Ecosystem Based Fishery Management Strategy Review at the Northeast Fisheries Science Center, Woods Hole MA

External Independent Peer Review

by

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Executive Summary

The Ecosystem Based Fishery Management Strategy review was organized by the Northeast Fisheries Science Center (NEFSC) and chaired by Dr Lisa Kerr, Gulf of Maine Research Institute and NEFMC Scientific and Statistical Committee. The review team included Dr Keith Brander, DTU Aqua, Copenhagen; Dr Daniel Howell, IMR, Bergen; and myself, Dr Villy Christensen from UBC, Vancouver, BC. Jointly, we conducted a review of a proposed methodology for incorporation of EBFM at the New England Fisheries Management Council (NEFMC). The review took place over four days where scientists from NEFSC and other institutions, led by Dr Mike Fogarty made numerous presentations covering all ToRs, and where there were 20-25 people in attendance each day.

In summary, my findings about the specific ToRs for the review are:

- ToR 1: The approach for defining Ecological Production Units is sensible, well-defined, and ready for use;
- ToR 2: The methods for evaluating ecosystem production potential may well be used to provide indicators for how the fisheries production may change, at least in a directional sense. The evaluations are, however, too uncertain when it comes to use for setting precise overall system caps;
- ToR 3: The approach for defining Fishery Functional Groups (FFGs) is well defined and conducted, and it will be interesting to see further work on the topic, including mapping onto the New England Groundfish Clusters and other actual fisheries management units;
- ToR 4: The "strawman" management objectives were broadly defined (as they should be) but fall short in what they cover. The operational objectives were general and rudimentary, and it was not clear how these would be translated into measurable objectives and metrics;
- ToR 5: The ecological reference points include catch caps overall and by FFGs, and limit reference biomass by FFG and by species. My recommendation is to use the caps as reference levels, and while the biomass floors were reasonable to use in the Hydra demonstration at the review, it is unclear how and if they can be convincingly implemented in real world applications;
- ToR 6: The Harvest Control Rules were well-defined for the specific use, i.e., to evaluate a range of possibilities. I do, however, not consider that they as defined are suited for actual implementation in real world Management Strategy Evaluations (MSEs);
- ToR 7: Two "operating" models were presented. The Hydra model is an interesting model, but needs refinement before it can be used in a credible manner to evaluate realistic HCRs. The limited implementation of the Kraken model complex makes evaluation of its potential for use as part of the EBFM rather impossible to

evaluate at present. Overall, I recommend in accordance with best practices for MSE that the group evaluates the feasibility of using MSE tools that have been developed for broad application;

- ToR 8: I consider the choice of assessment models pertinent; for the purpose of evaluating HCRs there is no need to implement the actual assessment models that will be used for eventual quota settings;
- ToR 9: The simulation tests as demonstrated at the review were cursory and incomplete, and even if some preliminary results seem plausible, others do not. I recommend to follow best practices for MSE and apply a portfolio approach to the simulations.

Overall, I note that the group at NEFSC-EAP is very capable, but are faced with a major task in developing procedures for actual implementation of EBFM. There are no clear models for how this should be done from other NOAA Centers, and it is not a simple task when it has to be done to the level and scrutiny required by Fisheries Management Councils. Still, it can and should be done.

The group involved in the EBFM development currently involves seven researchers, but with an effort level that corresponds to less than two person-years annually. I consider this vastly insufficient for full and credible development. The implementation of the pilot study has not yet attained a level where it credibly can be used to evaluate how EBFM should be implemented or what the consequences of the implementation might be. The work that has been done, however, represents a significant step on the way towards EBFM, and for this it should be complimented.

For the review, the Council explicitly asks for guidance on whether the proposed tools and approach would provide them with the tools they need for implementation of EBFM. The overall conclusion is that the required tools are not yet in place, even though considerable progress was demonstrated for the review. Following best practices for EBFM, including application of multiple model approaches and with emphasis on broadly developing model approaches is recommended as the fastest option.

Looking beyond the immediate requirement of NEFMC for implementation of EBFM, I note that NEFSC is tasked with the implementation of the National Ocean Policy (even if there's uncertainty about the future of the act) and that this calls for development of the scientific architecture in support of EBM. This includes development of methods to evaluate multi-sectoral policy questions, including ones related to land-coast interactions, spatial planning, energy development and numerous other issues, including EBFM and climate change adaptation. I do not have the impression that the Center has moved very far on this since 2011, and therefore strongly recommend, as I did back then, that the

NEFSC evaluates the resource allocation that implementation of EBFM and indeed of the overall EBM modeling strategy will call for.

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Background

The New England Fisheries Management Council (NEFMC, the Council) decided in 2008 to develop and implement an Ecosystem-Based Fishery Management (EBFM) plan and tasked its Scientific and Statistical Committee (SSC) to provide a strategic plan for this (NEFMC SSC, 2010). Implementation aspects of this were primarily the responsibility of the Northeast Fisheries Science Center (NEFSC, or the Center), and among others included development of a suite of multispecies and ecosystem modeling tools. These tools were reviewed as part of a CIE review in 2011[1], in which the present reviewer participated as a panel member.

The development was, however, delayed at the Council's request, due to pressing management issues, but it has been initiated again, and the intention is now (according to the Council website) to explore EBFM, "a new approach that involves all species and fisheries in a specific area, recognizes the energetic limits of the system, takes into account the trophic relationships among species, allows for greater adaptability to variability and change, and addresses multifaceted goals and objectives. As a first step, the Council is developing an example Fishery Ecosystem Plan for Georges Bank that will be used to solicit and focus public input. The example could lead to the development of a new Fishery Ecosystem Plan or contribute to a set of ecosystem policies and initiatives that would apply across multiple fishery management plans."

The development of EBFM in New England is in line with international and national strategies. NOAA indeed strives to adopt an ecosystem-based approach throughout its programs and regions, including EBFM as a central part of future management. As part of the move, the NOAA Science Centers are encouraged to develop Fisheries Ecosystem Plans, and such have now been developed for four of the Centers, with several more in progress. Still, it is noteworthy that few Centers and Councils have reached the state of EBFM implementation that has led to CIE reviews of their strategy or implementation. Underlying model approaches have thus been reviewed for Alaska in 2005, for New England in 2011, and for the Pacific Islands and the Northwest Pacific in 2014. The present review is the first to deal with implementation of EBFM, so it seems that NEFMC indeed is breaking new ground – surprisingly, giving the long-standing strategy in NOAA for EBFM.

As part of the Council's exploration of options for introduction of EBFM, it requested NOAA's Office for Science and Technology for an initial EBFM strategy implementation review through the Center for Independent Experts (CIE). The ensuing review was focused on a proposed management procedure developed by NEFSC's Ecosystems Dynamics &

[1] 2011_04_14; https://www.st.nmfs.noaa.gov/science-quality-assurance/cie-peer-reviews/cie-review-2011

Assessment (EDA) branch in cooperation with other units, and was to include evaluation of the models and approach used to test the proposed EBFM procedure. It is the expectation that an EBFM approach will include wider representation of factors in the management than currently considered, notably with regards to ecosystem and human components.

The EBFM Strategy review was organized by the NEFSC, and chaired by Dr Lisa Kerr, Gulf of Maine Research Institute and NEFMC Scientific and Statistical Committee. The review team included Dr Keith Brander, Danish Technical University Aqua, Copenhagen, Denmark; Dr Daniel Howell, Institute for Marine Research, Bergen, Norway; and myself, Dr Villy Christensen from The University of British Columbia in Vancouver, BC.

Jointly, we conducted an external review of a proposed methodology for incorporation of EBFM in the New England area with a focus on Georges Bank. The review took place at NEFSC during four days in late April to early May 2018 where scientists from NEFSC, led by Dr Mike Fogarty made numerous presentations covering the nine specific ToRs, and where there were around 25 people in attendance each day (partly listed in Appendix 3 on page 46).

It is noted that the review was not meant to consider, evaluate or develop management recommendations, but rather consider a set of choices that may be explored in order to ensure that the Center has the tools required for developing EBFM in the future. In this context the development of Management Strategy Evaluation (MSE, Smith et al., 1999) alias Management Procedures (MP, Butterworth and Punt, 1999), or, as it was originally known and developed, closed loop analysis (Walters, 1986) forms a central part.

