

**Modeling Approaches in Support of Ecosystem-Based Fishery
Management at the Northeast Fisheries Science Center,
Woods Hole MA**

External Independent Peer Review

by

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Executive Summary

This review focuses on the modeling strategy adopted by NEFSC in support of ecosystem based fishery management (EBFM) and in anticipation of the needs arising from implementation of Ocean Policy. It finds the science reviewed to be of a very high standard and consistent with and in some cases defining and leading current standards of best practice for ecosystem modeling. In particular the overall modeling strategy is comprehensive, well attuned to policy and management needs, and makes maximum use of the excellent ecological and fishery data sets available within the region. A very strong feature of the overall strategy is the use of a diverse set of modeling methods and approaches to address a common set of core issues in EBFM, providing the opportunity for multi-model inference and increasing the robustness of the advice arising. The number and range of models developed and applied in the strategy is particularly impressive given the fairly limited resources invested in this area to date. The review has identified several areas where the strategy could be strengthened. These include a broader focus on direct impacts of fishing on non-target species and on habitats, to complement the current strong focus on trophic interactions and impacts. Further input from the economic and social sciences would also be desirable. Several of the models already show promise or are being used as operating models to support management strategy evaluation, and this feature of the overall modeling strategy should be strengthened ahead of likely increased demand to examine tradeoffs between fisheries and across multiple sector users of the marine environment, arising from impending implementation of EBFM and Ocean Policy strategies. A significant increase in this demand from policy and management would require additional resources to help meet the demand.

Background

Description of the Individual Reviewer's Role in the Review Activities,

I was one of three external reviewers for this analysis, the other two being Professor Villy Christensen of the University of British Columbia and Professor Gunnar Stefansson of the University of Iceland. The review panel was selected by the Center for Independent Experts. The reports from each reviewer were written independently. This report was written following a workshop held March 29-31 2011 at the Northeast Fisheries Science Center, Woods Hole, MA to review modeling approaches in support of ecosystem based fishery management. Details of the workshop are described in Attachment 5. Scientific papers and reports relevant to the review are described in Attachment 1. Those provided to the reviewers ahead of the workshop are highlighted as bold in that attachment.

Project Description: The purpose of this review is to evaluate the appropriateness and performance characteristics of community-level and ecosystem models employed at NEFSC as operating models in support of the development of Ecosystem-Based Fishery Management (EBFM) strategies for the Northeast U.S. Continental Shelf. NMFS strongly endorsed the concept of Ecosystem-Based Management and the related need for the development of Integrated Ecosystem Assessment in support of EBFM. The models are also considered in relation to their use to support implementation of Ocean Policy. Although this review is directed at efforts in the NEFSC, the findings will be more broadly applicable throughout the agency. The statement of work for the review provided as Attachment 4.

Summary of Findings

General

This summary of findings pertains to consideration of the overall strategy for developing and applying ecosystem modeling in the NEFSC.

The EM strategy is comprehensive and multi-faceted and appears to be well directed towards regional and national needs. Strong aspects of the strategy include:

- A good understanding of the policy and management context for EBFM and EBM in the region, as well as nationally and internationally;
- A well-considered strategy for moving from current single species or single fishery management structures and plans to an ecosystem approach, and how science and modeling can assist in this transition;
- A comprehensive set of modeling tools across a range of classes of models that in total address the likely range of issues required to move to EBFM;
- A good understanding of the tradeoffs across complexity and accuracy of models and the importance of multi-model inference;
- Recognition of the key role of management strategy evaluation (MSE) and the use of models within this approach to inform tradeoffs across a range of management objectives in support of living marine resource management.

Areas for improvement in the strategy include:

- Broadening the EBFM focus beyond trophic impacts of fishing to include direct impacts on non-target species and benthic habitats;
- Development of models that better integrate economic and social factors in the analysis;
- Further development of models and methods that address multiple uses of the marine environment (in anticipation of needs arising from Ocean Policy);
- Capitalizing on the work already done to present a synthesis of the results of multi-model comparisons against a range of key issues in EBFM;
- Increasing the (already strong) focus on models and capability to support management strategy evaluation in anticipation of needs arising from implementation of EBFM and Ocean Policy.

1. Evaluation, findings and recommendations of overall modeling strategy

B. Summarize evaluations, findings and recommendations of overall community-ecosystem level modeling strategy in practice for the NEUS LME system

The overall modeling strategy at the Northeast Fisheries Science Center (NEFSC) is described in Link et al. (2011) and was presented at the review workshop in the presentation by Mike Fogarty, titled, "Toward Ecosystem-based Fishery Management on the Northeast U.S. Continental Shelf - Review of Modeling Approaches in Support of Ecosystem-Based Fishery Management".

Key aspects of the ecological modeling (EM) strategy include:

1. Capitalizing on the extensive ecological and environmental data sets available in the region;
2. Electing to develop a wide range of models spanning tactical to strategic and with a view to using multi-model comparison and inference;
3. Developing models to serve a range of needs including:
 - a. Estimating fishery production potential and system-level biological reference points (BRPs);
 - b. Identifying ecosystem overfishing thresholds and criteria;
 - c. Providing support for tactical living marine resource (LMR) advice (to improve stock assessments for particular species);
 - d. Considering multi-sector use and tradeoffs in the context of ocean policy;
 - e. Developing EMs that can be used as operating models in a management strategy evaluation (MSE) context;
4. A process of broad stakeholder engagement including developing a strategy to move from existing management structures to full implementation of an ecosystem based fishery management (EBFM) approach.

With regard to the first element of this strategy, the Northeast US Shelf Large Marine Ecosystem (NES LME) is clearly blessed with some of the best ecological data sets to support EM of any region in the world, and extensive use has been made of these data

in the various models reviewed. Notwithstanding the quality and extent of the data, the modeling has identified some key gaps which are noted in Link et al. (2011). Evidence was presented of how these gaps have been used to inform the monitoring strategy for the region, though the extent of uptake of the recommendations was not formally reviewed. Mention was also made of economic and other data (including spatial patterns of use of the marine environment), but these were not reviewed.

The development of a wide set of models and model types (second element in the strategy) is a striking and commendable aspect of the overall EM strategy (see Figure 1 in Link et al. (2011) for the full range of model types developed and their relationship to each other). Although a similar diversity of modeling approaches may be available for some other regions of the world, I am not aware of such a diversity having been developed and applied in one institution and indeed by such a small group of researchers (most of whom are currently in the Ecosystem Assessment Program – EAP – within the NEFSC). The models span the range from tactical (some of the ESAM models) to strategic (e.g. Atlantis) as outlined in the strategy, but also cover both empirical and process based, analytical and statistical, static and dynamic, single to multispecies to energy based, deterministic and stochastic, and simple to complex (see Table 1 in Link et al. 2011). Both individually and in sum, the various models have been used to address most of the needs outlined in element 3 of the strategy (Table 2 in Link et al. 2011). The value of multi-model inference was best illustrated with regard to the issue of system level BRPs (element 3a), with the observation that multispecies maximum sustainable yield (MSMSY) was less than the sum of individual species MSY values being found consistently across a range of models. Several models were also used to address single species assessment issues and in particular the need to estimate predation mortality in assessments and in estimating single species reference points. In my view, more could be made than has been to date of multi-model comparisons and the EAP is in a strong position to do so.

The range of applications of EM outlined in element 3 of the strategy is ambitious and reflects the broader policy and legislative setting in which the work is undertaken. In particular a variety of strategies call for an ecosystem or EBM approach to oceans and fisheries management, including the NOAA Strategic Plan (2005), the President's Executive Order on National Ocean Policy (2010) and, at a regional level, a developing strategy on EBFM through the regional fishery management council process, released as

a White Paper by the New England Fishery Management Council in November 2010 (NEFMC 2010).

Although not yet endorsed by the Council, the NEFMC White Paper is an important document that, if endorsed, will be a key determinant of the future strategy for EM in the region. The White Paper outlines the need for EBFM, provides an implementation plan including transition arrangements, points to likely management issues that will need to be addressed, and discusses possible consequences for Council institutions. The longer term strategy envisages EBFM plans based around a small number of Ecosystem Production Units (EPUs). The transition arrangements would retain current Fishery Management Plan (FMP) structures, but would start to “take into account biological and technological interactions and environmental/climate factors that cut across FMPs within defined EPUs ... or within FMPs where multiple species are included in the management unit”. The longer term strategies would be underpinned by estimates of fishery production potential for each EPU, together with the identification of ecosystem reference points. Components a, b and c of the third element of the EM strategy clearly address these needs, and several of the models developed at NEFSC, and reviewed in this report, already provide a strong basis to provide technical underpinning, both for the transitional arrangements and the longer term strategy.

