EXTERNAL PEER REVIEW OF ECOSYSTEM-BASED FISHERY MANAGEMENT STRATEGY

April 30 – May 3, 2018
Clark Conference Room
NEFSC Woods Hole Laboratory
Woods Hole, MA

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EXECUTIVE SUMMARY

The Ecosystem Based Fishery Management Strategy Review Panel was convened by the New England Fishery Management Council (NEFMC) on April 30 – May 3, 2018 in Woods Hole, MA. The goal of the review was to evaluate a proposed strategy for implementing Ecosystem Based Fishery Management (EBFM) for the New England Fishery Management Council (NEFMC). The work reviewed by the Panel was conducted by Northeast Fisheries Science Center (NEFSC) scientists in collaboration with the NEFMC Ecosystem Plan Develop Team and with input from the NEFMC. The Panel consisted of Dr. Lisa Kerr (Chair, Gulf of Maine Research Institute), and Council of Independent Expert reviewers: Dr. Keith Brander (Technical University of Denmark), Dr. Villy Christensen (University of British Columbia), and Dr. Daniel Howell (Institute of Marine Research, Norway). The Panel reviewed the written materials and presentations on the proposed EBFM procedure and addressed nine terms of reference. The terms of reference required the Panel to review the general EBFM approach proposed for implementation by the NEFMC and a simulation tested example of EBFM implementation on Georges Bank.

The Panel recognized the extensive work that went into developing the proposed strategy for implementing EBFM for the NEFMC and in demonstrating the approach in a worked example for the Georges Bank ecosystem. The Panel also appreciated this was a research-track review and that additional work is ongoing to improve aspects of the management procedure. Thus, the feedback and recommendations were intended to improve the EBFM approach. Overall, the Panel concluded that the materials presented during the review represented good progress toward an EBFM procedure, however, further work is needed to refine the approach before it is implemented by the NEFMC. In the following report, areas of strength, areas of concern, and recommendations for improvement of the EBFM procedure are summarized based on the individual reviews by Panel members. The full detail of the individual review of each Panelist is provided in Appendix V (Dr. Keith Brander), Appendix VI (Dr. Villy Christensen), and Appendix VII (Dr. Daniel Howell).

BACKGROUND

The Ecosystem Based Fishery Management Strategy Review Panel (hereafter referred to as the "Panel") was convened by the New England Fishery Management Council (NEFMC) on April 30 – May 3, 2018 in Woods Hole, MA. The goal of the review was to evaluate a proposed strategy for implementing Ecosystem Based Fishery Management (EBFM) for the New England Fishery Management Council. This was a research-track review, focused on evaluating the conceptual framework of the proposed EBFM strategy and a worked example of its application to the Georges Bank ecosystem. The work reviewed by the Panel was conducted by Northeast Fisheries Science Center (NEFSC) scientists in collaboration with the NEFMC Ecosystem Plan Develop Team and with input from the NEFMC. The review included a simulation study to evaluate the appropriateness of the strawman objectives, operating models, assessment models, reference points, harvest control rules, and performance metrics of the EBFM management procedure. The reviewers were asked to provide feedback on the EBFM strategy and to make recommendations that could improve performance of the EBFM strategy. The goal was not to evaluate the output of the EBFM procedure for use in management specification setting at this stage. If the review is favorable, subsequent steps will be necessary before the procedure can be used in specification setting. These subsequent steps would include: definition of management objectives by the NEFMC and careful consideration of the potential changes in management units, regulations, and fishery management plans that would be needed to implement EBFM.

REVIEW PANEL

The Panel consisted of Dr. Lisa Kerr (Chair), and Council of Independent Expert reviewers: Dr. Keith Brander, Dr. Villy Christensen, and Dr. Daniel Howell. Dr. Lisa Kerr is currently Vice Chair of the NEFMC Science and Statistical Committee and a research scientist with the Gulf of Maine Research Institute (Portland, Maine). Dr. Keith Brander is a Senior Researcher at Technical University of Denmark (Lyngby, Denmark) with a background in integrating ecosystem effects into fisheries assessment and management. Dr. Villy Christensen is a Professor at the University of British Columbia (Vancouver, Canada) specializing in ecosystem modelling. Dr. Daniel Howell is a Fisheries Mathematical Modeller at the Institute of Marine Research, Norway with expertise in multi-species modeling and management strategy evaluation. More information about each panelist's research and scientific expertise can be found at: https://www.nefsc.noaa.gov/program_review/reports2018.html.

As Chair of the Panel, Dr. Kerr facilitated the meeting and made sure that all the terms of reference were reviewed by the Panel. She also led the preparation of the Peer Review Panel Summary Report. Drs. Keith Brander, Villy Christensen, and Daniel Howell served as independent and impartial reviewers. The reviewers each completed independent peer review reports in accordance with the requirements specified in the Statement of Work and terms of reference (Appendix I); reviewers were not required to reach a consensus. Reviewers submitted Individual Peer Review Reports and contributed to the Peer Review Panel Summary Report.

REVIEW ACTIVITIES

During the review, the NEFMC tasked the Panel with two objectives:

Objective 1: Review a proposed implementation of Ecosystem Based Fishery Management for the New England Fishery Management Council (NEFMC), and

Objective 2: Review the proposed strategy for implementing EBFM on Georges Bank.

Under objective two the Panel was asked to address nine terms of reference (Appendix I):

1) Evaluate the approach used to identify Ecological Production Units on the Northeast Shelf of the United States and the strengths and weaknesses of using these Ecological Production Units as the spatial footprint for Ecosystem Based Fisheries Management in the region.

2) Evaluate the methods for estimating ecosystem productivity for the Georges Bank Ecological Production Unit and advise on the suitability of the above methods for defining limits on ecosystem removals as part of a management procedure.

3) Evaluate the approach and rationale for specifying Fishery Functional Groups as proposed management units.

4) Comment on the applicability and utility of the strawman management objectives and associated performance metrics which were used to guide the development of operating models.

5) Evaluate the utility of the proposed management reference points as part of a management control rule for ecosystem-based fishery management. These include: an overall catch cap at the Ecological Production Unit level conditioned on environmental conditions, ceilings on catch for each Fishery Functional Group (defining overfishing) conditioned on aggregate properties, and biomass floors at the single species level (defining overfished conditions).

6) Review harvest control rules embodying the proposed floors and ceilings approach using the ceiling reference points in ToR 5 to cap removals at the Ecological Production Unit and Functional Group levels, while ensuring that no species biomass falls below the single species floor reference points.

7) Review the structure and application of operating models for Georges Bank.

8) Review ecosystem assessment models and required data sources, as applied to the simulated data from the operating models in ToR 7.

9) Review simulation tests and performance of the proposed management procedure incorporating the floors and ceilings approach, given the set of EBFM goals and objectives.

