be available already, but time would be needed for compilation and synthesis. Given additional time and resources, a discussion on operating models and operating model scenarios at workshops would be recommended. It is probable that data and analysis needs can be separated into short- and long-term needs. A strategic approach to investment in work to address these needs could be made based on the expectation of adding value to the product. The MSE analyses themselves could be used to identify areas where addressing uncertainty could aid in understanding performance of control rule options. Many analyses that could be undertaken to provide information to address key uncertainties could be done separately from the MSE process, for example: statistical analysis of seabird data, updates to foodweb models, spatial dependence of prey and predators, etc. The economic models would benefit from further analyses and some of these are already planned.

3b. How to conduct future Atlantic Herring MSEs

The panel agreed that this first MSE for Atlantic herring had been successful and instructive for implementation of MSE in the region, and that a considerable amount of education and training had occurred in the region on understanding of what MSE is and how it can be used. Additional training opportunities could be done through other regional programs or be achieved through additional material ahead of meetings, perhaps in the form of instructional videos (e.g. recordings of presentations from the 2016 public workshops).

Additional iterations of MSEs for herring should consider the overall timing of the process, with perhaps a change in the expectations for the timeframe needed to complete the process and analyses. The panel recognized that MSE is an iterative process and that future MSEs for Atlantic herring should build from experience and analyses conducted in this first MSE, with development/updates of models when data becomes available. Part of the next iteration should include an evaluation of the workshop process, what worked and what didn’t, with discussion on alternatives for this process that maintain both broad participation but also provide specific relevant and useful advice. An increased emphasis on the economic and social science components of the analyses should be made during stakeholder workshops. The technical team mentioned that support for preparation of visuals for workshops and reports was needed.

Future MSEs for herring should more fully consider dimensions and more options for various sources of uncertainty. This would include the implications of getting things wrong in the assessment and management procedure. Consideration of alternative operating models could also

extend to the predators, and human parts of the modeling analyses too, in addition to herring. In addition, alternative model frameworks (MICE models, foodweb modeling, spatial modeling) could also be considered. Spatiotemporal issues are clearly important to stakeholders. All these analyses will require time, resources, and compilation of existing and collection of new data, and priorities must be balanced based on objectives and needs. However, these may provide the opportunity to extend analyses beyond thinking about MSE as a way of setting a ABC control rule but more about management of the socio-ecological system surrounding the herring fishery as a whole.

3c. How to clarify the current and future MSE final reports, including input on best practices for translating MSE results for a general audience

The current reports provided concise and clear descriptions of the modeling methods. The presentation of the vast quantity of results could be improved by adding more text summarizing the results and more descriptive Figure captions that walk readers through the tradeoff analyses. Several alternative presentations of the results might aid a range of audiences and it is likely that different versions of the report and results might be the best way of effectively communicating the results to the different intended audiences. Once a set of candidate control rules have been selected, some additional Figures and Tables summarizing the performance of these against all operating model scenarios and uncertainties will be needed. Infographic-type summaries of MSE and the results could be presented on the Council website. Summary reports should be focused around key questions to help guide users/readers through the results. Creation of a user-friendly, interactive format for visualization of results, say through a web-based tool (e.g. R Shiny app) that allows users to compare control rules and tradeoffs among metrics, would be very useful for this and other MSEs.

APPENDIX B: Terms of reference for peer review

TERMS OF REFERENCE FOR THE PEER REVIEW
of the
Management Strategy Evaluation (MSE) of
Atlantic Herring Acceptable Biological Catch (ABC) Control Rules

The peer review shall be conducted based on the following Terms of Reference (TORs):

1. Evaluate the strengths and weaknesses of the MSE methods used to evaluate Atlantic herring ABC control rules. Provide suggestions for improvements to the methods where appropriate. Evaluation should include the following:

   a. Methods to identify objectives, performance metrics, and control rules for testing (e.g. workshops to solicit stakeholder input)

   b. Methods to construct the Atlantic herring, predator, and economic models (e.g., structure and use of data)

   c. Methods to evaluate the control rules and performance metrics

2. Evaluate whether the methods, data, and results of the MSE are sufficient for the New England Fishery Management Council to use when identifying and analyzing a range of ABC control rule alternatives for the Atlantic Herring Fishery Management Plan. Comment on any constraints that may hinder use of the MSE in the development of management alternatives.