Element 3d of the EM strategy is designed to address the needs that will emerge under implementation of Ocean Policy. The need for technical support to address multiple uses and conflicts already exists, and is being exacerbated by rapidly emerging new uses of the marine environment such as for wind farms. EM tools that could help to meet this need include models such as Atlantis. A range of tools other than models, including the ability to mobilize data through GIS, will also be needed to address multiple use issues and are currently being provided by NEFSC, but are outside the scope of this review.

Element 3e of the EM strategy – development of operating models that can be used for MSE – is a critical component of the overall strategy that cuts across many other components of the work. It is addressed in more detail in the findings of this section of the report.

Element 4 of the EM strategy involves stakeholder engagement and the identification of strategies to move towards full implementation of EBFM. The latter has already been mentioned in the context of the White Paper, which has been led within the New

England Council process by the Scientific and Statistical Committee (SSC), of which Mike Fogarty is a member. The proposed strategy in the White Paper bears the clear hallmarks of the ideas and concepts presented by members of the EAP at the review. As noted above, there is a clear and strong link between the EM capability on display in the review and the future needs for technical support under the EBFM implementation strategy. There is as yet no clearly defined implementation strategy for Ocean Policy (or at least no such document was presented at the review) and further model development is likely needed to support such a strategy, as outlined further below and in section 2E of this report.

Stakeholder engagement to facilitate uptake of the research is a feature of the EM strategy, particularly through the Scientific and Statistical Committees (SSC) of the two regional Management Councils. A member of the Mid Atlantic Fishery Management Council participated in the review workshop (see workshop attendance list at Attachment 5) and confirmed the active engagement with his Council. Evidence of direct engagement with stakeholders such as the fishing industry, environmental NGOs, and community groups was made available to the review team though not discussed in detail at the workshop. This engagement includes a large number of presentations to councils and to the Atlantic States Marine Fisheries Commission, all of which are public meetings attended by fishers, environmental groups, and other interested parties. It also included 21 regional scoping sessions in 2005 to elicit community views on EBFM. It also includes formal training sessions for fishers and NGO representatives on EBFM through the Marine Resource Education Partnership program. Web-based ecosystem advisory reports have been available since 2006 and an ecosystem website covering much of the work of the EAP was established in January on the NEFSC website.

Findings

The EM strategy is comprehensive and multi-faceted and appears to be well directed towards regional and national needs. Strong aspects of the strategy include:

- A good understanding of the policy and management context for EBFM and EBM in the region as well as nationally and internationally

- A well-considered strategy for moving from current single species or single fishery management structures and plans to an ecosystem approach, and how science and modeling can assist in this transition
- A comprehensive set of modeling tools across a range of classes of models that in total address the likely range of issues required to move to EBFM
- A good understanding of the tradeoffs across complexity and accuracy of models and the importance of multi-model inference
- Recognition of the key role of management strategy evaluation (MSE) and the use of models within this approach to inform tradeoffs across a range of management objectives in support of living marine resource management.

Perhaps the main concern identified in reviewing the overall EM enterprise (rather than the strategy itself) is the limited uptake to date of results from the EM work into practical management outcomes and to some extent into other facets of the work of the NEFSC. This chiefly reflects the fact that although there is much discussion in the region about the value of moving to an ecosystem approach to fisheries management, there are as yet few concrete moves to do so. In this regard the importance of the NEFMC White Paper cannot be underestimated. If the main elements of the plan outlined in the White Paper are adopted by the Council then the EM strategy stands ready to deliver the technical support needed to implement key aspects of it. If the move towards adopting EBFM through the regional councils languishes, then other strategies need to be considered (discussed in more detail below) or the focus shifted to meeting the needs of implementing Ocean Policy.

One feature evident from discussions at the workshop was skepticism and resistance from some stock assessment scientists (one in particular) to incorporating species interaction considerations into single species stock assessments. This also extended to doubts expressed about other aspects of EM results including productive potential and system level BRP calculations. To some extent this reflects healthy debate within the wider NEFSC community and legitimate questions about the robustness of some of the EM models presented. It also probably reflects the pressures under which stock assessment scientists operate, and an awareness of the intense scrutiny that would arise if new models were to be utilized to provide tactical advice, particularly if

incorporating species interactions leads to more conservative management advice. As discussed in part two of this report (review of ESAMs but supported by multi-model comparisons) the data and some of the models do appear to be robust enough to incorporate directly into tactical management advice. This is an issue that deserves wider debate at senior levels within NEFSC (which no doubt already happens) but will also hinge on the demand from regional fishery management councils to incorporate such advice.

While most of the EM focus has been on models to support various aspects of EBFM, an emerging need is clearly to support tactical implementation of Ocean Policy. As noted earlier, the need to address aspects of multiple uses and inter-sector conflict already exists (and appears to be a growing issue for fishery management councils). The range of models to support multiple use management is less than the range to support EBFM. However, noting that EBFM is a subset of EBM, the tools and models to support EBFM contribute in part to EBM. Much of the conflict in multiple use plays out in a spatial arena, and spatially resolved models will be required to help address it. In this respect, of the models considered in this review, full system models such as Atlantis that are both spatially resolved and capable of representing multiple uses are likely to play the major role in support of implementing Ocean Policy, particularly as operating models to support MSE analysis of alternative spatial EBM strategies. As discussed in section 2E of this report, the current version of Atlantis used in the NES LME still needs some further development before it could be used to evaluate multiple use management strategies. While alternatives to Atlantis exist to evaluate multiple use management strategies, the investment already made in developing this model for the NES LME suggests that further investment in this particular model may be a sensible strategy, particularly as its highly modular structure allows testing of the robustness of strategies to a wide set of alternative model configurations and assumptions. Some of the simpler models developed in the EM strategy might well be considered as “assessment” models to be adopted as part of overall EB(F)M strategies, and tested in an MSE analysis using Atlantis as the main operating model. As noted earlier, tools other than models (such as GIS and risk assessment) are also likely to play a prominent role in support of implementing Ocean Policy.

Returning to consideration of the EM strategy in support of EBFM, one observation from this reviewer is that the models developed and the questions addressed focus very

strongly on what might be described as the “trophic” effects of fishing. This contrasts quite strongly with my experience in using models (and other tools) to address EBFM in Australia, where consideration of the ecological impacts of fishing has much less focus on trophic effects and has more focus on issues such as bycatch and impacts on protected species and benthic habitats. There are several possible explanations for this difference in focus, some of which were discussed briefly at the workshop. With regard to direct impacts of fishing on other species and on habitats, it was explained that these issues are mainly dealt with and modeled by other sections in NEFSC. If so, then some of these models will also need to be used when constructing operating models to support the implementation of the longer term EBFM strategy outlined in the NEFMC White Paper (although the Atlantis model developed for the NES LME can be used to evaluate these other aspects of EBFM). The difference in focus on trophic impacts between the NE US and SE Australia may in part reflect differences in the structure of those ecosystems and also perhaps the overall intensity of fishing in each region and the likelihood of trophic impacts arising. An alternative explanation is that the lower prominence given to the potential importance of trophic impacts in SE Australia simply reflects the lack of data (particularly diet data) to support understanding and modeling such effects in that region. The data and models examined in this review do generally support the likely importance of such effects in the NES LME (consistent with results from models and data for other well studied regions of the world) and therefore the need to consider them in developing ecosystem approaches to fisheries management in this region. But the point remains that more direct ecological impacts of fishing also need to be considered in formulating and implementing EBFM strategies.

As noted above, creating the ability to undertake MSE analyses and examine tradeoffs is an important part of the overall EM strategy. Several of the models that have been developed are suitable as operating models in various sorts of MSE, depending on the strategies being tested and the issues being investigated. For example if the focus is mainly on production potential and broad tradeoffs in exploitation levels across species and trophic levels, then several of the aggregate and multispecies production models constitute a suitable suite of operating models to explore the tradeoffs (and some have already been used in this way to explore this issue). To test the much broader-based strategies in the vision for regional EBFM and even more for multi-sector ocean use, spatially disaggregated full system models such as Atlantis are most suited to act as

operating models. Other models could also serve in this capacity (see section 2E) but all require some level of further development. Overall, the full utilization of the capacity developed in the EM strategy to undertake MSE still lies mainly in the (near term) future.