Prior to the in-person meeting, the Panel was provided written materials to review that described the EBFM strategy (see Appendix II for a full list). The main document intended for review by the Panel was an overview of the EBFM management procedure entitled "Ecosystem-Based Fishery Management Strategy, Georges Bank Prototype Study". In addition, a series of background materials were reviewed by the Panel. During the meeting, the EBFM technical team presented on model details and results of model simulations under different harvest control rules (see meeting agenda for a full list of presentations, Appendix III). The team of presenters included Mike Fogarty, Rob Gamble, Sean Lucy, Andy Beet, Geret Depiper (NEFSC scientists),

Richard Bell (Nature Conservancy), Amanda Hart (UMass Dartmouth), and Andy Applegate (NEFMC). 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 IV). All written materials and presentations were made available at the NEFMC website (https://www.nefsc.noaa.gov/program_review/).

EVALUATION OF TERMS OF REFERENCE

ToR 1: Evaluate the approach used to identify Ecological Production Units on the Northeast Shelf of the United States and the strengths and weaknesses of using these Ecological Production Units as the spatial footprint for Ecosystem Based Fisheries Management in the region.

The Panel reviewed the written materials and presentations on the methods used to identify ecological production units on the Northeast Shelf of the United States for application in EBFM in the region. The aim was to identify geographically-defined ecological units based on: 1) physical oceanography, 2) hydrographic variables, and 3) biological variables (including primary production, but not upper trophic levels). Multivariate analysis was applied to reduce dimensionality of the data (principal components analysis) and identify clusters of data (disjoint cluster analysis) that represent major ecological production units. This process led to the identification of four ecological production units: 1) Mid-Atlantic Bight, 2) Georges Bank, 3) Western-Central Gulf of Maine, and 4) Scotian Shelf-Eastern Gulf of Maine. These were put forth as the spatial management units that would underpin the EBFM approach in the region. The Panel identified strengths and concerns with the approach and made recommendations for consideration in future work.

Strengths

- Scientifically rigorous method: The Panel recognized that the approach was rigorous and allowed for objective identification of ecological production units (i.e., the data defined the geographic structure).
- Comparable to previous findings: The results of the analysis aligned well with previous approaches to define ecosystem management units using alternative methods (e.g., Clark and Brown 1977, Higgens et al. 1985). This provides support for the ecological production units.

Concerns

- Dynamics of boundaries: One of the concerns of the Panel was that that the boundaries of ecological production units are dynamic and will need to be revisited and updated at some interval. The EBFM technical team should consider an approach for dealing with this concern.
- Connectivity between ecological production units: The EBFM team will have to develop an approach for estimating the exchange of productivity across ecological production units. Many fish stocks will span these boundaries (i.e., migratory species) and this will need to be considered.
- Missing information on upper trophic levels: The approach did not include upper trophic levels (e.g., fish) in the definition of ecological production units. However, given the

desire to have management units that are relatively stable, the focus on physical, oceanographic, and lower trophic data is advisable.

- New management boundaries may create new difficulties: Re-definition of management boundaries may create difficulties in assigning historic fisheries information (both fishery independent and dependent data) and allocating catch shares. This concern will need to be addressed as the EBFM strategy moves forward toward application.

Recommendations

The Panel found the methods for defining ecological production units to be reasonable and recommends that the approach continue to be refined to consider the details of implementing new management units. For example, the Panel recommends consideration of how exchange across ecological production units would be estimated and the appropriate method and timeline for revisiting the boundaries of ecological production units in the future.

ToR 2: Evaluate the methods for estimating ecosystem productivity for the Georges Bank Ecological Production Unit and advise on the suitability of the above methods for defining limits on ecosystem removals as part of a management procedure.

The Panel evaluated the proposed method for estimating ecosystem production potential of ecological production units. The method was a bottom-up approach that was applied to determine fisheries production potential and exploitation for various ecosystem components. The approach utilized information on the: 1) net primary production for two functional groups (nanopicophytoplankton and microphytoplankton), 2) pathway of energy flow in the system, and 3) energy transfer efficiency to estimate total ecosystem production potential. Potential fishery production was then calculated based on applying a 20% exploitation rate on each functional group as described in Moiseev (1994). The approach was illustrated for the Georges Bank Ecological Production Unit. The Panel identified strengths and concerns with the approach and made recommendations for consideration in future work.

Strengths

- Scientifically rigorous method: The basic approach to estimating ecosystem production potential is straight forward and grounded in the scientific literature. In addition, there is good information on lower trophic level productivity in the region to support application of this approach.
- Appropriate for tracking trends: The Panel suggested that the approach is useful for tracking trends in primary production and for understanding how this might impact production at higher trophic levels (considering the lag in transfer of energy through system). This information could be used as a warning sign of changes in the ecosystem and could provide a general context for fisheries management decisions.
- Comparable to previous findings: The initial estimate of Georges Bank fisheries production (220,000 mt) seems to be in the ballpark of estimates produced by others (e.g., 90,000 mt; Link et al. 2008 and 130,000 mt; Collie et al. 2009), although somewhat higher. However, given that the Fogarty et al. estimate includes latent fishery resource production, it is expected to be higher than realized production.

Concerns

- High uncertainty in estimate: The approach of using primary production to estimate fishery production potential is highly uncertain. This estimate was viewed as an appropriate approximation of fishery production; however, the Panel was concerned about the use of this number as a reference point (i.e., a ceiling/overfishing limit). Furthermore, when this number is reported, the associated information on uncertainty should also be reported.
- Alternative approaches: The Panel suggested that other approaches to estimating fishery production (e.g., multi-species surplus production models, Ecopath model) be explored for comparison. Furthermore, different metrics of potential fish production should be considered (e.g., potential fish production vs. fished species production).
- Missing information on upper trophic levels: This method is a bottom-up approach and does not utilize information on upper trophic levels in the estimation of ecosystem production potential. It should be noted that the estimates of fisheries production includes both exploited and non-exploited species.

Recommendations

The Panel viewed the methods for estimating ecosystem productivity for Georges Bank as a useful means of tracking an important and dynamic metric of ecosystem status. However, they did not advise using this for defining limits (i.e., reference point) on fishery removals at this time due to the uncertainty in this method. The Panel suggested that the EBFM technical team explore other methods and metrics of estimating fishery production and continue simulation testing limits on removals defined from multiple approaches to resolve the best approach.

ToR 3: Evaluate the approach and rationale for specifying Fishery Functional Groups as proposed management units.

The Panel evaluated the approach and rationale for specifying fishery functional groups as proposed management units. Fishery functional groups were described as species that are caught together by specified fleet sectors, have similar life history characteristics, and play similar roles in the ecosystem with respect to energy transfer. The approach required characterization of: 1) catch characteristics and targeting practices by fleet, 2) trophic guilds (e.g., benthivore, piscivore, planktivore), and 3) issues of differential risk to species within functional groups based on life history characteristics. The approach is designed to address both technical and biological interactions of species in the definition of the management unit.