3. Provide any recommendations for future improvements. Comments should include the following:

   a. How to address any data limitations or needs

   b. How to conduct future Atlantic Herring MSEs

   c. How to clarify the current and future MSE final reports, including input on best practices for translating MSE results for a general audience

APPENDIX C: Peer review meeting agenda

AGENDA[1]
of the

NEFMC External Peer Review

Management Strategy Evaluation of

Atlantic Herring Acceptable Biological Catch Control Rules

Location: Embassy Suites Boston, MA

Date: March 13-15, 2017

Day 1: Monday, March 13, 2017

9:00 Executive Director's Welcome – *Tom Nies*

9:05 Panel Chairman's Opening Remarks – *Dr. Lisa Kerr*

- Introductions
- Agenda overview
- Conduct of meeting

9:15 Review Terms of Reference – *Deirdre Boelke*

9:30 Introduction to the Management Strategy Evaluation of Atlantic Herring ABC Control Rules – Dr. *Rachel Feeney*

- Management context
- Timeline
- Process for stakeholder input

9:50 Report of Technical Group – *Dr. Jon Deroba, Dr. Sarah Gaichas, Dr. Min-Yang Lee*

- Herring operating models, control rules, output metrics
- Predator models and output metrics
- Economic model and output metrics

10:30 Break

10:40 Report of the Technical Group CONTINUED

12:00 Lunch

1:00 Report of the Technical Group CONTINUED

[1] All times are approximate, and may be changed at the discretion of the Chairman. The meeting is open to the public. During scheduled "Public Comment" periods, the Chairman will welcome questions, clarifications, and opinions when noted. Each person will have a time limit set by the Chair.

2:30 Public Comment on presentations (clarifying questions and corrections only)

2:45 Break

3:00 Panel Discussion – TOR #1

4:30 Public Comment on TOR #1 only (questions and opinions invited)

4:45 Conclude Day 1, Charge for Day 2 - *Chairman*

5:00 Adjourn

Day 2: Tuesday, March 14, 2017

9:00 Charge for Day 2 - *Chairman*

9:05 Panel Discussion – TOR #1 CONTINUED

10:00 Panel Discussion of TOR #2

10:45 Break

11:00 Panel Discussion of #2 CONTINUED

11:45 Public Comment on TOR #2 only (questions and opinions invited)

12:00 Lunch

1:00 Panel Discussion of TOR #3

2:30 Break

2:45 Public Comment on TOR #3 only (questions and opinions invited)

3:00 Report Writing[2] (with presenters in attendance)

5:00 Adjourn

Day 3: Wednesday, March 15, 2017

9:00 Review Key Findings - *Chairman*

9:30 Report Writing CONTINUED

1:00 Adjourn

[2] The "Review Key Findings" session scheduled for the afternoon on Day 2 and the morning of Day 3 is primarily intended for the Panel to discuss and write its report. This agenda item is open to the public to observe, but there will not be a public comment period.

APPENDIX D: Public Attendance at MSE Peer Review

March 13, 2017

In-Person:

Morgan	Callahan
Bill	Hartford
Jeff	Kaelin
Rich	Ruias
MaryBeth	Tooley
Chris	Weiner
Greg	Wells

About 20 individuals participated via webinar.

March 14, 2017

In-Person:

Jeff	Kaelin
MaryBeth	Tooley
Greg	Wells

About 15 individuals participated via webinar.

March 15, 2017

In-Person:

None

About 5 individuals participated via webinar.