As already noted, the future focus on developing and testing overall strategies for EBFM will be greatly influenced by whether and how key recommendations in the NEFMC White Paper are adopted and implemented. If this proceeds smoothly, then the EM capability in the EAP, coupled with expertise with more direct impacts of fishing elsewhere in NEFSC, should be well placed to support the process. If this process gets stalled or fails to eventuate, and there is still a desire and will to pursue the EBFM focus at NEFSC, then a complementary strategy to build support for the process might be considered. My own experience in Australia (admittedly in different institutional and other circumstances) might suggest a way forward. With encouragement (funding) from the relevant management authorities (both fisheries and ocean policy), we put together a coalition of managers, key industry leaders, NGOs and scientists to undertake a “whole of fishery” MSE for federally managed fisheries in southeastern Australia. While this was initially seen by many stakeholders as a (possibly interesting) academic exercise, we obtained surprisingly rapid buy-on and even enthusiasm once they understood the full potential and scope of investigating “what if” scenarios through an MSE process. Moreover the project (known as the AMS or Alternative Management Strategies project) proved to be a major catalyst leading to rapid and far-reaching changes in management of the suite of fisheries in the region. One of the early strategies identified, labeled in the initial MSE analysis as “blue skies” (i.e. radically different from then current management arrangements and unlikely to be a serious practical option), was largely implemented in the fishery in the space of about three years. A key aspect of the buy-in was very active stakeholder engagement in the MSE process itself, particularly in identifying objectives (including environmental, economic, social, and aspects of governance – particularly cost effective management) and in identifying management strategies (how would you manage this suite of fisheries) and then testing all options. I will not burden this review with further detail on the study and its approach and outcomes (see Smith et al. 2009 and Fulton et al. 2011b), but I am happy to provide more detail and copies of unpublished reports if there is interest.

A final point to note is that the analysis just described relied on considerable input from economists and had a strong “social science” focus as well. While the focus of the present review is on EM and therefore on the ecological and environmental aspects of EBFM, integrating economic and social dynamics into models is vital (e.g. see Fulton et al. 2011a) and should be part of any modeling strategy going forward, particularly in MSE analyses where economic and social objectives sit side by side with ecological and environmental objectives. This is equally important whether the focus is EBFM or EBM.

Recommendations

With regard to the overall strategy for ecosystem modeling at NEFSC in support of EBFM and Ocean Policy, the following recommendations should be considered:

1. Broaden the scope of the models, particularly those used as operating models to test EBFM strategies, to include direct impacts of fishing on species and habitats, to complement the focus on the trophic impacts of fishing.
2. Extend EM models with input from economic and social scientists to allow greater focus on behavioral aspects of human uses of the marine environment, and to facilitate the evaluation of the economic and social consequences of alternative management strategies (for both EBFM and EBM).
3. Depending on the outcome of the NEFMC White Paper process, consider an “AMS” style project to help build stakeholder understanding of and support for EBFM.
4. Continue to develop models and tools that incorporate multiple uses of the marine environment to support implementation of Ocean Policy. These models should have a strong spatial focus.
5. Consolidate the work to date on multi-model inference with a view to producing a major publication on this topic drawing on the experience in the NES LME.

C. Determine whether the science reviewed is considered to be the best scientific information available.

The review of the science underpinning the overall modeling strategy is considered in more detail in section 2 of this report. Overall, the conclusion is that the science is of a very high standard and presents the best scientific information available to support EBFM for the region, though improvements in detail are possible and ongoing, as noted in section 2. This term of reference, focusing on the science itself, is not dealt with further in this section of the report, which focuses on the overall EM strategy.

D. Determine if the intended uses of overall community-ecosystem level modeling that have been identified as priorities for the NEUS LME are being executed in accordance with global best practices.

Global best practice in ecosystem modeling and its application to EBFM and EBM is an evolving standard. Recent reviews and statements of this standard include Plaganyi (2007), FAO (2008) and Link et al. (2010a). Key aspects of the standard include:

1. Models should be fit for purpose
2. Models should be carefully documented
3. There should be explicit treatment of uncertainty
4. There should be a formal process to review models
5. The need to consider alternative formulations for species and group interactions
6. Approaches to model complexity and simplification (amalgamation of species and groups, spatial disaggregation)
7. Development and use of operating models for MSE

Several of these issues are addressed directly in Link et al. (2011) in the section of that report on “Best Practices for NEFSC Ecosystem Modeling” and the subsequent section on “Appropriateness of Review Venues for Various Model Classes”. The report documents how issues 2, 3, 5 and 7 have been addressed in the overall EM strategy at NEFSC. This review supports those statements. Model documentation is extensive and generally of a high standard. The multi-model inference approach addresses points 3, 5

and 6, with extensive sensitivity analyses within model types also a feature of many of the models reviewed. Several of the models also incorporate a formal statistical approach to model fitting, although this is by no means straightforward for many types of ecosystem model and impossible for some. Where formal approaches are not possible, there is extensive use of existing data to parameterize models and serious attempts are made to compare model predictions with data, including development of criteria for such comparisons in the PREBAL approach.

With regard to point 2 (model review), this review of course constitutes part of that process. As noted in section 2 of this report, the number and variety of models presented for review has not allowed the detailed scrutiny of each model that might be warranted. I agree with the statement made in Link et al. (2011) that review of ecosystem models needs to be undertaken by “a subtly but importantly different set of expertise” than is usual for review of stock assessment models. In particular, the standards by which the suitability of operating models for MSE should be judged to provide strategic advice are different than the standards by which assessment models should be judged to provide tactical advice.

This review deals fairly extensively with point 7 in the standards. While the amount of formal MSE undertaken to date is fairly limited, and much of it has focused on the issue of production potential and identification of ecosystem-level BRPs, the EM strategy has placed the NEFSC in a strong position to undertake further MSE work in support of EBFM and EBM, noting that further development of some of the models is still required. However the focus of the strategy on MSE is fully consistent with the best practice standard. The issue of models fit for purpose (point 1) is addressed in part 2 of this report.

The overall finding is that the EM strategy at NEFSC is consistent with global best practice approaches to ecosystem modelling, noting that standards in this area are still evolving. Indeed members of the EM team at NEFSC have made substantial and important contributions to the evolution of these standards, both nationally through the NEMoW process, and internationally through collaborative studies, contributions to debate on standards through ICES and FAO, and development of explicit criteria for judging model performance such as PREBAL.

E. Provide recommendations for further improvements.

The key recommendations on the overall EM strategy are listed above in section 1A and are not repeated here. The strategy to date has focused on building a suite of models and model types to underpin future implementation of EBFM in the region. This strategy has been successful in building a very strong capability base, but less successful so far in uptake, for some of the reasons already discussed and notwithstanding fairly extensive stakeholder engagement. The future EM strategy will depend on future demand from various sources, including both the fishery management process (particularly implementation of an overarching EBFM strategy through the regional fishery management council process) and implementation of Ocean Policy. Both these demands could increase quickly and substantially. If they do, then **the EM strategy should increase its current focus on developing and applying operating models that can support MSE analyses of broad strategies for EBFM and EBM** – a recommendation already implicit in the stated objective to “increase the focus on tradeoffs” in the EM strategy. There was strong support at the workshop for an MSE and multiple use focus from the MAFM Council member present. If resources are fixed, this would imply a decrease in focus in other areas. However **a serious increase in demand on either or both fronts (EBFM and Oceans Policy) will require a substantial increase in resources allocated to EM and associated tool development in the region.**

2. Evaluation of strengths and weaknesses, and recommendations for specific methodologies

The terms of reference for the review specified the following considerations for each model and method: Data requirements; adequacy of input data; strengths and weaknesses of analytical methodologies; Evaluate if model structure, parameterization, calibration/tuning, validation/verification, and intended uses are adequately documented; Evaluate strengths and weaknesses of assumptions, example estimations, and sources of uncertainties, especially with respect to known best practices in the field; Review types/levels of use for model outputs, especially with respect to adequacy of modeling relative to major topical issues; Recommendations.