The perhaps key question asked of the review panel during the review was if we thought the research was on the right track.

Review Activities

The review started timely at 9 AM on April 20, 2018, with around 20 people in attendance (and with an additional handful trying to connect – eventually successfully – through a conference call line). The participants included the key representatives from the NEFSC-EAP and other parts of the Center as well as the review panel including Dr Lisa Kerr, Chair, and the CIE review team consisting of Drs. Keith Brander, Daniel Howell and Villy Christensen.

Dr Mike Simpkins (NEFSC Resource Evaluation and Assessment Division Chief) bid welcome (on behalf of Dr Jon Hare, NEFSC Science and Research Director), and emphasized the interest in moving forward with EBFM for the NEFSC area. For the present review, the Council had asked for a fully worked example to illustrate how EBFM might

be implemented. The Council asked if the science underpinning the EBFM implementation is valid.

The Review Chair, Dr Lisa Kerr, continued and outlined that the review was a research track review with consideration of EBFM procedures, potential operating models, and that the role of the review was to provide recommendations based on the ToR. So, not to focus on output, but on approach, on evaluating the science, and the best practices for the approach for implementation.

Dr Robert Gamble next described the logistics for the review, including the program for the week, (which had been updated compared to what the review team had received). Also, he showed the review website, which (by mistake) had not been shared with the review team prior to the review.

Dr Andrew Applegate, NEFMC Staff, EBFM Plan Development Team Chair, introduced the EBFM development by the NEFMC; provided management context, how this meeting fits into their plans and how they expect to go forward with EBFM; how the Council evaluated initiatives elsewhere and decided on a Fisheries Ecosystem Plan based on fundamental properties of ecosystem (e.g., energy flow and predator/prey interactions). It was noted that the requested worked example need not be implemented, and that the Council through the EBMF PDT has devised a five-phase strategy with an initial example focus on the Georges Bank ecosystem; multispecies ecosystem models (under development); integrated ecosystem assessment; of functional groups or stock complexes; and of placed-based spatial management.

Dr Mike Fogarty presented the overall EBFM plan, the focus of which was on multispecies interactions and mixed species fisheries. He emphasized the danger of ignoring unintended consequences that had been mentioned, and noted for instance that MSY-based reference points depend on species interactions, that predation mortalities are time varying, indeed at times with surprises such as concurrent decreasing predation mortality for herring and increasing for mackerel. Dr Fogarty mentioned current practices with the NEFSC groundfish sector management areas and how the proposed Ecosystem Production Units (EPUs) may replace current single species management areas, which vary by species, and which are difficult to define and manage.

The proposed method offers a well-defined physical/oceanographic/Lower Trophic Level (LTL) approach to defining EPUs, but does not consider fisheries as implemented. Mike Fogarty expressed that this would be covered by later presentations.

ToR 1: EPUs were introduced by Dr Gamble, who described the procedure that was used for establishing the EPUs. It was noted that these units were quite similar to those

developed for the Northeast Regional Ecosystem Plan in 1988, i.e., the approach is quite stable.

ToR 2: Ecosystem production potential was introduced by Dr Fogarty. It provides a simple approach to define fisheries production potential based on system production potential. There are only limited goals for how this is to be used, and the measure will be supplemented and supported by other approaches and lines of evidence.

The proposed approach builds on a detailed description of the LTL microbial loop, and a written comment on how this was specified was received from Dr Deborah Hart, NEFSC.

ToR 3 was introduced by Dr Sean Lucey after a lunch break. He described how Fisheries Functional Groups (FFGs) had been developed using cluster analysis – done before the introduction of groundfish sector management.

ToR 4: Dr Rick Bell presented Management Objectives and Performance Metrics, and discussed optimum yield. He noted that National Standard 1 allows using an aggregate approach to estimating the MSY of a fishery, and that according to National Standard 3, to the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination. He further introduced the "strawman" strategic level objectives and the operational objectives.

ToR 5: Dr Fogarty introduced the suggested management reference points, and discussed historic MSY estimated for Northeast US continental shelf estimated 0.98Mt in 1973-76 from an aggregate surplus production model. The sum of single species MSY for the same area was 1.3Mt. He also presented Murawski's (2000) criteria for how to evaluate if an ecosystem is overfished. The questions after Dr Fogarty presentation were focused on why there should be an overall catch cap, when the species or FFG caps would likely shut down fisheries first, and it was discussed if the overall catch cap would be constant.

After a coffee break, there was a round of questions from the Review Panel, followed by a public question session. In the public session, Dr Sissenwine raised the question of high grading and noted that while this indeed may be a real problem, it shouldn't stop EBFM from being considered. Rather, the key question is if the EBFM strategy makes more sense than current practices.

Dr Howell noted that overfishing as a reference level means depleted, not necessarily that a stock is overfished. Capelin in the Barents Sea regularly goes below the overfishing level even without fishing, but fishing is the only handle we have on rebuilding.

The plenary meeting finished at 5 PM, after which the review panel held an *in-camera* session that finished at 6 PM.

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On Day 2 of the review, the chair opened the meeting at 9.00 AM with an overview of what happened the first day of the review and of the program for the rest of the meeting. There were 24 in the meeting room plus additional people on the conference phone when the meeting started.

ToR 6: Harvest Control Rules (HCRs) were introduced first by Dr Fogarty who gave an overview of the "strawman" HCRs that were developed for the initial analysis. The discussion among other things raised the issue of choke species and the difficulty in estimating unfished biomass (B_0).

ToR 7: The Hydra operating model was introduced by Dr Andy Beet, and the presentation also included the implementation of the assessment model in Hydra. The discussion after the presentation was intensive, and focused on multiple aspects of the model implementation.

Dr Gamble continued with a presentation of how the Kraken operating model was implemented. There were some concerns in the discussion that Kraken is not far enough along in its development for it to be evaluated properly.

After lunch, ToR 8, Assessment models, was introduced by Dr Fogarty, and he continued with ToR 9, the Hydra part of the simulation results.

There was an open question period and a public question period next, and the day's meeting ended at 4.30 PM, followed by *in-camera* panel discussion.

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On the third day, Wednesday May 2, the meeting started at 9.00 AM with 24 in the room, and additional participants on the conference call line. Dr Kerr gave an overview of the day's program.

Dr Geret DePiper started off with a presentation of the portfolio economic model as part of the materials for ToR 9. The ensuing discussion focused on the model implementation, early results, and if the portfolio model could be coupled with Hydra.

Next, Ms. Amanda Hart, UMass, Dartmouth, gave a presentation based on her M.Sc. work on evaluating an EBFM procedure for Georges Bank using ceilings on system removals. Ms. Hart used multispecies production models with a ceiling on system removals, indicator-based harvest control rules, and $\%F_{MSY}$ rules. The multispecies production model was modified somewhat from the one used as part of Kraken. The analyses were well-conducted and presented, and its tree analysis provided an interesting alternative representation of the usually complex output from HCR evaluation.

The rest of the morning was used for open question periods, which saw extensive and wide-ranging topics being raised. Keywords to illustrate this include:

- Research group size vs demands
- Overfishing at group or species levels, consequences?
- Are there strawman management objectives that are missing, and does inclusion of such require changes to model structure?
- Technical and biological interactions: any hope that an aggregating strategy can help alleviate problems with these interactions?
- B_0 issues
- Marine mammals/seals
- Stakeholder inputs
- Time lags in the operating models, data collected one year, assessment the next year, next year the quota, there's always a lag.

After lunch, there was a public question session, in which it was noted that the Council has to follow the Guidelines for National Standards, and manage on a single species basis. The National Standards are, however, under review.

Dr Sissenwine noted that time delay needs to be included in MPs; discussed the B_0 question, and on the big picture front noted that for multispecies approaches, we don't address where most of the trophic interactions occur, i.e., in the pre-recruits. We may not be able to model this on a species basis, but it is important. To what degree are the modelling approaches we're using now tying us to the past? It's conditioned on historical conditions, but that is not necessarily something desirable. We may be able to model/describe how ecosystems have developed, but we also need to make predictions. Its worrisome that we now pretend we can manage species at a single species MSY level and we're moving to another area that may not be more credible.