Strengths

- Scientifically rigorous method: The approach of using fishery and biological characteristics is reasonable and aspects of this method have been previously published (Garrison and Link 2000, Lucey and Fogarty 2013).
- Addresses technical interactions: This approach enables consideration of biological and technical interactions together in the definition of a management unit. Well-defined

fishery functional groups may help alleviate some of the current issues associated with technical interactions in the mixed stock groundfish fishery.

Concerns

- Appropriateness of fishery functional groups as management units: It is not clear if fishery functional groups are the most appropriate management unit. Further work needs to be done to understand whether grouping by both trophic guilds and fishery characteristics will improve and/or simplify management of the system. These units do not map onto existing management units (single-species stocks) or the scale at which harvest is allocated (sectors), and the transition may be a challenge. Furthermore, the appropriateness of the fishery functional group as a management unit will depend on the management objectives which are currently not determined. Therefore, the definition of management units may need to be revisited after final definition of management objectives.
- Dynamics of fishery functional groups: As the availability of fish to the fishery and fisheries practices change, fishery functional groups will change. Due to the definition of these groups being based on historical targeting and catch composition of fisheries in the region, this approach could be inflexible to future changes. The EBFM technical team should consider a method for modification of fishery functional groups to consider future change (e.g., distributional shifts of species or change in fishing behavior). Furthermore, they will need to evaluate the potential changes in fisher behavior associated with the change to EBFM in the region (i.e., quota allocation at the fishery functional group level may change targeting practices).
- Individual species/stock concerns: It will be important to make sure that monitoring and attention to single species will not be lost in this approach. There may be stocks that managers would want to continue to monitor and assess at the individual-level based on management concerns.

Recommendations

The Panel found the definition of fishery functional groups to be a reasonable approach that would enable consideration of biological and technical interactions together in the definition of a management unit. However, the Panel recommends further examination of the appropriateness of this unit for management through simulation testing with a more realistic representation of the fishery functional groups on Georges Bank. The Panel recommends further research into the dynamics of fishery functional groups over time and development of an approach to update management units with changes in the system. In addition, practical considerations of implementing new management units will need to be addressed as these units do not map onto existing management units (single-species stocks) or the scale at which harvest is allocated (sectors), and the transition may be a challenge.

ToR 4: Comment on the applicability and utility of the strawman management objectives and associated performance metrics which were used to guide the development of operating models.

The Panel reviewed a presentation of the strawman management objectives and associated performance metrics for the EBFM procedure. The strawman objectives were used to guide the development of operating models and outputs of the management procedure. The strategic management objectives presented included:

1) maintain/restore sustainable production levels (ecosystem),
2) maintain/restore biomass levels (functional group/species), and
3) maintain/restore functional trophic structure.

A range of operational management objectives were also presented. These included:

1) Ecosystem and community/aggregate fishing mortality and or total catch is below a dynamic threshold,
2) Fishing-related mortality for threatened/endangered/protected species is minimized,
3) Managed and protected species biomass is above established minimum threshold,
4) Maintain ecosystem structure within historical variation recognizing inherent dynamic properties of the system,
5) Maintain habitat productivity and diversity,
6) Habitat structure and function are maintained for exploited species, and
7) Minimize the risk of permanent habitat impacts.

The performance metrics presented were:

1) Functional group status (proportion overfished/depleted)
2) Species status (proportion overfished/depleted)
3) Landings
4) Biomass at species and functional group levels
5) Stability of landings
6) Large fish index (population)
7) Large fish index (landings)
8) Revenue

The presenter indicated that this was a sample list of potential management objectives and ultimately these objectives would be determined by the NEFMC through outreach and engagement with stakeholders. The presentation also discussed the Magnuson-Stevens Act and outlined how EBFM is consistent with new National Standard 1 guidelines (i.e., NS 1 would allow for using an aggregate approach to estimate the maximum sustainable yield of a fishery).

Strengths

- Reasonable approach: The strawman management objectives were reasonable, high level objectives, but will need to be refined for operational use. The expectation is that these will be refined and expanded upon through the stakeholder engagement process.

Concerns

- Limited in scope: The strawman objectives should not limit the full scope of objectives considered in the MSE. For example, economic and social management objectives should be considered more fully.

- Single species metrics: Another concern is that the only metric of single species stock status being tracked is reduction below 20% of unfished biomass (B_{lim}). This provides information on reduced stock reproduction potential, but does not give information on reduced yield potential. The fraction of stocks falling below the higher trigger point of the ramp-down harvest control rule (point at which fishing is reduced) should be tracked as a metric as well.
- Strawman objectives limit model structure: The Panel notes that the strawman objectives have, in part, defined the metrics that are output from the current MSE framework. As the management objectives evolve, there may be a need to revisit the structure of the model and HCRs as management objectives will need quantifiable outputs to track performance from the model. Furthermore, some of the operational objectives presented (i.e. habitat objectives) are not integrated into the MSE or linked to performance tracking.
- Strategic and operational objectives not linked: When management objectives are finalized, there should be a clear linkage made between strategic objectives, operational objectives and the associated performance metrics.

Recommendations

The Panel viewed the strawman management objectives as a reasonable starting point for the EBFM procedure, however, the Panel expects that these will be refined and expanded upon in the future through the stakeholder engagement process. The Panel recommends that additional objectives are explored based on input from stakeholder engagement, these should include biological, economic, and social objectives. Expansion of management objectives may require iteration of the model to accommodate performance measures which are not currently quantified in the current structure.

ToR 5: Evaluate the utility of the proposed management reference points as part of a management control rule for ecosystem-based fishery management. These include: an overall catch cap at the Ecological Production Unit level conditioned on environmental conditions, ceilings on catch for each Fishery Functional Group (defining overfishing) conditioned on aggregate properties, and biomass floors at the single species level (defining overfished conditions).

The Panel reviewed the proposed management reference points for the EBFM management procedure, which included: 1) an overall catch cap at the ecological production unit level conditioned on system productivity, 2) ceilings on catch for each fishery functional group (defining overfishing) conditioned on aggregate properties, and 3) biomass floors at the single species level (defining overfished conditions). The definition of the ecosystem overfishing limit was proposed to be based on the dynamic 'carrying capacity' of the ecosystem as a function of production at the base of the food web. The methods for estimating this value were reviewed under ToR 2. It was not clear how the ceilings on catch for fishery functional groups would be calculated, just that their sum would not exceed the overall cap. Biomass floors were proposed to be calculated at either the fishery functional group (biomass of fishery functional group not to fall below 20% of unfished biomass) or individual species level (biomass of any species not to fall below 20% of unfished biomass).