A large number of background papers were made available to the review panel prior to the review workshop (Attachment 2), divided into different types of model according to

the sections listed below (see also Figure 1 in Link et al. 2011). In addition, a presentation on each model type and on several additional cross-cutting topics was given during the workshop (Attachment 3). Given the very large number of models presented and the limited time available for the review, it was not possible to comprehensively review each model or to address all the terms of reference for each model type. Nevertheless the following sections present overall findings for each model type with associated specific recommendations focusing on key issues for each type of model. It should also be noted that one of the strengths of the approach taken to EM in the NEFSC is the diversity of approaches and model types used. Considering models and model types one by one does not fully recognize this strength, but the strengths and weaknesses of the overall approach are considered in more detail in part 1 of this report, as well as in the final section on Conclusions and Recommendations. Where possible I draw attention to the more specific role of each model or model type in the larger enterprise.

A. Energy Transfer Models (Fogarty) - Production Potential Models

This topic was covered in presentation 4 and in the background paper by Fogarty et al. (2008). These models are referred to in Link et al. (2011) as linear and stochastic production potential models (see Tables 1 and 2 therein). In the broader framework of Figure 1, they are a subset of full ecosystem models but of a particularly simple form representing energy transfer from primary production through a set of trophic levels. Their primary purpose is to assess the total fishery production potential of an ecosystem – in Fogarty et al. (2008) for the NE continental shelf of the US. This in turn could be used to set an upper constraint on total system removals (including, potentially, the consumption needs of threatened and endangered species and upper level predators that may be the subject of a recovery plan). Link et al. (2011) note that these models were previously reviewed as part of GARM III (NEFSC 2008).

Data requirements for these models are fairly modest and include net primary production, ecological transfer efficiencies by trophic level, consumption needs of top predators, and trophic level of the catch. The stochastic version allows input of distributions of these parameters, resulting in a posterior probability distribution of production potential. These models are not formally fitted to data (as in stock assessment models) but the various parameters can be estimated from existing data using more or less formal methods and uncertainties can be included as noted above.

Strengths of the method include its relative simplicity, its ease of communication, and its formal treatment of uncertainty. Weaknesses include its highly aggregated structure. Fogarty et al. (2008) compare the estimates produced for the NE shelf with similar estimates from other methods and previous studies (which range quite widely).

Findings: Production potential models are suitable for estimating potential caps on total system removals, particularly if multi-model comparisons are made with a range of other methods, including some of those reviewed in this report, to check for robustness of such estimates.

B. Energy Transfer Models (Link) - Network Models

This topic was covered in presentation 3 and in a series of background papers provided prior to the review including Link et al. (2006), Overholtz and Link (2009), Link (2010), Link et al. (2009), Link et al. (2008), Gaichas et al. (2009), Link et al. (2008), Link (2002), Pranovi and Link (2009), Link et al. (2008) and Fogarty et al. (2008). These models are referred to in Link et al. (2011) as network models (see Tables 1 and 2 therein) and include mass balance models such as Ecopath and Econetwrk, dynamic simulation models such as GOMAGG, and topological webs. In the broader framework of Figure 1, they are a subset of ecosystem models referred to as full network models or dynamic network models, and are also referred to as food web models. The focus of much of this work in the NEFSC has been in the EMAX project (Energy Modeling and Analysis eXercise). The models have been developed and used for a range of scientific purposes, including data synthesis, fundamental studies of energy flow and comparative studies across ecosystems, as well as for more applied purposes such as development of ecosystem indicators and exploration of scenarios of system change including climate change (Link et al. 2011). Other uses have included estimating production potential caps, examining the “ecological footprint” of fish predators, and examining the role of marine mammals and seabirds in the ecosystem. Given the extent and diversity of this program of work, it is not possible to address all the terms of reference for this suite of models. Instead I focus on selected issues, outlined below.

Ecopath is the most widely used ecosystem-level model currently in use, and much of the NEFSC food web modeling has used Ecopath. However it is notable and commendable that a range of similar models and methods has also been used to check for robustness of results and sensitivity to model assumptions. At least four Ecopath

models have been developed for various parts of the NE US, drawing on and making good use of the extensive data sets (including surveys and diet information) available for the region. Notwithstanding the excellent data available (in comparison to most other regions of the world), the analyses have revealed some important gaps in data, particularly with regard to non-commercial species and groups. Some evidence was presented that gaps identified through the EM process have helped inform data collection strategies for the region, though implementation is subject to a range of priorities and some gaps still remain. An important innovation in the body of work, and one that deserves wider notice, is the development of the PREBAL approach (Link 2010) that provides diagnostics for network models that can be used in model development and review. Another positive feature of the use of mass balance models such as Ecopath in the NEFSC is the extensive use of sensitivity analysis to data and parameter uncertainty. In summary, the extensive development and use of mass balance network models in the region provides a very firm foundation for further development of dynamic ecosystem models that can be used to address a range of strategic management questions and issues. The comparative studies with other regional ecosystems also provide an important contribution to the understanding of the trophic dynamics of fished ecosystems more generally.

While presentation 3 provided some early results from the extension of the static Ecopath to the dynamic Ecosim models, this work is still clearly at an early stage of development (but should be continued). However a dynamic network simulation model for the Gulf of Maine – GOMAGG – has been developed at NEFSC and a background paper was provided for the review (Overholtz and Link 2009). As the publication states, this model was developed “to address the gap between Ecosim and some of the more detailed ecosystem models such as Atlantis”. Like Ecosim, it builds on the mass balance framework provided by Ecopath, and uses the same biomass update equation as is used in Ecosim. It differs from Ecosim in the equation used to represent predation, and as the paper notes, the equation used generally results in a Holling type II functional response. The published paper uses the model to explore a range of future scenarios including changes in primary productivity, the abundance of small pelagic fish, the abundance of top predators, fishing mortality rates on various groups, and various combinations of these scenarios. The main finding is that the Gulf of Maine ecosystem tends to be driven from the bottom up (consistent with other studies) and is generally robust to structural

changes in abundance of top order predators. While the model is based on a lot of data and structural knowledge summarized in the extensive Ecopath work referred to previously, no attempt has been made to compare the dynamic simulations to time series of historical data (i.e. the model has not been tuned to historical data). This seems like an obvious next step. It is also widely recognized that ecological models can be sensitive to the way in which predation is portrayed (e.g. Fulton et al. 2003). Sensitivity to this source of uncertainty could be explored either by varying the formulation for predation within the model or by comparing the model dynamics and predictions with an Ecosim model for the same system (which uses the foraging arena formulation for predation).

As outlined in the background section of this report, one of the main purposes of the review is to “evaluate the appropriateness and performance characteristics of community-level and ecosystem models employed at NEFSC as operating models in support of the development of Ecosystem-Based Fishery Management (EBFM) strategies for the Northeast U.S. Continental Shelf”. Both the GOMAGG model and the (still under development) Ecosim models are clearly suitable for use as operating models in testing various aspects of strategies for EBFM, though both model types would benefit from further verification (comparison with historical time series data). As operating models, they could be used to explore issues such as system level caps on production and the use of “two tier” harvest strategies, as well as the implications of managing some parts of the ecosystem (e.g. groundfish, small pelagics, benthic invertebrates) for other parts (including protected or recovering species) and the tradeoffs involved.

C. Aggregate Production Models (Link/Fogarty)

This topic was covered in presentation 7 and in the background papers by Link et al. (2010), Overholtz et al. (2007), Overholtz et al. (2008) and Link et al. (2008). These models are referred to in Link et al. (2011) as aggregate production models (see Tables 1 and 2 therein). In the broader framework of Figure 1, they are a subset of multispecies models that include (some) biological interactions among groups but do not represent age or size structure. Their primary purpose so far is to explore broad tradeoffs in exploiting different components of the ecosystem in simple MSE analyses.

This suite of models represents variations of a multispecies logistic or Schaefer model with species grouped into various guilds (e.g. flatfish, groundfish, forage fish and

elasmobranchs) rather than represented individually. The range of models in this category is listed in Table 2 of Link et al. (2011) and is quite extensive. The relative simplicity of the models allows some aspects of formal fitting to data, though where biological interactions are included these parameters are generally drawn from other studies. An interesting feature of the analyses presented examined depletion levels across species within guilds to determine tradeoffs between overall guild exploitation rates and catch levels against depletion levels of individual species. This starts to identify BRPs associated with caps (total system productivity) and floors (no species collapsed) that meets one of the overall objectives of the EM strategy (to identify system level reference points) and is a valuable outcome of this modeling approach. The approach will also be useful in evaluating broad strategies for the longer term implementation of EBFM into regional plans, where tradeoffs across fisheries will have to be addressed. This provides a nice complement to the more detailed system level models that will also be used to evaluate such strategies.