The public question period closed around 2.30 PM, and the review team spent the rest of the afternoon *in-camera*.

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The review team spent the entire fourth day, Thursday May 2, from 9.00 AM to 4.00 PM, discussing the review outcome and findings. Dr Fogarty was consulted several times during the day for questions to clarify aspects that the review team was uncertain about. The review team discussed findings for each of the ToRs in some detail in order to allow the Chair to get an early overview and notes of what would go in the summary report of the review.

Reviewers' Complementarity

The Chair, Dr Kerr, provides knowledge of the workings of the NEFMC and was familiar with regional questions, background, capabilities, and perspectives on management issues, which was important for the review. The three CIE reviewers have a diverse background and experience relevant to the theme of the review. In summary and very generalized, Dr Brander's strengths are in integrating ecosystem effects into fisheries assessment and management, Dr Howell has wide experience with multispecies models and implementation of MSE, and mine is in ecosystem modeling and development of EBM. During the review, we all participated in all activities, and we jointly discussed issues and findings. We discussed aspects of our findings and recommendations, and while we seemed in general agreement on all major points, we did not seek consensus.

NMFS Review Process

Independent reviews of the form conducted for NMFS by CIE are unique globally and provide independent evaluations of a character and quality that should serve as a model for other countries.

The procedure for conducting the reviews is well established and well organized by the NEFSC, and while the NEFSC-EDA branch has much less experience with CIE reviews than their assessment colleagues, the scientific parts of the review were well organized and conducted.

The present review suffered under the shutdown of the Government when the review was originally scheduled to take place in January of 2018. The review was thus postponed only hours before we were to leave for Woods Hole. Due to the required rescheduling of the review, many tasks had to be repeated in April. There were some minor glitches in the preparations for the review, likely due to the postponement, but overall, the review was a smooth operation, and I do not have specific suggestions for improvement of process or form.

Summary of Findings

General

Overfishing and overfished populations have been recurrent themes for the NEFSC for decades, back to the time of extensive foreign fishing in the 1960s and 1970s. There are notably problems with technical interactions in the ground fisheries, and we sensed an implicit hope during the review hearings that the introduction of EBFM might somehow,

magically, help resolve those issues. That is, however, not likely (unless major changes happen concurrently), but EBFM may make it clearer what the involved tradeoffs are, and potentially set a path for addressing those. It is indeed an important aspect of EBFM implementation that it calls for a cooperation across traditional disciplinary boundaries as well as for cooperation with diverse stakeholder groups. Cooperation is indeed necessary for evaluation of tradeoffs, which must be based on data-rich information, transparent analysis, and with strong stakeholder involvement throughout the process.

For the review, the Council explicitly asked for guidance on whether the proposed tools and approach would provide them with the tools they need for implementation of EBFM. The overall conclusion, as detailed in the following sections, is that the required tools are not yet in place, even though considerable progress was demonstrated for the review.

I had the opportunity seven years ago to review the model development for EBFM at NEFSC, and among other things found about the research group:

> *"The NEFSC-EAP is a small and efficient group. Given the urgency that implementation of the new Ocean Policy Act calls for, and given the expanded scope of what is required to timely address key policy questions for spatial planning, EBM, and climate change, I strongly recommend that the NEFSC evaluates the resource allocation that implementation of the recommended NEFSC-EAP modeling strategy will call for. "*

I do not see, however, that much if anything has happened in the direction I recommended. I understand that the group currently involved in the reviewed EBFM development involves seven researchers, but with a combined effort level that corresponds to less than two person-years annually. I consider this vastly insufficient to the task at hand.

I further note, that introduction of EBFM is only part of the development that the Center is tasked with. And while this for the Council is of overarching concern, the National Ocean Policy establishes Ecosystem-Based Management (EBM) as a guiding principle, and marine spatial planning as a primary tool for ocean resource management in the United States (The White House, 2010). While I cannot evaluate what progress the Center is making toward multi-sectoral EBM, I note that there is need to develop capacity to evaluate the impact of, e.g., alternative energy production in ocean planning, and that this calls for spatial modeling capabilities that to my knowledge not are under development at the Center. Also, EBFM calls for spatial considerations, including for evaluation of MPAs, and the Center (to my knowledge) is not far with the development of tools for this. Atlantis could in principle be used, but as was expressed during the review, it is not in an operative state but will need considerable development for the purposes, including development of a specific spatial framework for the spatial questions

that are to be evaluated. I would recommend the Center to consider alternative, simpler approaches; such do exist.

Finally, I note that climate change is becoming increasingly important for management of ocean resources, not the least for planning and consideration of adaptation. While such questions were not part of the review, it is an area that should be considered by the Center, e.g., in cooperation with climate modelers at the NOAA Geophysical Fluid Dynamics Laboratory and the Princeton Cooperative Lab. Further, this can be combined with the development of spatial modeling techniques as discussed above.

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

The review was defined as a research-track review focused on specific aspects of a desktop Management Strategy Evaluation (MSE) implementation, which was intended to illustrate a plausible route for initial evaluation of harvest control rules (HCRs), and consider possible management options as part of an EBFM strategy for managed New England Fisheries.

The details of the proposed implementation review along with findings and recommendations are discussed under the following objective.

The review guidelines asked "for recommendations that could improve EBFM strategy performance, as well as potential data inputs, operating model structures, and performance metrics." Of these tasks, I have not addressed the question of "potential data inputs" as this was not addressed explicitly during the review, and it was not clear what the potential data inputs of concern were to be used for. A thorough evaluation of data inputs is a review in itself.

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

The review as outlined was focused as a research track review of specific aspects of the implementation of EBFM rather than as a review of the overall strategy for EBFM. In essence, this means dealing with "how" questions for implementation, instead of "why" as for the choices that led to the specific MSE implementation at the NEFSC's EDA branch.

It is pertinent, however, to also consider the "why" questions, given that NEFMC and NEFSC to my knowledge are breaking new ground by being the first to have CIE reviews of their EBFM strategy. I will therefore inject a bit of strategy consideration in this report, while concentrating on the research track of the draft implementation.

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.

Ecological Production Units (EPUs) are proposed as management units to replace the current hierarchy of single species management areas, which varies by species, and which are complex to develop, manage and use in practice, not the least for industry.

The proposed method was presented in detail by Dr Gamble, and it offers a well-defined physical/oceanographic/lower trophic level (LTL) approach to defining EPUs. As implemented, it does not consider higher trophic levels (HTL) and fisheries. The main argument for not including HTL and fisheries in the EPU definitions is that these entities have changed considerable over the time period of concern. Hence, if EPUs were based on current conditions, they could not be relied on to be stable over time.

In contrast, the approach for defining EPUs based on physical/oceanographic/LTL has shown to be remarkably stable. The 2010 NEFMC White Paper on EBM (NEFMC SSC, 2010) presented an earlier version of the EPUs for the US Northeast Continental Shelf, and the changes based on new and updated analysis with additional data showed only small changes. The approach for defining EPUs can thus be considered stable, and my overall conclusion about it is that it is a sensible and well-defined approach.

The EPUs as defined provide an objective way of defining ecological boundaries, and given their stability, they may well be suitable for management purposes (as discussed further under ToR 3).

It may be considered a weakness that the EPUs do not consider the distribution of upper trophic level groups (notably fish) nor fisheries. Given, however, the variability of these entities, and that it is desirable to have management units that are stable over the medium to long-term, it seems that adoption of the EPUs as defined for this review is advisable.

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.

Dr Fogarty presented an approach for evaluating ecosystem production potential. This was a simple approach to define fisheries production potential based on system productivity. There were only limited suggestions for how this is to be used, and it will need to be supplemented and supported by other approaches and lines of evidence.

The main questions that are asked through the approach are:

- How efficiently is primary production transferred to higher trophic levels?
- Can this be used to set a cap for productivity? and
- Can this through monitoring be used to guide how exploitation should be modified due to changes in system productivity?

There have been numerous evaluations of the relationship between system primary production and fisheries production, dating back to Ryther's classic study (1969), with an illustrative more recent and developed application being published by Stock et al. (2017). The evaluations have as a common element that fisheries production potential (FPP) is estimated through a relationship of the type $FPP = PP \times TE^{TL-1}$, where PP is the primary production, TE the ecological transfer efficiency between trophic levels, TL, (typically 10%).