Strengths

- Reasonable approach: The Panel viewed the proposed approach to define management reference points (i.e., floors and ceilings) as a reasonable approach, however there was substantial concern regarding the details of how reference points would be calculated. The implementation of these reference points will require simulation testing.

Concerns

- Definition of biomass floors: The Panel had concerns about biomass floors for single species and how are these will be defined (e.g., the use of unfished biomass to define the limit, and what percentage of unfished biomass should be used as a limit [i.e. should all species be at 20% ?]).
- Definition of ecosystem ceiling: The concept of the overall catch cap is useful, but the Panel was concerned about using primary production as the basis for limiting fishing and it was unclear how the ecosystem ceiling would be applied in fisheries decision making. In theory it seems like the catch cap should not be breached, however, there was concern that this could be risky if this value is viewed as a target. Further work needs to be done to define the role of the ecosystem ceiling in management and the corresponding action that would occur when the ceiling is breached (HCRs need to specify this). The simulations only included action when biomass dropped below floors.
- Definition of fishery functional group ceiling: There is a need to clarify the calculation of the catch cap for fishery functional groups. What was proposed in the general description of the management procedure and what was implemented in the worked example for Georges Bank (sum of single species MSYs) were different approaches. If the MSY approach is pursued for this purpose, the MSY for fishery functional groups, should be calculated based on a multispecies model (not sum of single species MSY).
- Dynamics of reference points: The Panel was concerned whether these reference points will be responsive to ecosystem change. This concern is not specific to an EBFM approach, but the EBFM team should carefully consider the data used in estimation, how linked reference points will be to historic production, and how often values will be re-estimated to reflect current conditions.

Recommendations

The Panel approved of the general approach of defining floors and ceilings for use as reference points in an EBFM procedure. However, there was substantial concern about how these numbers would be estimated and applied in operational management. In addition, the Panel recommends further examination of how ceilings will be used in a real-world application (e.g., what action would be taken when an ecosystem or fishery functional group ceiling is breached).

ToR 6: Review harvest control rules embodying the proposed floors and ceilings approach using the ceiling reference points in ToR 5 to cap removals at the Ecological Production Unit and Functional Group levels, while ensuring that no species biomass falls below the single species floor reference points.

The Panel reviewed potential harvest control rules embodying the proposed floors and ceilings approach to management whereby overfishing is determined at the fishery functional group level and the overfished status is determined either at the fishery functional group or individual species level. Two main forms of harvest control rules were explored: 1) threshold exploitation, whereby exploitation rate is constant until a threshold biomass level is reached (i.e., a fishery functional group or individual species floor), and 2) ramp-down exploitation whereby exploitation rate ramps down (step-wise approach) when a trigger point in reached and ceases then threshold is reached (i.e., fishery functional group or individual species floor). In addition, scenarios were examined which provided additional protection for vulnerable species (e.g., skates and sharks). For each scenario, system-based exploitation rates were simulated ranging from 0.05 to 0.4. The evaluation used performance metrics for revenue, functional group status, species status, landings, biomass, stability of landings, the proportion of large fish in the population, and the proportion of large fish in the landings. Overall, ramp-down harvest control rules, structured with a reduction in exploitation prior to declines in biomass approaching overfished, performed better than threshold harvest control rules. Early intervention preserved resilience as measured by species diversity and representation of large fish in system.

Strengths

- Reasonable approach: If reasonable floors and ceilings can be defined, the Panel indicated that the shapes of HCRs investigated make sense. The Panel expects that the current HCRs would be expanded upon and refined as the approach develops.

Concerns

- Definition of triggers and thresholds: The Panel was concerned about the estimation of reference points that define the triggers and threshold within the HCRs (see ToR 5). How to calculate reference points in an operational manner remains a serious concern.
- Lack of status quo comparison: The EBFM technical team has built the EBFM MSE for the purpose of testing fishery functional group HCRs. However, there is no comparison of the performance of this multispecies approach to the current single species management.
- Form of harvest control rule: In general, the form of HCRs investigated was reasonable, however, the use of step functions within the ramp-down HCR was not supported by the Panel. The use of a step-functions can have unintended consequences when applied in management, with small changes in an assessment producing large changes in quotas. This places stress on the reliability of the assessment and can lead to implementation difficulties. The Panel recommends that step functions within HCRs be replaced with a slope.

- Ramp-down trigger: The Panel recommends further consideration of the appropriate trigger point (currently 40% B_0) for use in the ramp-down harvest control rules through simulation testing.
- Hybrid approach: The Panel suggested consideration of a hybrid approach whereby in addition to overall quotas for a fishery group there is a more specific constraint on one (or several) key species (not necessarily only related to life history vulnerability).
- Simulation testing: The Panel noted that HCRs were only tested using the Hydra operating model. Ideally, HCRs would be tested using multiple operating models (e.g., Kraken, Atlantis).

Recommendations

The Panel viewed the proposed harvest control rules as a reasonable starting point, provided the stepwise changes in fishing level are removed from the ramp-down HCR, but recommends that more harvest control rules are explored and that alternative control rules are simulation tested and compared to the performance of current single species harvest strategies. The Panel was concerned about the estimation of reference points (floors, ceilings, and trigger points) within the HCRs and recommends this as an area requiring more development and simulation testing.

ToR 7: Review the structure and application of operating models for Georges Bank.

The Panel reviewed the written materials and presentations on two operating models for Georges Bank: 1) Hydra, a multispecies-multifleet length-structured simulation model; Gaichas et al. 2017) and 2) Kraken, a multispecies production model; Gamble and Link 2009.

Hydra is a ten species, size-structured model, implemented for three fleets: demersal trawl, fixed gear (longline and gillnet), and pelagic trawl. Hydra traces population trajectories of a multispecies assemblage as a function of size, growth, recruitment and survival. Hydra was applied as a basis for testing the EBFM management procedure. Hydra includes technical and biological interactions as the fish species have size structure, which determines interactions and catchabilities.

Kraken is a ten species production model that requires biomass/abundance time series or survey index and a catch time series as inputs. The Kraken surplus production function acts as an operating model, simulating biomasses for 10 species. In the worked example, Kraken was applied for the purpose of portfolio analysis. The portfolio approach involves the application of financial portfolio theory to multispecies fishery management. The approach allows economic risks and returns to be calculated across varying combinations of species' harvest and allows for simulating an optimal harvest strategy for the system. Kraken was also used as the basis for assessing the use of catch ceilings which limit total removals from the ecosystem in the EBFM procedure (work by A. Hart).