D. Multispecies Production Models (Gamble/Fogarty)

This topic was covered in presentation 5 and in the background papers by Gamble and Link (2009) and Link (2003). These models are referred to in Link et al. (2011) as multispecies production models (see Tables 1 and 2 therein) and include MS-PROD. In the broader framework of Figure 1, they are a subset of multispecies models referred to as community level models. Their primary purpose is very similar to the aggregate production models discussed in the previous section.

The main model presented was MS-PROD (Gamble and Link 2009) which is based around the Schaefer production model applied at various levels of aggregation from individual species up to guilds (at which point it is similar to the models reviewed in section 2C). It has been used to look at the relative importance of predation, competition (within and between guilds) and fishing mortality. As currently implemented, MS-PROD is a simulation tool and is not fitted to data. More work is needed to establish the credibility of the parameters selected, by comparing model output to historical time series data for major groups represented in the model. The model is simple enough to allow formal fitting though probably not with all biological interaction terms switched on. The data needs are fairly modest. While sensitivity analyses are possible and have been explored, further work is required to determine how to represent uncertainties in predictions. With some further work, the model looks

to be useful as an operating model to explore tradeoffs among fisheries given a two-tiered harvest strategy embracing overall caps and individual species limits on catch. One of its main virtues in an MSE context is that it is very fast to run so that extensive robustness testing should be possible.

E. Full System Models (Link/Gamble) - ATLANTIS

This topic was covered in presentation 8. These models are referred to in Link et al. (2011) as full system models (see Tables 1 and 2 therein) with the single regional example being the NE US version of Atlantis (Link et al. 2010 with a supporting technical document on model calibration). In the broader framework of Figure 1, Atlantis is an example of a full ecosystem model categorized as age/size/space structured models. Atlantis is intended as an operating model for strategic evaluation of whole of system management strategies and is not intended to provide tactical advice.

Atlantis is by far the largest and most complex ecosystem model developed in the region and in its current form represents the product of 2 to 3 years research time and effort. It includes a lot of spatial structure, a full ecosystem model (including 45 biological groups), representation of all the main fleets and fisheries in the region, and has the ability to explore a very diverse set of management options that can be bundled in various ways into regional management strategies. In principle it can also be used to represent diverse uses of the marine environment other than fishing. It is not user friendly, is very slow to run, and is extremely challenging to parameterize. Formal fitting to data is impossible with such a large model, but a four stage calibration process has been applied to match as nearly as possible model predictions with historical data. Further calibration effort is required (e.g. comparing predictions post 2004 with observed trends in key groups) and no doubt further will be required when additional forward predictions are examined. In general, the model now fits broad trends in historical time series. There was some debate about the “tolerance” to be applied in such fitting, and about why the model might not fit some of the variation around these trends, but it is unlikely to ever fit all such higher frequency variation across so many groups. The model was seen to do a reasonably good job of fitting key ecological groups and those with better data. An example of the use of the model was presented, to examine the relative effects of climate, fishing and predation.

While the model has not been used so far to provide even strategic advice, there was general acceptance that it could be used as a simulation tool to examine a range of broader issues discussed during the workshop, including the robustness of some of the simpler models (making use of its data generating facility). In principle, it can be used to examine aspects of all of the issues that the overall EM strategy is designed to address (see section 1A). In particular, its ability to explore the consequences of spatial management in many forms lends itself to application in an MSE sense for designing and testing both EBFM and Ocean Policy strategies.

As noted in the presentation and in Link et al. (2011), the strengths of Atlantis include its modular structure and flexibility in process representation, its explicit incorporation of physics, ecology, economics and human use and behavior, its spatial structure, and its explicit design to facilitate use in an MSE context. Its chief drawbacks are its ease of use, its long run and calibration times, and the difficulty of fully embracing the wide range of uncertainties inherent in such a complex model. With regard to the drawbacks, this suggests that additional effort should continue to be invested in simpler alternatives that combine some of its key features. These might include extending the current Ecopath models to Ecosim and Ecospace, and perhaps ongoing development of models such as GOMAGG. This would continue the EM strategy of using comparisons across multiple models at different levels of complexity to check for robustness of results to model uncertainty.

F. Other models (Fogarty/Link)

F1. Empirical multivariate time series

This topic was covered in presentation 2 with no background papers provided prior to the review. These models are referred to in Link et al. (2011) as multi-variate time series models. In the broader framework of Figure 1, they are non-mechanistic models referred to as empirical multi-variate models, including both linear and non-linear state space models.

These are the simplest models of all the classes presented in the review. The simplicity is a virtue in two respects. They can be fitted directly to time series data (where they show good forecast skill) and their stability properties can be analysed, potentially leading to inference about global stability properties (including threshold effects) of the systems they represent. They are unlikely to be used to provide either tactical or strategic advice

to management, but they may play a useful role in informing the development and use of more complex models. For example they have been used to infer where non-linear processes may be driving key system variables.

F2. Extended Stock Assessment Models (ESAMs)

This topic was covered in presentation 6 and in the background papers by Hare et al. (2010) and NEFSC (2011). These models are referred to in Link et al. (2011) in the section on minimum realistic models and include models that extend single species assessments to include, in particular, predation mortality (see pp 16-23). In the broader framework of Figure 1, they are a subset of multispecies models and include models that use age structure and others that do not.

This is a diverse class of models with many examples developed for the NES LME. They serve the primary (potential) purpose of underpinning the transition strategy to EBFM outlined in the NEFMC White Paper – dealing with species interactions in the context of existing management structures. This set of models addresses the impact of consumptive removals on single species models, in particular leading to time varying estimates for natural mortality due to predation. A second class also deals with environmental drivers leading to time varying parameters in single species stock assessment models (including r and K or their equivalents). The presentation showed a range of analyses of ecological footprint, ecological interactions, and environmental interactions, applied to a wide range of species. Overall (and without detailed critical review), the methods and the data underpinning them appear to be robust. Many of the models are fit directly to data and the fitting methods appear to be as robust as those used in typical single species assessments. Some of the assumptions were queried but the overall picture is of effects of predation on M that are both substantial and time varying, across a range of assumptions and model formulations. While several of these analyses have been used to provide “context” for single species assessments, only one of the analyses appears to have been used directly in a stock assessment model to provide tactical advice. While some of the reasons for this were discussed at the workshop and are mentioned in section 1A of this report, this represents a very poor return on considerable investment. The EAP should consider their investment in this type of model pending clarification of proper mechanisms for uptake, such as

acceptance of the broad strategy for implementation of EBFM outlined in the NEFMC White Paper.

Conclusions and Recommendations

The terms of reference for this review address two different aspects of the development and use of ecosystem modeling in the NEFSC. The first concerns the overall strategy for ecosystem modeling in the NEFSC. The second concerns the robustness of particular models and model types used in the overall strategy. While both terms of reference were addressed to some extent in this review, by far the greater focus has been on the overall strategy, and the recommendations arising in the review pertain to this aspect of the work, as outlined below.

With regard to the overall strategy for ecosystem modeling at NEFSC in support of EBFM and Ocean Policy, the following recommendations should be considered (for context see section 1A of this report):

1. Broaden the scope of the models, particularly those used as operating models to test EBFM strategies, to include direct impacts of fishing on species and habitats, to complement the focus on the trophic impacts of fishing.
2. Extend EM models with input from economic and social scientists to allow greater focus on behavioral aspects of human uses of the marine environment, and to facilitate the evaluation of the economic and social consequences of alternative management strategies (for both EBFM and EBM).
3. Depending on the outcome of the NEFMC White Paper process, consider an “AMS” style project to help build stakeholder understanding of and support for EBFM.
4. Continue to develop models and tools that incorporate multiple uses of the marine environment to support implementation of Ocean Policy. These models should have a strong spatial focus.
5. Consolidate the work to date on multi-model inference with a view to producing a major publication on this topic drawing on the experience in the NES LME.