The approach presented at the review includes a detailed description of the LTL microbial loop, and has few details on the fish populations (upper trophic levels, UTL). Uncertainty is recognized and analyzed through a Monte Carlo approach, which is well done, but which does not consider structural uncertainty due to chain length, (which in turn is due to the aggregation of UTLs).

For illustration, the Summary Document for this review lists 11 piscivore species with trophic levels varying between 3.3 and 4.45 (ToR 3 - Appendix 3, NEFSC EDA, 2018). Assuming a 10% trophic transfer efficiency, this indicates a 14-fold (= $10^{4.45-3.3}$) difference in production efficiency between the lowest TL and highest TL species within the piscivore guild. It follows, that the average production efficiency of the piscivore guild will be very dependent on the biomass distribution by species, and that the absolute measure can be indicative only – while trends may be more informative.

Further, the estimate of guild productivity obtained from this method includes all fish species within guilds, exploited as well as non-exploited and non-exploitable species. As such, even if the estimates were precise, they would indicate latent productivity, and as such not be directly useable to provide caps for realizable productivity.

The overall conclusion is that the projections of ecosystem production potential from primary production in this study are highly uncertain – as is indeed always the case for this form for projections. It is worth noting, however, that there is excellent information available about primary production in the New England area (as compared to many other areas), and that there indeed is useful information in this.

A key question then is, how will the primary productivity and microplankton abundance change over time? We have seen in numerous ecosystem studies that changes in environmental productivity can have amplified, non-linear impacts on HTL (Christensen and Walters, 2011). Assuming further, that the microbial loop doesn't show major

structural changes over time, it seems fair to use changes in environmental productivity as indicators for how the fisheries production may change, at least in a directional sense.

Tracking changes in environmental productivity may thus be useful for providing context, and possibly even connecting such trends to exploitation trends. If, e.g., the indications are that environmental productivity is decreasing, it should set off alarm signals that fish productivity may be declining as well, calling for more caution in quota setting – or vice versa.

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

There are considerable problems with the management of multispecies fisheries in the New England area, and this has unintended ecological, economic, and social consequences. On this background, it is timely to give the problem a fresh look to consider:

- Can the spatial management units be better defined? and
- Can fisheries be categorized so that biological and technical interactions are considered more appropriately in the management?

The first of these questions was evaluated in ToR 1, where the conclusion was that EPUs could indeed be defined so as to fit with ecological productivity patterns. Hence, the present ToR (3) is designed to evaluate how fisheries can be categorized more appropriately.

Internationally, the question of how to handle biological and technical interactions have led to categorization of what is here called Fisheries Functional Groups (FFG) or what (especially in Europe) is called métiers (e.g., Ulrich et al., 2001). The aim being to better manage effects due to competitive externalities such as competition for shared resources and fishing grounds. In the NEFSC-EDA application to Georges Bank, the FFGs were defined as “species that are caught together, have similar life history characteristics, and play similar roles in the transfer of energy in the system”. As such, the FFGs have two dimensions (fleet – fish species), and indeed corresponds closely to what elsewhere is called métiers.

For the Georges Bank, Dr Lucey presented an overview of how FFGs can be developed as operational fisheries units based vessel trip reports (VTRs) of landings, species caught and area fished in New England fisheries. Landings were combined into spatial and temporal units based on fishing gear categories, segregated by vessel size and species caught, after which k-means clustering was used for FFG categorization. The approach as presented

has been described more fully in a journal publication by Lucey and Fogarty (2013), an interesting and well conducted study.

The example presented at the review, was intended to illustrate how clusters could be mapped onto real fisheries. As an example, otter trawl fisheries were categorized in ten clusters, some of which were fishing only one species, (e.g., shrimp) others as many as ten. As for the mapping of these clusters, Dr Applegate, NEFMC, expressed confidence that the clusters could be mapped clearly onto defined fleets. This is promising, and indeed in agreement with experience from elsewhere (e.g., Mackinson et al., 2018).

Yet, it remains to be evaluated how the FFGs map on to the entire fishing operations for each of the EPUs as well as for the groupings used for the New England Groundfish Management Sectors.

The analysis presented a number of cases where the spatial clusters were grouped within EPUs, notably for Georges Bank, but it was also clear that this was not always the case. As an example, the diverse Otter Trawl Cluster 1 while having substantial representation on Georges Bank spilled over to the Gulf of Maine. This was seemingly due to groundfish seeking deeper, warmer water in the colder months. This illustrates an unavoidable problem, EPUs cannot be defined so as to unequivocally represent FFGs/métiers. There will be cases where occurrence spreads out over EPUs and will call for shared management within and between management councils.

Still, well-defined FFGs can help alleviate such issues, and it will be interesting to see further work on the topic, including mapping onto the New England Groundfish Clusters and other actual fisheries management units.

Also, FFGs will change over time as fisheries evolve and fish populations change. This will call for periodic reanalysis and updates.

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 following “strawman” objectives for the strategic level of the proposed EBFM in preparation for the CIE review were defined in a presentation given by Dr Bell as:

- Maintain/restore sustainable production levels
- Maintain/restore biomass levels
- Maintain/restore functional trophic structure

These strawman objectives are, as strategic objectives should be, broad and oriented at the mid-term, i.e., typically with a 5-10 years’ time horizon, depending on species

dynamics. They cover, as they should, the key aspects, i.e,. keeping productivity at levels where yield is maximized and where populations have a healthy buffer size (without growing to an unproductive level), and maintaining biodiversity.

The strategic objectives are not explicit on social and economic strategic objectives (though it may to some degree be implicit in the maintenance/restoration of sustainable production levels). I presume, however, this is the intention, given the wording of a strategic objective defined by NEFMC's SSC (2010): "Protect ecosystem structure and function to allow optimal harvest for fishing communities and future generations". It may thus be pertinent to make this explicit in the strategic objectives.

The strategic objectives, being "strawman" fall short on a few other aspects. As an example, the management objectives for the North Pacific FMC ground fisheries[2] are far more wide-ranging:

> *"prevent overfishing, promote sustainable fisheries and communities, preserve the food web, manage incidental catch and reduce bycatch and waste, avoid impacts to seabirds and marine mammals, reduce and avoid impacts to habitat, promote equitable and efficient use of fishery resources, increase Alaska Native consultation, and improve data quality, monitoring and enforcement."*

A critical aspect is how the strategic objectives are to be operationalized. For this, the following associated operational objectives were defined as:

- Maintain habitat productivity
- Ensure that F is below threshold
- Minimize the risk of permanent impacts on vulnerable components

For operational objectives, the above are quite general and rudimentary, and it is not clear how they will be translated into measurable objectives and performance metrics – likely because the analyses as presented are representative only, and not intended to be complete with regards to specificity. A notable omission is that they do not include social or economic metrics.

I take it for granted that the actual operational objectives, once implemented will follow more closely what is done for management elsewhere – NPFMC may be a good example.

[2] https://www.npfmc.org/management-policies/

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).

Dr Fogarty made a presentation about ecosystem-based reference points, in which he outlined the proposed schedule as used for the Hydra simulations. They consist of:

- An overall catch cap (ceiling), based on system productivity
- Ceilings for catch by individual FFGs with their sum not to exceed the overall cap
- Biomass floors:
    - For FFGs the total biomass is not to fall below 20% B_0
    - For individual fish species, their biomass is not to fall below 20% B_0

The overall catch cap was proposed to be based on system productivity. As discussed for ToR 2, the methods for estimating fisheries production from primary productivity are highly uncertain, and I do not recommend such a procedure for setting hard caps. From discussion during the review, it further seemed that the catch ceiling estimated from productivity was unlikely to be reached – which raises the question, why have a ceiling that is unlikely to be reached.

Ceilings by FFGs would be more specific, but it was not clear from the review how these ceilings would be set in the real world. Here, there would be a large number of FFGs, and setting the ceilings would likely involve estimation of an MSY level by species, then allocating each species across FFGs, and finally summing up the maximum catches by FFG. It, thus, also involves setting catch shares across FFGs.

Some alternative ways of estimating maximum exploitation rate (for ceilings) were presented at the review. One was derived from Iverson (1990) and Ware (2000) and expressed "exploitation rate should not exceed the fraction of microplankton production in the system". This relationship is, however, not well established or defined (microplankton?). As it also seems difficult to both parameterize and evaluate, I do not think that it is a suitable measure for actual use as it stands.