Strengths

- Hydra model: The Hydra model provides a good basic structure for this purpose, combining detail and potential realism with moderate run times. This is a peer-reviewed, published model (Gaichas et al. 2017).
- Kraken model: The Kraken model is simpler in form and thus enables different applications due to the speed of model runs (e.g., portfolio analysis).
- Alternative models: There are two potential operating models (Hydra and Kraken). It is good practice to have multiple operating models.

Concerns

- Hydra scope and structure: The Panel suggests that the EBFM technical team evaluate the appropriate number of species for the operating models and expand on the fleet structure to ensure they are able to emulate realistic biological and technical interactions. It is not necessary that the model completely matches the "real world", but it may be necessary to increase the level of detail in the model to approximate population and fishery dynamics for robust testing of HCRs. Another concern with the Hydra model structure is whether the model is stable when moving away from the base scenario (e.g., is there a tendency for populations to crash in the model?).
- Hydra trophic interactions: Ideally, the key food components for species within the model should be fully modelled. If this is not possible, then care should be taken with modeling "other food", giving as much realism as possible and checking for model sensitivity to this input. In addition, the trophic interactions in the model do not include interactions at early life history stages and it would be worthwhile for the team to consider how important this may be to the realism of the model.
- Hydra stock recruit relationships: The Panel questioned the form and range of S-R models included in Hydra. The Panel was concerned with the use of a hockey stick form, as it tends to produce lower compensation than Beverton and Holt models at low spawning stock biomass. On the other hand, the range of curves explored were all to the left of the fitted function, which will provide stronger compensation and perhaps spurious robustness to the effect of fishing in the model (i.e., making it hard to fish-down stocks). In addition, the variability included on the recruitment functions are currently lognormal. This may be too restrictive for some stocks, such as haddock where other methods may be better at approximating erratic high recruitment. The Panel recommends exploring different forms and a balanced representation of possible S-R curves around the fitted function.
- Further development of Kraken model: The Panel suggests that further development of the Kraken model is needed, including work to evaluate the appropriate number of species in the model and incorporation of more realistic fleet structure, as well as simulation testing of the performance of the operating model.
- Hydra and Kraken model performance uncertain: The Hydra and Kraken models seem appropriate in structure, but realizations of operating models have not been checked. There is a need to evaluate the model against real world observations/trends to demonstrate that these models can produce credible results (e.g., when model is informed

by high catch levels on the order of historic catch does the model demonstrate a decline for those species).

- Range of model complexity: There are trade-offs in modelling between providing a detailed representation of ecosystem dynamics as compared to a simple representation that captures the dynamics that matter for a specific question. The Hydra and Kraken simulations could be regarded as an example of each. It would be worthwhile to explore other models that varying in their level of detail and complexity (e.g., models that include the full size spectrum of fish life histories and therefore take account of early life interactions).
- Application of alternative operating models: Kraken was used for the portfolio analysis and testing ceilings and Hydra was used for harvest control rule testing. If feasible, the operating models should each be utilized as a basis for the portfolio analysis as well as testing of harvest control rules. However, it is important to note that the two models are not truly independent as Kraken was tuned to results from Hydra. Ideally, the two models would be independent and applied for each purpose. Furthermore, additional alternative operating models could be utilized that include greater complexity (e.g., Atlantis model once update is complete and ecopath model).

Recommendations

The Panel viewed the development of two multispecies operating models (Hydra and Kraken) with varying levels of complexity as good practice for testing aspects of the EBFM procedure. The Panel recommends specific areas for improvement for each model. The biggest concern is the need to evaluate the model output against real world observations/trends to demonstrate that these models can produce credible results. The Panel recommends further work evaluating the output of both operating models (Hydra and Kraken) to evaluate how well they can approximate current and past stock dynamics given similar fishing conditions. The Panel also recommends that the operating models should be used for cross purposes if possible (i.e., each be applied for harvest control rule testing and portfolio analysis). In addition, the Panel recommends that additional operating models for the Georges Bank ecosystem (e.g., the Atlantis model which is being updated and Ecopath model that is in development) be considered as a basis for simulation testing.

ToR 8: Review ecosystem assessment models and required data sources, as applied to the simulated data from the operating models in ToR 7.

During the meeting, the Panel reviewed a presentation on ecosystem assessment models and their required data sources. The proposed alternative assessment methods included a: 1) model-free simulated survey index, 2) multispecies production model, and 3) multispecies delay-difference model. The models require biomass and catch data as inputs. The proposed models range in their complexity, enabling evaluation of whether simpler assessment models can capture population dynamics of a complex underlying model. A modeling efficiency index used in evaluating the performance of the stock assessment. The performance of assessment models was tested with white noise only, however, in the future, bias can be added to performance testing. Simulation

testing revealed that the more complex delay-difference model performed similarly to the simpler production model.

Strengths

- Comparison of multiple models: The comparison of multiple alternative models is a good approach to understand the appropriate model and level of complexity for the ecosystem assessment model.

Concerns

- Multispecies vs. single species assessment models: The Panel noted that multispecies assessment models were examined, but no comparison was conducted between the performance of multispecies and single species assessments.
- Testing alternative assessments and HCRs: The testing of alternative assessment methods (e.g. multispecies assessments) should be conducted separately from testing of alternative HCRs.

Recommendations

The Panel viewed the comparison of alternative models as a good approach to understand the appropriate model and level of complexity for the ecosystem assessment model. The Panel recommends that the alternative multispecies assessment models be compared to single species models. Furthermore, the Panel recommends that evaluation of new assessment methods and new harvest control rules not be conducted simultaneously, as this will make it difficult to evaluate what was causing any successes or failures in the simulated management.

ToR 9: Review simulation tests and performance of the proposed management procedure incorporating the floors and ceilings approach, given the set of EBFM goals and objectives.

The Panel reviewed written materials and presentations on simulation tests and the performance of the proposed management procedure as implemented for the Georges Bank example. The Panel was instructed that performance was not being reviewed for the context of implementation for management, but to evaluate the approach.

Strengths

- Reasonable performance: The Panel noted that the initial results presented during the review seem reasonable in terms of performance based on their response to different forms of harvest control rule, although more critical evaluation of performance is required.
- Evaluation of ceilings: The Panel found the simulation testing of a range of ceilings and their impact on the performance of the EBFM procedure to be very useful and this work should be continued (A. Hart presentation).