In addition to these specific recommendations, section 1D of this report also provided the following advice:

The future EM strategy will depend on future demand from various sources, including both the fishery management process (particularly implementation of an overarching EBFM strategy through the regional fishery management council process) and implementation of Ocean Policy. Both these demands could increase quickly and substantially. If they do, then **the EM strategy should increase its current focus on developing and applying operating models that can support MSE analyses of broad strategies for EBFM and EBM** – a recommendation already implicit in the stated objective to “increase the focus on tradeoffs” in the EM strategy. There was strong support at the workshop for an MSE and multiple use focus from the MAFMC council member present. If resources are fixed, this would imply a decrease in focus in other areas. However **a serious increase in demand on either or both fronts (EBFM and Oceans Policy) will require a substantial increase in resources allocated to EM and associated tool development in the region.**

In addition to specific recommendations, reviewers were asked to provide a critique of the NMFS review process, including suggestions for improvements of both process and products. My comments in this regard are as follows:

The logistic arrangements for the review were highly efficient and professional. The background material was provided on time and the key summary document for the review (Link et al. 2011) provided an excellent and very well structured overview of the EM strategy and content, addressing all the significant aspects of the terms of reference. The organization for the workshop was excellent and the presentations highly professional. There was good attendance at the workshop (see Attachment 5) and good engagement from several of those attending. In particular it was very helpful to have a member of one of the regional fishery management councils present throughout the workshop. I would like to thank the members of the Ecosystem Assessment Program, and in particular Mike Fogarty and Jason Link, for the huge effort put into providing and presenting material to facilitate the work of the reviewers, and for the professional quality of that material.

The only criticism I have of the process (but it is a significant one) is that it proved impossible to meet fully all the terms of reference of the review because of the

enormous amount of material that was put forward for review. Given the time constraints it proved impossible to do justice to all this material, and my review has focused largely on the first aspect of the terms of reference (assessing the overall EM strategy) and has not provided the detailed critical review of each of the models and methods that seemed to be expected. While I have made comments on each of the model types listed in the terms of reference, this falls way short of fully meeting the terms of reference associated with review of each model type. The advice therefore is to more fully consider the scope of the terms of reference and the number of models to be considered in future reviews of this nature.

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Attachment 1: Bibliography of materials provided for review

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Attachment 2: Statement of Work

External Independent Peer Review by the Center for Independent Experts

Review of Modeling Approaches in Support of Ecosystem-Based Fishery Management

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description: The purpose of this review is to evaluate the appropriateness and performance characteristics of community-level and ecosystem models employed at NEFSC as operating models in support of the development of Ecosystem-Based Fishery Management (EBFM) strategies for the Northeast U.S. Continental Shelf. NMFS strongly endorsed the concept of Ecosystem-Based Management and the related need for the development of Integrated Ecosystem Assessment in support of EBFM. Although this review is directed at efforts in the NEFSC, the findings will be more broadly applicable throughout the agency. The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**. The tentative agenda of the panel review meeting is attached in **Annex 3**.

Requirements for CIE Reviewers: Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein.

CIE reviewers shall have working knowledge and recent experience in the application of community-level and ecosystem models for EBFM. The CIE reviewers shall have expertise with a broad spectrum of complexity and mechanistic detail from static energy flow models to detailed simulation models, and familiarity with the ATLANTIS model is desirable. Our objective is to employ multi-model inference to assess options for EBFM. We are particularly interested in the question of tradeoffs between model complexity

and predictive skill in meeting the needs for scientific advice in support of EBFM. Operating models lie at the heart of the development of Integrated Ecosystem Assessments (IEAs). IEAs have been strongly advocated at the agency level as the principle vehicle for developing and evaluating scientific advice in support of EBFM. It is essential that a rigorous review of modeling activities be undertaken to meet this need.

CIE reviewers shall have experience in different approaches to modeling exploited marine ecosystems. The approaches currently employed in this region include mass balance energy flow models, aggregate-species production models with implicit consideration of species interactions, multispecies production models with explicit consideration of interspecific interactions, state-space multispecies models, multispecies delay-difference models, and the ATLANTIS modeling framework. Reviewers shall have direct experience in model development with EBFM application.

Each CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein.

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review during the panel review meeting scheduled in Woods Hole, Massachusetts during 29-31 March 2011.

Statement of Tasks: Each CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Upon completion of the CIE reviewer selection by the CIE Steering Committee, the CIE shall provide the CIE reviewer information (full name, title, affiliation, country, address, email) to the COTR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contact is responsible for providing the CIE reviewers with the background documents, reports, foreign national security clearance, and other information concerning pertinent meeting arrangements. The NMFS Project Contact is also responsible for providing the Chair a copy of the SoW in advance of the panel review meeting. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When CIE 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 CIE reviewers who are non-US citizens. For this reason, the CIE 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/sponsor.html>).

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE Lead Coordinator on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

The reviewers will be supplied with a review document describing ongoing modeling efforts at NEFSC in support of ecosystem-based fishery management:

Community and Ecosystem Models in Support of Ecosystem-Based Fishery Management for the Northeast U.S. Continental Shelf. Projected length 125-150 pp maximum

Panel Review Meeting: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. **Modifications to the SoW and ToRs can not be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COTR and CIE Lead Coordinator.** Each CIE reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the ToRs as specified herein. The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The NMFS Project Contact is responsible for ensuring that the Chair understands the contractual role of the CIE reviewers as specified herein. The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

The CIE peer reviewers will provide a critical evaluation of the community-level and ecosystem modeling conducted at NEFSC in support of EBFM. The adequacy of the overall modeling framework to meet the needs of EBFM in this region will be assessed and recommended changes to modeling strategies will be provided. The reviewers will contribute individual perspectives on the findings and recommendations for each ToRs. The panel Chair will be responsible for overall compilation of the report of the peer review and in the development of a summary statement of the adequacy of the modeling effort in relationship to the requirements for EBFM in this region.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and

content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Other Tasks – Contribution to Summary Report: Each CIE reviewer may assist the Chair of the panel review meeting with contributions to the Summary Report, based on the terms of reference of the review. Each CIE reviewer is not required to reach a consensus, and should provide a brief summary of the reviewer’s views on the summary of findings and conclusions reached by the review panel in accordance with the ToRs.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

- 1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
- 2) Participate during the panel review meeting at the Northeast Fisheries Science Center in Woods Hole, Massachusetts during 29-31 March 2011.
- 3) At the Northeast Fisheries Science Center in Woods Hole, Massachusetts during 29-31 March 2011 as specified herein, conduct an independent peer review in accordance with the ToRs (**Annex 2**).
- 4) No later than 14 April 2011, each CIE reviewer shall submit an independent peer review report addressed to the “Center for Independent Experts,” and sent to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and to Dr. David Sampson, CIE Regional Coordinator, via email to david.sampson@oregonstate.edu. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

22 February 2011	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
15 March 2011	NMFS Project Contact sends the CIE Reviewers the pre-review documents
March 29-31 2011	Each reviewer participates and conducts an independent peer review during the panel review meeting
14 April 2011	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
28 April 2011	CIE submits CIE independent peer review reports to the COTR
5 May 2011	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: Requests to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on substitutions. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the CIE reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards:

- (1) each CIE report shall be completed with the format and content in accordance with **Annex 1**,
- (2) each CIE report shall address each ToR as specified in **Annex 2**,
- (3) the CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the CIE reports to the NMFS Project Contact and Center Director.

Support Personnel:

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Key Personnel:

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Annex 1: 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.