Another measure, by Moiseev (1994) proposed that the ecosystem exploitation rate should not exceed 20%, (which seems a reasonable safe level based on Iverson, 1990), and Iverson (1990) suggested that exploitation rates (fisheries and predation combined) should not exceed the ratio of new primary production to total primary production (the *f*-ratio) in marine systems.

The core problems with rules such as outlined above are that the methods are uncertain, and that the rules are difficult to communicate to and get acceptance for from stakeholders. It seems that it easily becomes a "trust me, I am a highly trained expert …" – indicators should be reliable and easy to explain.

It may potentially (as pointed out by Dr Fogarty) be possible to empirically calculate FFG ceilings by aggregating all species in FFGs, and plotting yield vs effort (from VTR data) to obtain estimates of max yield by FFGs. Such would be historically based and it would be necessary to consider how representative they would be for later time periods.

My sentiment for the catch caps (ceilings) is that they should rather be used as a reference level (max catch as estimated from MSY analysis, e.g., 75% of F_{MSY}) giving the maximum exploitation rate that can be applied when biomasses exceed the upper reference threshold.

The biomass floors are in principle reasonable, but not without issues. A biomass floor by FFGs thus calls for two rather impossible measures, (1) the biomass of the part of the overall species biomasses that are included in a given FFG, and (2) how to estimate the unfished biomass (B_0) for such a species/fleet grouping. Add to this, that the calculation of B_0 always is uncertain, given its model dependence.

The biomass floors are to be used to set overfishing levels for species (and by splitting and summing up, by FFGs as well). Given the uncertainties associated with estimating B_0 and splitting these across FFGs, it is reasonable to consider if there may be alternative methods for evaluating overfishing (and target fishing rates). Related, Dr Fogarty raised this question if NEFSC research vessel surveys could be used to provide a basis for determination of target fishing rates and overfished status. While interesting propositions, translating biomass/tows into fishing rates and biomass status would involve a number of assumptions, which have not been specified.

Overall, the biomass floors are reasonable to use in the Hydra demonstration, but it is very unclear how and if they can be convincingly implemented in real world applications.

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.

Dr Fogarty gave an overview of the harvest control rules (HCR) as implemented in the Hydra simulation structure with the proposed floors and ceilings approach. The overall cap is to "provide a context based on energetics, if we set it appropriately is should not or seldom be breached"; "if it is breached, it is a clear warning that remedy measures

should be taken". The floor for FFGs was – as expected – found to be less conservative than for individual species.

Dr Fogarty further provided an overview of the HCRs, and I conclude that these are well-defined for the specific use, i.e., to evaluate a range of possibilities. I do, however, not consider that the HCRs as defined are suited for actual implementation in real world MSEs; their use is limited to an initial evaluation of characteristics. Notably, the use of step functions would not work in actual evaluations. Building on what is done elsewhere would be warranted.

Also, for actual MSE evaluations, it would be worthwhile to compare evaluations of HCRs to single species management rules, other ecosystem management rules, and also some mixed version.

As discussed under ToR 5, I would recommend evaluating the performance of reference points based on the current NEFMC procedure for estimating ABLs, i.e. ceilings at MSY, targets at 75% MSY. It would also be pertinent to consider that when below the limit reference points, fishing cannot be assumed to go to zero, but rather a suitable low level (for instance F=0.04 $year^{-1}$ as in Mackinson et al., 2018).

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

Hydra

Dr Beet gave a presentation about the structure and application of operating models with focus on the Hydra implementation. Hydra is a multispecies model with technical and (partial) biological interactions. As implemented, it has ten fish species and three fishing fleets, and the fish species have size structure, which determines interactions and catchabilities. Predation is size selective (for which, Ursin, 1973 is a good reference).

Stock-recruitment relationships are not pre-defined, but initial hockey-stick models are obtained from data fitting, and these initial S/R models are subsequently resampled so as to obtain viable (non-crashed) populations throughout the system. The S/R model and resampling scheme is in principle a neat idea and implementation, but not without issues.

One issue is that hockey-stick recruitment models have two parts, when below the change-point (δ, the level of spawning stock biomass, SSB, at which the slope changes), recruitment is a linear increasing function of SSB, above recruitment is either constant or linearly changing. At the change-point there will usually be a sharp bend, which can lead to numerical problems (Barrowman and Myers, 2000). Given this, it may be worth considering a logistic or generalized hockey-stick to minimize the problems.

Hockey-stick S/R models tend to produce lower compensation than B&H S/R models at low SSB densities (Barrowman and Myers, 2000), which isn't surprising given that the hockey-stick form does not have density dependence at low spawning biomasses. The logistic hockey-stick model also has a broader range of spawning biomass over which density dependence occurs. Indeed the consequence of the hockey-stick linear relationship is a constant recruit/spawner ratio (and hence survival to recruitment) at low spawning biomass (Hilborn and Walters, 1992, pp. 248-9). This can cause instability, and provides another argument for using a range of S/R relationships when exploring the performance of HCRs.

Hydra is implemented as a full MSE model with operating and assessment model coupled in a framework, much in line with common practice (Punt et al., 2014). The operating model has species interactions where consumers' intake set predation mortality rates for prey, but where predators growth rates are constant – predators always get their model, they are "efficient predators" (Butterworth and Plaganyi, 2004). An implication of this model structure is that it is known to cause instability when moving away from the base situation, e.g., when introducing major changes in fishing effort.

Such instability is likely an issue for the Hydra implementation. I note from the resampling of S/R models (Figure 4.4 in NEFSC EDA, 2018) that all of the "plausible" resampled models for all ten species have higher compensation ratio than the initial S/R models. This indicates that the compensation ratios had to be increased to avoid population crashes. This assumption is in line with Figure 2 in Gaichas et al. (2016), the core Hydra publication, which for a simulation aimed at estimating unfished biomass shows major instability with 5-10 year cycling patterns indicated for many species. I presume based on the figure, that the model is unstable, and that whenever a species crashes, it quickly rebounds because of the high compensation ratios, leading to instability with medium-term cycling.

The Hydra model structure is in line with similar approaches and has the advantage of being developed in-house, and thus targeted to the specific application, but details of the implementation aspects are not clear from the available materials. This is indeed a problem with using a newly developed model, and, as one of the developers stated during the review, the code "needs to be cleaned up a little bit". Also, I'm surprised that the Hydra model was reported as "slow to run" given that ADMB is not used for optimizations as implemented.

While the in-house development has some clear advantages, it also has issues. Best practices for MSE (Punt et al., 2014) thus recommends to "base the operating model(s) and the management strategy on software that has been developed for broad application and has been tested extensively." The main implication of using in-house software is that such will need to be tested much more thoroughly, starting at the level, does it do what it is supposed to do when there's no variability?

Overall, my conclusion regarding Hydra is that it is an interesting model, and that it needs refinement before it can be used in a credible manner to evaluate realistic HCRs.

Kraken

Kraken builds on a multi-species production model, and is implemented with group definitions that follows those of the Hydra model. While Kraken was described as an operating model, it is actually developed with a coupled optimization model based on economic portfolio techniques, which are also developed in-house ("Applying Portfolio Management to Implement Ecosystem-Based Fishery Management (EBFM)," 2016).

The implementation is still work in progress – as was expressed during Dr Gamble's presentation, which among others called for more robust estimation routines, more realistic fleet structure, simulations to compare current management strategies with portfolio model, and simulations with misspecified reference points.

The present implementation relies heavily on the Hydra implementation to which Kraken was tuned. Given that a major advantage of having several operating models is that they can provide independence from model structure, it seems unfortunate that the Kraken model had to be tuned to Hydra results.

The Kraken model has, as does Hydra, ten species, which were aggregated in three functional groups, and the linking of the Kraken operating models to the portfolio model was through biomass, species floor (0.2 x unfished) and functional group ceiling (0.18 * functional group biomass). Work on adding fleet structure to Kraken was reported in progress, but not operational.

Dr Gamble presented results for predicted catches and predator removals of prey (and could also show diet compositions over time). These plots could be compared to actual catches and known diet compositions, but this had not been done yet.