Concerns

- Limited simulation testing: The Panel suggested that a broader representation of simulation results is needed to fully evaluate the performance of HCRs in the future. This should include a status quo comparison where the current single species management approach is approximated for comparison to the EBFM approach. Furthermore, one factor within the EBFM procedure should be changed at a time to be able to fully evaluate its impacts on performance. More generally, wherever there is a simplification (e.g., thresholds, trigger points, global exploitation rates, FFG structure) in the model, the Panel recommends that the effects of adding realism are investigated for each simplification separately. It may be that some of the current simplifications are justified, increasing speed and robustness without harming accuracy, but this needs to be tested.
- Presentation of HCR testing results: It is important to note that the performance metrics shown in radar plots were normalized to the highest value across simulations (i.e., highest value was defined as 100%) which can lead to potential misinterpretations of performance. Further work resolving management objectives with stakeholders may help to define the desire performance of the system and allow for performance to be evaluated relative to these values. The box plots will need some refinement for clarity (e.g., labels, similar scales, titles, etc.) in final reporting.
- Exploitation rates in HCR testing: In the current presentation of results the initial global exploitation rates used in the simulated scenario were shown, but not the realized exploitation levels. Information on realized F and realized F/nominal F would help identify the degree to which catch in a given FFG was being reduced by the single species protections within the HCRs.
- Alternative performance metrics: The current overfished metric tracks the fraction of time spent in a depleted state. This is problematic as it is influenced by the recruitment at low stock sizes. Alternatively, this could also be assessed by counting how many stocks crash at least once in any given 10-year reporting period.
- Portfolio analysis It was unclear how the portfolio analysis will be used in the EBFM procedure. Further linkage and description of the role portfolio analysis could play is needed.

Recommendations

The Panel noted that the initial results presented during the review seem reasonable in terms of performance, however, the performance of the EBFM procedure cannot be fully evaluated at this stage due the preliminary state of the work (i.e., many decisions need to be finalized both on model details and management objectives) and the limited nature of simulations run. The Panel suggested that a broader representation of simulation results is needed, including a comparison of EBFM to single species management, to fully evaluate the performance of the EBFM procedure. Furthermore, one factor within the EBFM procedure should be changed at a time to be able to fully evaluate its impacts on performance and the impact of model simplifications should be critically evaluated. The simulated output is an example of how performance would be evaluated, and the Panel provided specific suggestions on the presentation of results.

CONCLUSIONS

The Panel recognized the extensive work that went into developing the proposed strategy for implementing EBFM for the NEFMC and in demonstrating the approach in a worked example for the Georges Bank ecosystem. The Panel also appreciated this was a research-track review and that additional work is ongoing to improve aspects of the management procedure. Thus, the feedback and recommendations were intended to improve the EBFM approach. This summary report synthesized individual Panelists' feedback on areas of strength, areas of concern, and recommendations for improvement of the EBFM procedure. For the full details of the individual review of each Panelist see Appendix V (Dr. Keith Brander), Appendix VI (Dr. Villy Christensen), and Appendix VII (Dr. Daniel Howell).

Overall, the Panel concluded that the materials presented during the review represented good progress toward an EBFM procedure, however, further work is needed to refine the approach before it is implemented by the NEFMC. Below is a summary of feedback and recommendations for each term of reference.

ToR 1: Evaluate the approach used to identify Ecological Production Units on the Northeast Shelf of the United States and the strengths and weaknesses of using these Ecological Production Units as the spatial footprint for Ecosystem Based Fisheries Management in the region.
The Panel found the methods for defining ecological production units to be reasonable and recommends that the approach continue to be refined to consider the details of implementing new management units. For example, the Panel recommends consideration of how exchange across ecological production units would be estimated and the appropriate method and timeline for revisiting the boundaries of ecological production units in the future.

ToR 2: Evaluate the methods for estimating ecosystem productivity for the Georges Bank Ecological Production Unit and advise on the suitability of the above methods for defining limits on ecosystem removals as part of a management procedure.
The Panel viewed the methods for estimating ecosystem productivity for Georges Bank as a useful means of tracking an important and dynamic metric of ecosystem status. However, they did not advise using this for defining limits (i.e., reference point) on fishery removals at this time due to the uncertainty in this estimate. The Panel suggested that the EBFM technical team explore other methods and metrics of estimating fishery production and continue simulation testing limits on removals defined from multiple approaches to resolve the best approach.

ToR 3: Evaluate the approach and rationale for specifying Fishery Functional Groups as proposed management units.
The Panel found the definition of fishery functional groups to be a reasonable approach that would enable consideration of biological and technical interactions together in the definition of a management unit. However, the Panel recommends further examination of the appropriateness of this unit for management through simulation testing with a more realistic representation of the fishery functional groups on Georges Bank. The Panel recommends further research into the dynamics of fishery functional groups over time and development of an approach to update management units with changes in the system. In addition, practical considerations of implementing new management units will need to be addressed as these units do not map onto

existing management units (single-species stocks) or the scale at which harvest is allocated (sectors), and the transition may be a challenge.

ToR 4: Comment on the applicability and utility of the strawman management objectives and associated performance metrics which were used to guide the development of operating models.
The Panel viewed the strawman management objectives as a reasonable starting point for the EBFM procedure; however, the Panel expects these will be refined and expanded upon in the future through the stakeholder engagement process. The Panel recommends additional objectives are explored based on input from stakeholder engagement, these should include biological, economic, and social objectives. Expansion of management objectives may require iteration of the model to accommodate performance measures which are not currently quantified in the current structure.

ToR 5: Evaluate the utility of the proposed management reference points as part of a management control rule for ecosystem-based fishery management.
The Panel approved the general approach of defining floors and ceilings for use as reference points in an EBFM procedure. However, there was substantial concern about how these numbers would be estimated and applied in operational management. In addition, the Panel recommends further examination of how ceilings will be used in a real-world application (e.g., what action would be taken when an ecosystem or fishery functional group ceiling is breached).

ToR 6: Review harvest control rules embodying the proposed floors and ceilings approach using the ceiling reference points in ToR 5 to cap removals at the Ecological Production Unit and Functional Group levels, while ensuring that no species biomass falls below the single species floor reference points.
The Panel viewed the proposed harvest control rules as a reasonable starting point, provided the stepwise changes in fishing level are removed from the ramp-down HCR, but recommends that more harvest control rules are explored and that alternative control rules are simulation tested and compared to the performance of current single species harvest strategies. The Panel was concerned about the estimation of reference points (floors, ceilings, and trigger points) within the HCRs and recommends this as an area requiring more development and simulation testing.

ToR 7: Review the structure and application of operating models for Georges Bank.
The Panel viewed the development of two multispecies operating models (Hydra and Kraken) with varying levels of complexity as good practice for testing aspects of the EBFM procedure. The Panel recommends specific areas for improvement for each model. The biggest concern is the need to evaluate the model output against real world observations/trends to demonstrate that these models can produce credible results. The Panel recommends further work evaluating the output of both operating models (Hydra and Kraken) to evaluate how well they can approximate current and past stock dynamics given similar fishing conditions. The Panel also recommends that the operating models should be used for cross purposes if possible (i.e., each be applied for harvest control rule testing and portfolio analysis). In addition, the Panel recommends that additional operating models for the Georges Bank ecosystem (e.g., the Atlantis model which is being updated and Ecopath model that is in development) be considered as a basis for simulation testing.