Annex 2.1: Terms of Reference for the Peer Review

Review of Modeling Approaches in Support of Ecosystem-Based Fishery Management

1. Evaluation, findings and recommendations of overall community-ecosystem level modeling strategy
2. Evaluation of strengths and weaknesses, and recommendations of analytic methodologies
3. Evaluation and recommendations of model assumptions, estimates, and uncertainty
4. Evaluation, findings, and recommendations of result interpretation and conclusions
5. Determine whether the science reviewed is considered to be the best scientific information available.
6. Recommendations for further improvements
7. Brief description on panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations

Annex 2.2: Terms of Reference for the Peer Review provided at Review Panel Meeting

Review of Modeling Approaches in Support of Ecosystem-Based Fishery Management

- A. Overall Review- Synthesis & Summary
 - a. Summarize evaluations, findings and recommendations of overall community-ecosystem level modeling strategy in practice for the NEUS LMR system
 - b. Determine whether the science reviewed is considered to be the best scientific information available.
 - c. Determine if the intended uses of overall community-ecosystem level modeling that have been identified as priorities for the NEUS LME are being executed in accordance with global best practices.
 - d. Provide recommendations for further improvements.
 - e. Provide brief description on panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations

- B. Energy Transfer Models (*Fogarty*)- *Production Potential Models*
 - i. Review and agree upon data requirements requisite for the model
 - ii. Evaluate adequacy of input data as applied for the NEUS application of this model
 - iii. Evaluate strengths and weaknesses of analytical methodologies
 - iv. Evaluate if model structure, parameterization, calibration/tuning, validation/verification, and intended uses are adequately documented
 - v. Evaluate strengths and weaknesses of assumptions, example estimations, and sources of uncertainties, especially with respect to known best practices in the field
 - vi. Review types/levels of use for model outputs, especially with respect to adequacy of modeling relative to major topical issues
 - vii. Recommendations

- C. Energy Transfer Models (*Link*)- *Network Models*
 - i. Review and agree upon data requirements requisite for the model
 - ii. Evaluate adequacy of input data as applied for the NEUS application of this model
 - iii. Evaluate strengths and weaknesses of analytical methodologies
 - iv. Evaluate if model structure, parameterization, calibration/tuning, validation/verification, and intended uses are adequately documented
 - v. Evaluate strengths and weaknesses of assumptions, example estimations, and sources of uncertainties, especially with respect to known best practices in the field

- vi. Review types/levels of use for model outputs, especially with respect to adequacy of modeling relative to major topical issues
- vii. Recommendations

D. Aggregate Production Models (*Link/Fogarty*)

- i. Review and agree upon data requirements requisite for the model
- ii. Evaluate adequacy of input data as applied for the NEUS application of this model
- iii. Evaluate strengths and weaknesses of analytical methodologies
- iv. Evaluate if model structure, parameterization, calibration/tuning, validation/verification, and intended uses are adequately documented
- v. Evaluate strengths and weaknesses of assumptions, example estimations, and sources of uncertainties, especially with respect to known best practices in the field
- vi. Evaluate levels, methods and ramifications for aggregation and compare to single species summaries
- vii. Review types/levels of use for model outputs, especially with respect to adequacy of modeling relative to major topical issues
- viii. Recommendations

E. Multispecies Production Models (*Gamble/Fogarty*)

- i. Review and agree upon data requirements requisite for the model
- ii. Evaluate adequacy of input data as applied for the NEUS application of this model
- iii. Evaluate strengths and weaknesses of analytical methodologies
- iv. Evaluate if model structure, parameterization, calibration/tuning, validation/verification, and intended uses are adequately documented
- v. Evaluate strengths and weaknesses of assumptions, example estimations, and sources of uncertainties, especially with respect to known best practices in the field
- vi. Review types/levels of use for model outputs, especially with respect to adequacy of modeling relative to major topical issues
- vii. Recommendations

F. Full System Models (*Link/Gamble*)- *ATLANTIS*

- i. Review and agree upon data requirements requisite for the model
- ii. Evaluate adequacy of input data as applied for the NEUS application of this model
- iii. Evaluate strengths and weaknesses of analytical methodologies
- iv. Evaluate if model structure, parameterization, calibration/tuning, validation/verification, and intended uses are adequately documented

- v. Evaluate strengths and weaknesses of assumptions, example estimations, and sources of uncertainties, especially with respect to known best practices in the field
- vi. Evaluate levels, methods and ramifications for aggregation
- vii. Review types/levels of use for model outputs, especially with respect to adequacy of modeling relative to major topical issues
- viii. Recommendations

G. Other models (*Fogarty/Link*)

- i. Briefly review and comment upon other community and ecosystem models for the NEUS ecosystem. For each:
 - 1. Review simple summaries
 - 2. Evaluate examples of intended/extant uses
 - 3. Identify any gaps in model uses
- ii. Empirical multivariate time series
- iii. MRMs
 - 1. ESAMs
 - 2. Other MS models
- iv. Others
- v. Recommendations

Attachment 3: Presentations at the workshop

Review of Modeling Approaches in Support of Ecosystem-Based Fishery Management

1. Toward Ecosystem-based Fishery Management on the Northeast U.S. Continental Shelf (Fogarty) [TOR 1]
2. A Review of Empirical Time Series Models (Fogarty) [TOR 2F1]
3. A Review of Energy Transfer (Network) Models (Link) [TOR 2B]
4. A Review of Fishery Production Potential Models (Fogarty) [TOR 2A]
5. A Review of Multispecies Production Models (Gamble) [TOR 2D]
6. A Review of Extended Stock Assessment Models (Link) [TOR 2F2]
7. A Review of Aggregate Production Models (Fogarty) [TOR 2C]
8. A Review of Full System Models (Link) [TOR 2E]
9. Discussion of Multi-Model Inference (Link)
10. Discussion on Model Uses for MSE (Link)

Attachment 4: Workshop attendance

Participants in the workshop on Review of Modeling Approaches in Support of EBFM
Meeting 29/3/2011 - 31/3/2011

1. Ingrid Biedson – Cornell
2. Tom Hoff – MAFMC
3. Wendy Gabriel – NEFSC
4. Kiersten Curti – NEFSC
5. Rich Bell – URI/NMFS
6. Anne Richards – NEFSC
7. Sean Lucey – NEFSC
8. Steve Sutton – NEFSC
9. Ron Schlitz – NEFSC
10. Burton Shank – NEFSC
11. Linda Deegan – MBL
12. Hui Liu – NEFSC
13. Rob Gamble – NEFSC
14. Tony Smith – CSIRO Australia
15. Villy Christensen - UBC
16. Gunnar Stefausson – University of Iceland
17. Frank Almeida – NEFSC
18. Jon Hare – NEFSC – Narragansett
19. Michael Jones – NEFSC
20. Kimberly Murray – NEFSC
21. David McElroy
22. Laurel Col – NEFSC
23. Deborah Hart – NEFSC
24. Mike Fogarty – NEFSC
25. Jason Link – NEFSC

Attachment 5: Workshop program

Review of Modeling Approaches in Support of Ecosystem-Based Fishery Management

Northeast Fisheries Science Center, Woods Hole MA 02543

March 29-31 2011

March 29 2011

- 900 Welcome to Workshop and Overview of Objectives for the Review
- 930 Review of Overview Modeling Strategy and Philosophy for Multi-Model Inference (TOR A)
- 1030 Break
- 1100 Empirical Multivariate Models (TOR G)
- 1145 Review of Energy Transfer Models (TOR B)

- 1230 Lunch
- 1330 Review of Energy Transfer Models (TOR C)

- 1530 Break
- 1600 Discussion
- 1730 Adjourn main meeting
- 1730-1800 Panel Deliberations, as needed (TOR A)

March 30 2011

- 0900 Transition Approaches to Enhance Single Species Advice
- 1030 Break
- 1100 Review of Aggregate Production Models (TOR D)
- 1230 Lunch
- 1400 Review of Multispecies Production Models (TOR E)
- 1530 Break
- 1600 Discussion
- 1730 Adjourn main meeting
- 1730-1800 Panel Deliberations, as needed (TOR A)

March 31 2011

- 0900 Review of Full System Models (TOR F)
- 1030 Break
- 1100 Discussion of Model Uses for Production Potential, Ecosystem Overfishing & Related BRPs
- 1230 Lunch
- 1400 Discussion on Model Uses for MSE, Tradeoffs & Multisector Uses
- 1500 Panel Deliberations (TOR A)
- 1730 Adjourn

**Modeling Approaches in Support of Ecosystem-Based Fishery
Management at the Northeast Fisheries Science Center,
Woods Hole MA**

External Independent Peer Review

by

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Prepared for the Center for Independent Experts

April 2011

Executive Summary

The CIE review team consisted of Gunnar Stefansson from The University of Reykjavik, Iceland, Tony Smith, The Commonwealth Scientific and Industrial Research Organisation (CSIRO) from Hobart, Australia, and Villy Christensen from The University of British Columbia in Vancouver, BC. Jointly, we conducted an external peer review of modeling activities developed at the Northeast Fisheries Science Center in support of ecosystem-based management. The review took place during three days in late March 2011 where scientists from NEFSC, notably Dr Mike Fogarty and Dr Jason Link, made numerous presentations, and with around 20 people in attendance each day.