The economic optimizations presently consider only revenue, not cost. Currently, this limitation was because of difficulty standardizing costs across fisheries/species, so they were left out of initial analysis. This is, however, a major constraint, as maximization of revenue by itself isn't a suitable objective for fisheries.

It was noted that the current portfolio implementation should be considered at the proof of concept level only. Also, it is currently only linked to the Kraken multispecies production models, but could be coupled to other models notably Hydra.

The limited implementation of the Kraken model complex makes evaluation of its potential for use as part of the EBFM process difficult, or rather it is not possible to evaluate this at present. Some general conclusions can, however, be drawn:

- The modeling complex is interesting and builds on techniques with well-known characteristics.
- The optimizations build on an objective function, which will need to be defined in a process involving the Council and stakeholders.
- Given that the optimizations may well involve strong tradeoffs, it is unlikely that they will ever be used to set actual management objectives.
- The optimizations can, however, be used to provide reference levels for notably revenue (but likely other economic parameters as well, e.g., net revenue, jobs). These reference levels can, in turn, be used for scaling when evaluating results from HCR evaluations.

Operating models, overall

The present exploratory evaluation of HCRs and steps towards EBFM relies on the use of two operating models, which is very much in line with best practices of using multiple models (Punt et al., 2014). Generally, however, it is assumed that the operating models are used to evaluate the same set of HCRs, and this has not been the intention with the NEFSC-EDA draft implementation. I think it would be worth considering if it is possible, i.e., to also use Kraken for HCR evaluation, similar to what's (intended to be) done for the Hydra model.

A question was raised if ten was the right number of fish species to include in the evaluations. In reply, we heard that it wasn't really possible to go further with the Kraken model, and we expect the answer to be somewhat similar for Hydra. Diversity is good, as is model ensemble approaches.

Given what has been developed in NEFSC-EDA, the possibility was raised during a question session of the review: why the NEUS Atlantis model had not been used as an operating model for evaluating HCRs? The Atlantis model was designed to be an operating model for MSE, and it was noted that the Center over the last decade has extended considerable resources to the Atlantis development. The answer we received was that "Atlantis is not currently operational and we don't trust it for use here. Also, it is not practical to include any form for stochasticity." It was described that the NEUS Atlantis model currently is undergoing a major revamp and update. I note that when I reviewed the NEFSC EBFM models in 2011, I wrote "The NEUS Atlantis model, which resource-wise is the biggest investment of the [group] has after five years of development not reached a state where it can provide credible output". Seven years later this still holds.

NEFSC-EDA has also worked extensively to develop its own implementations of the EwE approach (EMAX and R-path), and it was mentioned by Dr Lucey that he will be working with an MSE approach with Dr Punt in the near future, based on adding MSE capabilities to R-Path. I can only recommend this, noting that a corresponding North Sea MSE study

using EwE combined with a MSE routine developed at CEFAS has reached a state where it can convincingly be used as part of EBFM (Mackinson et al., 2018). Indeed, the North Sea application has reached far beyond the work reviewed here.

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

To set the stage, assessments in the NEFMC management have changed to increasingly use survey index methods, which by now are used for a majority (22) of the managed species (39). In addition, 14 are age-based, two length-based, and there's one "other" methodology. The limited use of methods-based assessments was described during the review as being due to consistent problems with retrospective analysis.

For the review's ToR 8, Dr Fogarty gave an overview of assessment models and required data. In total, three simulated assessment models had been implemented in connection with the Hydra operating model:

1. Model-free simulated survey index
2. Multi-species production model
3. Multi-species delay-difference model

The model data requirements are much lower for these model types than for, e.g., corresponding age-based models. We did, however, not discuss data availability or requirements in any detail during the review, and I refrain from commenting on data availability and sources as part of the review due to lack of experience with New England fisheries.

The aim with these multispecies assessment is to evaluate how well they perform. The finding, as reported by Dr Fogarty was that the more complex delay-difference model (#3) did not behave much better than the simpler production model (#2). While this may seem surprising, it is, however, aligned with earlier findings that a simpler model often outperforms a more complex one when it comes to making predictions (Ludwig and Walters, 1985).

I consider the choice of assessment models pertinent, for the purpose of evaluating HCRs there is no need to implement the actual assessment models that will be used for actual quota settings.

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.

An interesting question when evaluating management procedures is if the underlying operating models have to be realistic for the HCR evaluations to be credible. There are diverging opinions about whether this is a requirement. Some of the overall best practice requirements for operating models (Punt et al., 2014) are:

- Use of more than one operating model
- Set parameters from fitting to data
- Consistency with reality with regards to model performance

Where the last item points towards a requirement for realistic model behavior, and such a view was also expressed at the review by Dr Applegate, it is questionable, however, if the modeling complexes reviewed here have reached this state.

For the Hydra MSE simulations, I especially noted that the piscivores and elasmobranchs showed little sensitivity to fishing, while planktivores were very sensitive and collapsed at seemingly low fishing pressure. During a question session at the review, it was expressed that this model behavior was linked to how the models were parameterized, notably with regards to biomass levels and fishing pressure. That may well be the cause, but it raises a question about how the results can be evaluated at least in the present round.

Still, some of the very preliminary results seem to make sense, e.g., that ramp down of exploitation rate improves the general situation, and that using individual floors results in better protection than using floors by FFGs.

Overall in the simulations as presented, there were too many things happening in one go, which makes it difficult to understand why reactions were as they were. I would prefer more simulations where only one factor was changed at the time to be able to better evaluate the findings. But, the bottom line is that one cannot evaluate the performance of the implemented HCRs from the model runs with the current model and MSE implementation.

As discussed earlier, I do not think the overall ceiling, i.e., the overall system catch cap, can be defined objectively from productivity calculations. The inherent uncertainty is too big. If such a ceiling is to be implemented, it should be for precautionary management considerations, and the level should be a management decision – perhaps with the ecological evaluations as guide.

For the HCR evaluations, my recommendation would be to use the system and FFG ceilings as reference points as part of an exploration of the maximum allowable exploitation levels.

With regards to the portfolio simulations, it is clear that co-variance between landings is important for how managers can manage risk, and hence evaluations of this should be encouraged. Co-variance is time-variant, and it is interesting that the NEFSC team has developed a portfolio analysis to hedge value of landing through mean-variance tradeoff analysis, built on an optimization analysis. The analysis as described above, builds on coupling of biological and portfolio models with three constraints, 1 revenue target, 2, species floor (0.2 x Bo) and guild ceiling (0.18 x guild sum), and the optimization involves tradeoffs between fisheries, species and guilds.

One aspect of the coupled portfolio results was that there was higher variability in catches in optimized runs, which to some extent was due to comparison with a period with low stocks and catches. Further, it was due to moving toward equilibrium states, but not reaching it.

For the results, I would suggest to show not just relative results by species (which were unnamed on plots), but also overall and absolute results, e.g., as stacked bar plots over time summarizing across the ecosystem.

While I laud the analysis and optimizations, I do think the main application of portfolio methods will be to provide reference points for how far it would be possible to go. It's not likely to be used to give directions for where we should go.

Conclusions and Recommendations

The group of scientists in the NEFSC-EAP is very capable, but are faced with a major task in developing procedures for actual implementation of EBFM. There are no clear models for how this should be done from other NOAA Centers, and it is not a simple task when it has to be done to the level and scrutiny required by Fisheries Management Councils.

For the present review, my overall conclusion is that a lot of good work has been done, but the overall strategy is not ready for evaluation or implementation of EBFM by NEFMC. Yet, there is considerable progress, as summarized next by ToR:

- ToR 1, Ecological Production Units: These are ecologically well-defined and likely to be stable. I recommend that they be considered as substitution for the elaborate spatial scheme used currently for individual species.
- ToR 2, Ecosystem Productivity: Tracking productivity is not likely to be useful for objectively setting ecosystem-level caps for exploitation given the inherent

uncertainty involved, but may indeed be useful for evaluating trends for exploitation pressure.