ToR 8: Review ecosystem assessment models and required data sources, as applied to the simulated data from the operating models in ToR 7.
The Panel viewed the comparison of alternative models as a good approach to understand the appropriate model and level of complexity for the ecosystem assessment model. The Panel recommends that the alternative multispecies assessment models be compared to single species models. Furthermore, the Panel recommends conducting the evaluation of new assessment methods and new harvest control rules separately, as this will make it easier to evaluate what was causing any successes or failures in the simulated scenario.

ToR 9: Review simulation tests and performance of the proposed management procedure incorporating the floors and ceilings approach, given the set of EBFM goals and objectives.
The Panel noted that the initial results presented during the review seem reasonable in terms of performance, however, the performance of the EBFM procedure cannot be fully evaluated at this stage due the preliminary state of the work (i.e., many decisions need to be finalized both on model details and management objectives) and the limited nature of simulations run. The Panel suggested that a broader representation of simulation results is needed, including a comparison of EBFM to single species management, to fully evaluate the performance of the EBFM procedure. Furthermore, one factor within the EBFM procedure should be changed at a time to be able to fully evaluate its impacts on performance and the impact of model simplifications should be critically evaluated. The simulated output is an example of how performance would be evaluated, and the Panel provided specific suggestions on the presentation of results.

APPENDIX I: Terms of Reference

Final Terms of Reference
Ecosystem Based Fishery Management Strategy Review

April 30-May 3, 2018
NOAA Fisheries/Clark Conference Room
Woods Hole MA

Objective 1

Review a proposed implementation of Ecosystem Based Fishery Management for the New England Fishery Management Council (NEFMC).

The review is essentially a research-track review, the goal of which is to illustrate how the proposed EBFM strategy and conceptual framework would be applied to provide the information needed for fisheries management by the New England Fishery Management Council. The review will focus on the management procedure performance relative to a specified set of metrics related to NEFMC strawman management objectives as well as evaluate a worked example intended to simulate the performance of the EBFM procedure. (The strawman objectives were used to develop the EBFM strategy and framework; final objectives will be developed and approved by the NEFMC at a later date.)

The reviewers will be asked to provide recommendations that could improve EBFM strategy performance, as well as potential data inputs, operating model structures, and performance metrics. The goal is not to evaluate output of the procedure for use in specification setting (e.g., this is not a SAW/SARC assessment review).

The review will encompass the EBFM procedure, the potential operating models used to test the procedure, and a worked example of the relative performance of the EBFM procedure for providing quota advice as they pertain to fisheries management of Georges Bank fisheries.

If the review is favorable, subsequent steps will be necessary before the procedure can be used in specification setting. These subsequent steps include: definition of management objectives by the NEFMC, potential changes in regulations and fishery management plans, clarification from NMFS on the application of functional group OFLs, potential changes in management units, etc. The identification of the management changes needed to use the model results are not part of the review.

Objective 2

Review the proposed strategy for implementing EBFM on Georges Bank

Terms of Reference

1) Evaluate the approach used to identify Ecological Production Units on the Northeast Shelf of the United States and the strengths and weaknesses of using these Ecological Production Units as the spatial footprint for Ecosystem Based Fisheries Management in the region.

2) Evaluate the methods for estimating ecosystem productivity for the Georges Bank Ecological Production Unit and advise on the suitability of the above methods for defining limits on ecosystem removals as part of a management procedure.

3) Evaluate the approach and rationale for specifying Fishery Functional Groups as proposed management units.

4) Comment on the applicability and utility of the strawman management objectives and associated performance metrics which were used to guide the development of operating models.

5) Evaluate the utility of the proposed management reference points as part of a management control rule for ecosystem-based fishery management. These include: an overall catch cap at the Ecological Production Unit level conditioned on environmental conditions, ceilings on catch for each Fishery Functional Group (defining overfishing) conditioned on aggregate properties, and biomass floors at the single species level (defining overfished conditions).

6) Review harvest control rules embodying the proposed floors and ceilings approach using the ceiling reference points in ToR 5 to cap removals at the Ecological Production Unit and Functional Group levels, while ensuring that no species biomass falls below the single species floor reference points.

7) Review the structure and application of operating models for Georges Bank.

8) Review ecosystem assessment models and required data sources, as applied to the simulated data from the operating models in ToR 7.

9) Review simulation tests and performance of the proposed management procedure incorporating the floors and ceilings approach, given the set of EBFM goals and objectives.

APPENDIX II: Documents for Review

Main Review Document

NEFSC Fishery Ecosystem Dynamics Assessment Branch. 2018. Ecosystem-Based Fishery Management Strategy, Georges Bank Prototype Study. Summary Document. April 20-May 2, 2018, Woods Hole, MA. https://www.nefsc.noaa.gov/program_review/docs/Georges%20Bank%20EBFM%20Summary%20Document.pdf.

Background Documents for Review

Ecosystem Based Fishery Management PDT. 2017. A Framework for Providing Catch Advice for Prototype Georges Bank, Fishery Ecosystem Plan. Catch Advice Framework, a Worked Example #2. New England Fishery Management Council. September 26-28, 2017. http://s3.amazonaws.com/nefmc.org/2_A-Framework-for-Proividing-Catch-Advice-for-a-Prototype-Georges-Bank-FEP.pdf.

Ecosystem Based Fishery Management PDT. 2017. A Framework for Providing Catch Advice for a Fishery Ecosystem Plan (FEP). New England Fishery Management Council. January 2017. http://s3.amazonaws.com/nefmc.org/Document-2b.-Providing-catch-advice-for-a-fishery-ecosystem-plan-eFEP.pdf.

Ecosystem Based Fishery Management PDT. 2017. DRAFT: Example application of operation models for Georges Bank ecosystem production unit (EPU) strategy evaluation. New England Fishery Management Council. January 2017. http://s3.amazonaws.com/nefmc.org/Document-3.-Example-application-of-operating-models-for-Georges-Bank-ecosystem.pdf.

Fogarty, M. J., Overholtz, W. J., Link, J. S. 2012. Aggregate surplus production models for demersal fisher resources of the Gulf of Maine. Marine Ecology Progress Series, 459:247-258. https://www.nefsc.noaa.gov/program_review/docs/b4-fogarty%20et%20al%20MEPS.pdf.

Gaichas, S., Gamble, R., Fogarty, M., Benoît, H., Essington, T., Fu, C., Koen-Alonso, M., Link., J. 2012. Assembly rules for aggregate-species production models: simulations in support of management strategy evaluation. Marine Ecology Progress Series, 459:275-292. https://www.nefsc.noaa.gov/program_review/docs/b5-Gaichas%20et%20al%20MEPS.pdf.