- ToR 3, Fishery Functional Groups: The FFGs are well-defined and potentially useful for operationalization, and I do recommend that they be evaluated at the full scale of interest for NEFMC. It remains, however, to be seen if there will be too many cases where quota sharing between FFGs will cause problems, and the extent to which the FFG will map onto NE Groundfish Management Sectors is unknown. It is noted that EPUs (ToR 1) will only partly be aligned with FFG spatial distributions, and this in some cases will call for shared management within and between Councils.
- ToR 4, Strawman management objectives: These strategic objectives fall somewhat short as defined, and the associated operational objectives are quite general and rudimentary, and it is not defined how they will be mapped to measurable objectives and performance statistics. Notably, social and economic metrics are not (yet) considered. My recommendation is obvious: follow best practices from other Councils.
- ToR 5, Management reference points: I think the proposed "ceilings" should rather be used as reference levels than as absolute catch caps, given the inherent uncertainty involved, and the prospects for high-grading. In essence, I do not think an overall cap will be useful, unless it is set so low as to be invoked regularly. If so, it may improve the overfished situation, but my preference would be for this to happen with focus on the overfished species, rather than through an overall ecosystem catch cap.

  The biomass floors are in principle reasonable, notably, it is unclear how well and effective they can be set at the FFG level. I do, however, encourage the further development of FFG biomass floors as these may well show to be useful for management (and industry) at the FG level. The most efficient floors are those defined for individual species, and they should be included at least for the core species, including species of special concern.
- ToR 6, Harvest Control Rules: The HCRs presented at the review were suitable for the initial cursory implementation, but not for actual implementation. Also, given that the operating models are not yet at a stage where I find them credible for the HCR evaluations, there clearly is more work to be done on these issues.
- ToR 7, Operating models: Both the Hydra and the Kraken models will need further development before they can be used convincingly to evaluate HCRs. I recommend a multi operating model approach for the evaluations, including with the use of models with different layers of complexity (including more species and fleet resolution).

  The economic optimizations are interesting, and it is good to see economic considerations involved. Such along with social aspects should indeed be included

in all analysis related to EBFM in order to better evaluate the properties of tradeoffs. The economic optimizations can be useful for providing reference points, rather than to provide targets for management. Also, the economic optimizations provide information about co-variance between landings, which may be useful for risk management.

- ToR 8, Assessment models: The assessment models implemented are simple (as they should be), and do not require extensive data input. The choice of assessment models is reasonable, and they are useful for further evaluations.
- ToR 9, Simulation tests: I don't find the characteristics of the operating models realistic as implemented, and this has implications for how I view the outcome of the simulations. While some of the results from the simulations are sensible, my overall conclusion is that the simulation testing is not at a stage where the results can be evaluated in a credible manner.

Overall, one cannot evaluate the performance of the implemented HCRs from the model runs with the current model and MSE implementation – which, I gather, wasn't the intention either.

The NEFSC-EDA group is capable, and is doing pioneering work on implementation of EBFM. Still, my conclusion is that the resources that are assigned to the task are vastly insufficient for full and credible development. The implementation of the preliminary pilot study has not received a level where it credibly can be used to evaluate how EBFM should be implemented or what the consequences of the implementation might be. The work that has been done, however, represents a significant step on the way towards EBFM, and for this it should be complimented.

The perhaps key question asked of the review panel several times during the review was if we thought the research was on the right track. That's a different question to answer; there clearly has been planning behind the strategy that is partly implemented at NEFSC-EDA, but the rationale for the pilot implementation of especially ToR 4-9 was not clear. I recognize the tendency within NMFS in general for developing in-house approaches, but also that requires substantial personnel resources for full implementation, and the staffing of NEFSC-EDA that is allocated to EBFM is rudimentary and seemingly not sufficient for this – we heard that less than two person-years annually was allocated. I also note the best practice guidelines for MSE (Punt et al., 2014), which recommend to "base the operating model(s) and the management strategy on software that has been developed for broad application and has been tested extensively." I find it likely that this would be more efficient than development of new methodologies.

Looking beyond the immediate requirement of NEFMC for implementation of EBFM, I also note that the NEFSC-EDA website[3] mentions that "the foundation for Ecosystem Based Management is now being developed and refined". With reference to the National Ocean Policy (The White House, 2010) the "need to establish the scientific architecture in support of EBM in the region to meet […] emerging challenges and opportunities" is recognized. This need is for EBM (not EBFM only), and I feel inclined to cite my report from the 2011 EBFM review at NEFSC:

"To guide the NEFSC toward implementation of EBM my most important recommendation is that the NEFSC-[EDA then EAP] takes on the role of an interdisciplinary unit that can foster broad modeling initiatives and cooperation. An important aspect of this should be to define a clear and explicit policy-driven strategy for what modeling to conduct in order to implement EBM at the NEFSC. "

"For the strategy-development, it may serve to develop a number of over-arching, yet specific questions, to help define the required modeling capabilities. Examples that go beyond what is currently considered by [EDA] could be:

- How does land-use patterns (including nutrient runoff) impact productivity of key LMR?
- What are the ecological impacts of bottom-modifying gear and how can the impacts be minimized considering economic and social impacts?
- How does current and alternative fisheries management impact non-target species, e.g., those under the Endangered Species Act (ESA)?
- What are the potential consequences of developing a large wind farm in NEUS, and where would the impact be minimized?
- What are the potential ecological impacts of oil exploration (and potential spills) in New England marine waters?
- How will the LMR populations and their productivity in NEUS be in 2020 and 2050? What adaptations are possible? "

While I do not have a clear overview of what NEFSC has done and is doing to implement EBM, I have not seen indications that the Center is much closer to this than they were seven years ago.

I recognize that the NEFSC-EDA is a small and efficient branch with very limited staffing dedicated to EBFM/EBM, and conclude that for successful implementation of the National Ocean Policy Act, an expended scope is required to address key policy questions related to spatial planning, EBM and climate change adaptation. I therefore strongly recommend

[3] https://www.nefsc.noaa.gov/ecosys/

that the NEFSC evaluates the resource allocation that implementation of EBFM, and indeed of the overall EBM modeling strategy will call for.

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NEFSC EDA, 2018. Ecosystem-Based Fishery Management Strategy, Georges Bank Prototype Study. Summary Document. NEFSC Fishery Ecosystem Dynamics and Assessment Branch, Woods Hole, MA, USA.

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Ware, D.M., 2000. Aquatic Ecosystems: Properties and Models, in: Harrison, P.J., Parsons, T.R. (Eds.), Fisheries Oceanography: an Integrative Approach to Fisheries Ecology and Management. pp. 160–194.

Appendix 1: Bibliography of materials provided for review

NEFSC Ecosystem Modeling Review
Background Readings

The main document provided for reviewed by the Panel was an overview of the EBFM management procedure:

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.

In addition, the following background materials were reviewed by the Panel:

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.

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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.

Presentations for Review

Presentations covered the following topics were reviewed by the Panel during the in-person meeting:

1. Objectives for the Review (Mike Simpkins, NEFSC)
2. Logistics (Rob Gamble, NEFSC)
3. NEFMC Ecosystem-Based Fisheries Management Plan Development Team (Andrew Applegate, NEFMC)
4. Background and Overview of Proposed Management Procedure (Mike Fogarty, NEFSC)
5. Defining Ecological Production Units (Robert Gamble, NEFSC)
6. Ecosystem Production Potential (Michael Fogarty, NEFSC and Kimberly Hyde, NEFSC)
7. Defining Fisheries Functional Groups (Sean Lucey, NEFSC and Mike Fogarty, NEFSC)
8. Strawman Management Objectives and Performance Metrics (Richard Bell, The Nature Conservancy)
9. Ecosystem-Based Reference Points (Mike Fogarty, NEFSC)
10. Harvest Control Rules (Mike Fogarty, NEFSC)
11. Structure and Application of Operating Models -- Part 2 Hydra (Andy Beet, NEFSC and Mike Fogarty, NEFSC)

12. Structure and Application of Operating Models --Part 2 Kraken (Robert Gamble, NEFSC and Geret DePiper, NEFSC)
13. Structure and Application of Assessment Models (Charles Perretti, NEFSC and Mike Fogarty, NEFSC)
14. Simulation Tests and Performance Management Procedure -- Part 1 Hydra (Andy Beet, NEFSC and Mike Fogarty, NEFSC)
15. Simulation Tests and Performance Management Procedure -- Part 2 Kraken (Andy Beet, NEFSC and Mike Fogarty, NEFSC)

Appendix 2: CIE Statement of Work

Statement of Work
National Oceanic and Atmospheric Administration (NOAA)
National Marine Fisheries Service (NMFS)
Center for Independent Experts (CIE) Program
External Independent Peer Review

Ecosystem Based Fishery Management Strategy Review

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevenson Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the base scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards. (http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf).

Further information on the CIE program may be obtained from www.ciereviews.org.

Scope

Ecosystem Based Fishery Management (EBFM) Strategy Review

Objective: Review a proposed implementation of EBFM 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 NEFMC. The review will focus on the management procedure performance relative to a specified set of metrics related to NEFMC management objectives, as well as evaluate an "operating model" intended to simulate the performance of the EBFM procedure. The "operating model" in this case is a multi-model suite that can include empirical approaches as well as simulation models. The reviewers will be asked to provide recommendations to 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 Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC) review process).

The review will encompass the EBFM procedure, the suite of operating models, and a worked example of quota advice as they pertain to fisheries management in the Northeast region. If the review is favorable, subsequent steps will be necessary before the procedure can be used in specification setting. These subsequent steps include: potential changes in regulations and fishery management plans, clarification from NMFS on the application of functional group, Overfishing Limits (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.

Reviewer Requirements

NMFS requires three reviewers to conduct an impartial and independent peer review in accordance with the SOW, OMB Guidelines, and the TORs below. The reviewers should have working knowledge and recent experience in ecosystem-based fishery management particularly in areas of Management Strategy Evaluation/Management Procedures, Fishery Ecosystem Plans, Integrated Ecosystem Assessments, ecosystem models, multi-species models, population dynamics, harvest strategies, and fisheries management regulations as they apply to EBFM. We prefer having at least one international reviewer and at least one reviewer from the U.S. The third reviewer can be an international or U.S reviewer.

Tasks for Reviewers

- Review background materials and reports prior to the review meeting related to the Terms of Reference.
- Attend and participate in the panel review meeting
    - The meeting will consist of presentations by NOAA and other scientists, and other experts to facilitate the review, to provide any additional information required by the reviewers, and to answer any questions from reviewers
- After the review meeting, reviewers shall conduct an independent peer review in accordance with the requirements specified in this SOW, OMB guidelines, and TORs, in adherence with the required formatting and content guidelines; reviewers are not required to reach a consensus
- Each reviewer may assist the Chair of the meeting with contributions to the summary report, if required by the TORs
- Deliver their reports to the Government according to the specified milestone dates

Foreign National Security Clearance

When reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for reviewers who are non-US citizens. For this reason, the reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/ and http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreignnational-registration-system.html . The contractor is required to use all appropriate methods to safeguard Personally Identifiable Information (PII).

Place of Performance

The place of performance shall be at Northeast Fisheries Science Center Woods Hole, MA

Period of Performance

The period of performance shall be from the time of award through March 2018. Each reviewer's duties shall not exceed 14 days to complete all required tasks.

Schedule of Milestones and Deliverables: The contractor shall complete the tasks and deliverables in accordance with the following schedule.

Within two weeks of award	Contractor selects and confirms reviewers
Approximately 2 weeks later	Contractor provides the pre-review documents to the reviewers
April/May 2018	Panel review meeting
Approximately 3 weeks later	Contractor receives draft reports
Within 2 weeks of receiving draft reports	Contractor submits final reports to the Government

Applicable Performance Standards

The acceptance of the contract deliverables shall be based on three performance standards: (1) The reports shall be completed in accordance with the required formatting and content (2) The reports shall address each ToR as specified (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel

All travel expenses shall be reimbursable in accordance with Federal Travel Regulations (http://www.gsa.gov/portal/content/104790). International travel is authorized for this contract. Travel is not to exceed $12,000.

Restricted or Limited Use of Data
The contractors may be required to sign and adhere to a non-disclosure agreement.

NMFS Project Contact:
Robert Gamble
166 Water Street
Woods Hole, MA 02543
robert.gamble@noaa.gov

Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs.

   a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including providing a brief summary of findings, of the science, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

   c. Reviewers should elaborate on any points raised in the Summary Report that they feel might require further clarification.

   d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. The CIE independent report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The CIE independent report shall be an independent peer review of each ToRs, and shall not simply repeat the contents of the summary report.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review

   Appendix 2: A copy of the CIE Statement of Work

   Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

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 3: Panel Membership or other pertinent information from the panel review meeting

The review panel consisted of,

- Dr Lisa Kerr, (Chair), Research Scientist at the Gulf of Maine Research Institute, Portland Maine and Vice Chair of the NEFMC Science and Statistical Committee
- Dr Keith Brander, Senior Scientist Emeritus, Danish Technical University Aqua, Lyngby, Denmark, who has expertise in integrating ecosystem effects into fisheries assessment and management
- Dr Daniel Howell, Fisheries Mathematical Modeller, Institute of Marine Research, Bergen, Norway with expertise in multi-species modeling and management strategy evaluation
- Dr Villy Christensen, Professor at The University of British Columbia, Vancouver, Canada, with expertise in ecosystem modeling and EBM.

Dr Kerr facilitated the review, including the public sessions, the *in-camera* sessions of the review panel, and its meetings with key contacts at NEFSC. Several scientists from NEFSC/EDAB and other institutions made presentations at the review, notably Dr Mike Fogarty, Dr Robert Gamble, and Dr Andy Beet.

The following registered as participants in the review meeting over the three days of panel presentations,

Name	Affiliation	E-Mail
Michael Fogarty	NEFSC/EDAB	michael.fogarty@noaa.gov
Robert Gamble	NEFSC/EDAB	robert.gamble@noaa.gov
Mary Kavanagh	Kavanagh Fisheries	MBYPAT@aol.com
Laurel Smith	NEFSC/EDAB	laurel.smith@noaa.gov
Robert Hildermith	UMass Dartmouth	rhildreth@umassd.edu
Sean Lucey	NEFSC/EDAB	sean.lucey@noaa.gov
Charles Adams	NEFSC/EDAB	charles.adams@noaa.gov
George Lapointe	Fisheries Survival Fund	georgelapointe@gmail.com
Wendy Morrison	NMFS/SF HQ	wendy.morrison@noaa.gov
Anne Richards	NEFSC	anne.richards@noaa.gov
Scott Large	NEFSC	scott.large@noaa.gov
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Charles Perretti	NEFSC	charles.perretti@noaa.gov

Andy Beet	NEFSC	andrew.beet@noaa.gov
Amanda Hart	UMass Dartmouth	ahart1@umassd.edu
Geret DePiper	NEFSC	geret.depipes@noaa.gov

In addition, there were a number of people participating via conference call, and some that did not register above. The proceedings of the review are detailed in the Review Activities section of this report, starting on page 8.

Appendix 4: List of abbreviations

ABL	Acceptable Biological Limit
Atlantis	Modeling approach and software
B_0	Unfished biomass, a poorly defined reference point
CEFAS	Centre for Environment, Fisheries and Aquaculture Science, Lowestoft, UK (NMFS' sister organization in England)
Center	NEFSC
Council	NEFMC
CIE	Center for Independent Experts
EBFM	Ecosystem-based fisheries management
EBM	Ecosystem-based management
EDA	Ecosystem Dynamics and Assessment Branch at NEFSC
EMAX	Energy Modeling and Analysis eXercise
EPU	Ecological Production Unit
ESA	Endangered Species Act
ESAM	Extended Stock Assessment Models
EwE	Ecopath with Ecosim (modeling approach and software)
f-ratio	Ratio of new primary production to total primary production
HCR	Harvest Control Rules
HTL	Higher Trophic Levels
LMR	Living Marine Resources
MP	Management Procedures (= MSE)
MSE	Management Strategy Evaluation (= MP)
MSY	Maximum Sustainable Yield
NEFMC	New England Fisheries Management Council (the Council)
NEFSC	Northeast Fisheries Science Center of NOAA/NMFS (the Center)
LTL	Lower trophic levels
NEUS	Northeast U.S. Continental Shelf
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
PDT	NEFMC Plan Development Team for EBFM
PP	Primary productivity
SSB	Spawning Stock Biomass
TE	Trophic transfer efficiency
TL	Trophic Level
ToR	Terms of Reference
VTR	Vessel Trip Reports