Gamble, R. J., Link, J. S. 2012. Using an aggregate production simulation model with ecological interactions to explore effects of fishing and climate on a fish community. Marine Ecology Progress Series, 459:259-274. https://www.nefsc.noaa.gov/program_review/docs/b-6Gamble%20and%20Link%20MEPS.pdf.

Hennemuth, R. C., Rothschild, B. J., Anderson, L. G., Kund, Jr., W. A. 1980. Overview Document of the Northeast Fisher Management Task Force, Phase 1. NOAA Technical Memorandum NMFS-F/NEC-1. October 1980. https://www.nefsc.noaa.gov/program_review/docs/b3-tm-1-hennemuith.pdf.

Link, J. S., Gamble, R. J., Fogarty, M. J. 2011. An Overview of the NEFSC's Ecosystem Modeling Enterprise for the Northeast US Shelf Large Marine Ecosystem: Towards

Ecosystem-based Fisheries Management. Northeast Fisheries Science Center Reference Document 11-23. October 2011. https://www.nefsc.noaa.gov/program_review/docs/b2-crd-1123.pdf.

Lucey, S. M., Cook, A. M., Boldt, J. L., Link, J. S., Essington, T. E., Miller, T. J. 2012. Comparative analyses of surplus production dynamics of functional feeding groups across 12 northern hemisphere marine ecosystems. Marine Ecology Progress Series, 469:219-229. https://www.nefsc.noaa.gov/program_review/docs/b-7Lucey%20et%20al%20MEPS.pdf.

NEFMC Scientific and Statistical Committee. 2010. White paper on Ecosystem-Based Fishery Management for New England Fishery Management Council. October 2010. https://www.nefsc.noaa.gov/program_review/docs/b1NEFMC%20EBFM%20White%20Paper_report_15%20oct%202010.pdf

APPENDIX III: Meeting Agenda

Agenda, Documentation, and Presentations for 2018 Ecosystem Based Fishery Management (EBFM) Strategy Review

Date	*Time*	*Topic and Related Documents*	*Presenter/Lead*	*Theme Area*
Monday April 30	9:00 AM	**Welcome and Objectives for the Review** Background Documents **Ecosystem-Based Fishery Management Strategy Georges Bank Prototype Study Summary Document** **White paper on Ecosystem-Based Fishery Management for New England Fishery Management Council (2010)** **An Overview of the NEFSC's Ecosystem Modeling Enterprise for the Northeast US Shelf Large Marine Ecosystem: Towards Ecosystem-based Fisheries Management** **Overview of the Northeast Fishery Management Task Force Phase 1 (1980)** **Aggregate surplus production models for demersal fishery resources of the Gulf of Maine** **Assembly rules for aggregate-species production models: simulations in support of management strategy evaluation** **Using an aggregate production simulation model with ecological interactions to explore effects of fishing and climate on a fish community** **Comparative analyses of surplus production dynamics of functional feeding groups across 12 northern hemisphere marine ecosystems**	Jon Hare *NEFSC Science and Research Director* Mike Simpkins *Resource Evaluation and Assessment Division Chief*	
	9:15 AM	**Logistics**	Robert Gamble, NEFSC	
	9:30 AM	**NEFMC Ecosystem-Based Fisheries Management Plan Development Team** Background Documents **A Framework for Providing Catch Advice for a Prototype Georges Bank Fishery Ecosystem Plan** **A Framework for Providing Catch Advice For a Fishery Ecosystem Plan** **DRAFT: Example application of operating models for Georges Bank ecosystem production unit (EPU) strategy evaluation**	**Andrew Applegate**, NEFMC	

	10:00 AM	**Background and Overview of Proposed Management Procedure**	**Michael Fogarty**, NEFSC	
	10:30 Break			
	11:00 AM	**Defining Ecological Production Units**	**Robert Gamble**, NEFSC	TOR 1
	11:30 AM	**Ecosystem Production Potential**	**Michael Fogarty**, NEFSC Kimberly Hyde, NEFSC	TOR 2
	12:00 Lunch			
	1:30 PM	**Defining Fishery Functional Groups**	**Sean Lucey**, NEFSC Mike Fogarty, NEFSC	TOR 3
	2:00 PM	**Strawman Management Objectives and Performance Metrics**	**Richard Bell** The Nature Conservancy	TOR 4
	2:30 PM	**Ecosystem-Based Reference Points**	**Michael Fogarty**NEFSC	TOR 5
	3:00 Break			
	3:30 PM	**Open Question Period**		
	4:30 PM	**Public Comment Period**		
	5:00 PM	**Review Panel Discussion (private)**		
Tuesday May 1	9:00 AM	**Harvest Control Rules**	**Mike Fogarty**, NEFSC	TOR 6
	9:30 AM	**Structure and Application of Operating Models -- Part 1 Hydra**	**Andy Beet**, NEFSC Mike Fogarty, NEFSC	TOR 7
	10:30 Break			
	11:00 AM	**Structure and Application of Operating Models -- Part 2 Kraken**	**Robert Gamble**, NEFSC Geret DePiper, NEFSC	TOR 7
	12:00 Lunch			

	1:30 PM	**Structure and Application of Assessment Models**	**Mike Fogarty**, NEFSC	TOR 8
	2:00 PM	**Simulation Tests and Performance Management Procedure -- Part 1 Hydra**	Andy Beet, NEFSC **Michael Fogarty**, NEFSC	TOR 9
	3:00 PM Break			
	3:30 PM	**Open Question Period**		
	4:30 PM	**Public Comment Period**		
	5:00 PM	**Review Panel Discussion (private)**		
Wednesday May 2	9:00 AM	**Simulation Tests and Performance of Management Procedure -- Part 1 Hydra, continued**	Andy Beet, NEFSC Mike Fogarty, NEFSC	TOR 9
	10:00 AM	**Simulation Tests and Performance of Management Procedure -- Part 2 Kraken**	**Amanda Hart**, UMASS Dartmouth **Geret Depiper**, NEFSC Robert Gamble, NEFSC	TOR 9
	10:30 Break			
	11:00 AM	**Simulation Tests and Performance of Management Procedure -- Part 2 Kraken,continued**	Geret Depiper, NEFSC Robert Gamble, NEFSC Amanda Hart, UMASS Dartmouth	TOR 9
	12:00 Lunch			
	1:30 PM	**Open Question Period**		
	3:00 PM Break			
	3:30 PM	**Public Comment Period**		
	4:30 PM	**Review Panel Discussion (private)**		
Thursday May 3	9:00 AM	**Review Panel Report Writing (private)**		

APPENDIX IV: Meeting Participants

Name	Affiliation	E-Mail
Robert Gamble	NEFSC/EDAB	robert.gamble@noaa.gov
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