My independent findings from the review are summarized in this report in more detail, see the Summary of Findings section starting on page 14, but with the key conclusions and recommendations summarized in this section.

The group of scientists in the NEFSC-EAP is jointly and individually very productive and capable. They have developed a very diverse modeling portfolio, and they are active locally, nationally, and internationally in developing and promoting ecosystem approaches to fisheries. They enjoy international reputations as scientists, and they are clearly well positioned to lead NEFSC as it prepares to implement EBM and EBFM.

When it comes to evaluating if the science reviewed is the best scientific information available, the answer must be a qualified yes. From reading the background documents, from the review panel proceedings, from reflections while writing this report, and from general knowledge of the group members and their work over the last decades, I conclude that it is a very qualified group of scientists that constitutes the NEFSC-EAP.

When evaluating the individual models and their use, I find that the simpler models applications fit under the category of best scientific information available. The same holds for the EMAX modeling for as far as the model documentation is concerned, but not for the way this modeling has been used, it has not gone beyond being an “exercise”. The limited use is not up to current standards, and underutilizes the potential of the modeling approach as realized by many other research groups.

The NEUS Atlantis model, which resource-wise is the biggest investment of the EAP, has after five years of development not reached a state where it can provide credible output – or at least such was not demonstrated to the review panel; we only heard about preliminary and less convincing results. It would therefore be stretched to classify the outcome as the best scientific information available though the amount of work and information going into it is impressive.

More importantly, as the NEFSC-EAP has been preparing the move to EBFM the policy implementing bodies, such as notably the regional fisheries management councils have,

naturally, been focused on management based on the existing, productivity-oriented legislation. As a result there has been little request for the more advanced aspects of the work in the EAP, and overall progress toward EBM has been slow. Given a lack of clear prioritization the EAP has spread itself thin, spanning from the simplest approaches for EBFM to the most complicated, and working without defined milestones.

It is time for a new, explicit strategy. The situation in the US has changed with President Obama's Executive Order announcing the new Ocean Policy Act (The White House, 2010) and with its focus on implementation of ecosystem-based coastal and marine spatial planning. The NEFSC-EAP is now in a unique situation to guide the Center as it prepares for the new Act. This will, however, call for the EAP to widen its scope beyond EBFM to embrace EBM, and, notably, to clearly define the program's modeling strategy and resource allocation and requirements.

Noting that spatial planning will be a focus for the Ocean Policy, and noting that there is considerable urgency to include alternative sector use in the modeling, (such as notably wind farms); I stress the need for the EAP to include in its toolbox higher-resolution spatial modeling that will be of use for zoning. For this, and indeed for evaluating tradeoffs of EBFM and EBM in general, it is also important that the group incorporates economic and social aspects into the modeling.

EBM modeling has to be data-driven to be credible, which calls for access to and inclusion of a very wide variety of ecosystem-level information. The economic and social aspects as mentioned above are but examples of this. The EAP already has access to a variety of spatial databases at the NEFSC as well as considerable expertise for analyzing such data. This is an important part of the foundation for EBM, and it should be expanded, in cooperation with other organizations as required, to encompass the full specter of what is required for implementation of EBM.

I also emphasize that climate change is becoming an ever-increasing factor for ocean productivity, and that specific consideration of this should be built into the strategic planning of the work of the NEFSC-EAP. Preparing for the future, notably with regard to adaptive measures, calls for the Center to take initiative. A key to this is to build on the suite of ocean circulation models that have been developed (notably for the IPCC) to acknowledge and express the range of uncertainty in the forward projections. Linking such climate models to ecosystem models describing how the environment impacts life in the oceans and in consequence fisheries, is important for NEFSC as it prepares to embrace EBM and be in position to give advice for the future.

Jointly, the need for EBFM, EBM, spatial planning, and incorporation of climate change consideration in the work of the NEFSC, calls for the EAP to rethink and indeed clearly

define its modeling strategy. Emphasis should be on using alternative modeling approaches, spanning from very simple to more data-intensive and complex. It should also be on developing tools that are available for use in the foreseeable future, which I see as one of the shortcomings of the current implementation.

Developing models for the sake of "being prepared" is however not a viable strategy. It is inefficient, and it leads to model development for the sake of modeling. It is important that the strategy is defined based on very clear and specified policy questions, and that this is done with a realistic estimation of the resources that are needed for efficient and timely implementation.

To guide the NEFSC toward implementation of EBM my most important recommendation is that the NEFSC-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. The strategy should include modeling selection criteria to ensure that the group stays abreast with the model development. It is considered a crucial aspect of best modeling practices for EBM to include alternative modeling approaches in EBM analysis, and this is especially important given that uncertainty is difficult to model conclusively at the ecosystem level.

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.

The current resource level is insufficient given the expanded, future scope. For the EAP to successfully take the initiative on implementation of EBM calls for interdisciplinary expertise beyond what is currently covered by the group. Having such expertise in the group will serve to facilitate cooperation with the more disciplinary NEFSC Divisions as well as with other institutions.

It is a very strong side of the EBM implementation that it opens for, even calls for a strong cooperation across traditional disciplinary boundaries as well as for cooperation with diverse stakeholder groups. Strong cooperation is indeed necessary as evaluation of tradeoffs is required, and tradeoffs must be evaluated based on data-rich information, transparent analysis, and with strong stakeholder involvement throughout the process.

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Background

The CIE review team consisted of Gunnar Stefansson from The University of Reykjavik, Iceland, Tony Smith, The Commonwealth Scientific and Industrial Research Organisation (CSIRO) from Hobart, Australia, and myself, Villy Christensen from The University of British Columbia in Vancouver, BC. Jointly, we conducted an external review of modeling activities developed at the Northeast Fisheries Science Center (NEFSC, or the Center) in support of ecosystem-based management. The review took place during three days in late March 2011 where scientists from NEFSC, notably Dr Mike Fogarty and Dr Jason Link, made numerous presentations, and where there were around 20 people in attendance each day (listed in Appendix 3 on page 53).

The overall purpose of the review was defined with focus on evaluating the appropriateness and performance characteristics of community-level and ecosystem models employed at NEFSC as operating models in support of the development of Ecosystem-Based Fishery Management (EBFM) strategies for the Northeast U.S. Continental Shelf (NEUS), (Project Description in

Appendix 2: CIE Statement of Work, see page 42). It was expected that while the review was directed at efforts in the NEFSC, the findings could be more widely applicable to provide direction within the NMFS.

I find the focus on evaluating the models performance as operating models narrow as it directs attention to the use of the models for Management Strategy Evaluation (MSE, Walters, 1986, Sainsbury et al., 2000), which indicates a focus for the work on development of management procedures that are robust to uncertainty. While this is important, it is only a part of the work that should be (and is) conducted at the NEFSC Ecosystem Assessment Program (NEFSC-EAP) as it prepares the Center in its ongoing move toward EBFM and EBM.

I especially notice that the new US National Ocean Policy signed by President Obama on July 19, 2010 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). The CIE Statement of Work, final version (see this report's Appendix 2, page 42) for the present review was dated July 22, 2010, and does not fully encompasses the implications of the new National Ocean Policy. In consequence, I seek in my report to consider actions that can help prepare NEFSC for the implementation of the new National Ocean Policy, even if this goes beyond the Terms of Reference as specified for this review.

Review Activities

The review started at 9 AM on March 29, with around 20 people in attendance, including the key representatives from the NEFSC-EAP and other parts of the Center as well as the three-person CIE review team consisting of Dr Gunnar Stefansson, Dr Tony Smith, and Dr Villy Christensen.

Mr. Frank Almeida, the Deputy Director of the NEFSC gave a welcome to start off the review, and pointed out that the center has outstanding capacity and experience conducting single species assessments, but also made it clear that there are occasional failures in the system. As some of these may be due to lack of ecosystem considerations, he very much welcomed the review as an opportunity for the Center to move forward with implementation of EBM.

Dr Mike Fogarty, head of the NEFSC-EAP continued with his welcome, he introduced the review panel, focused on what NEFSC needs to do to be prepared for the future, and welcomed an open debate among all participants on how the Center can make progress with its intention of conducting EBFM as well as EBM. All, approximately twenty

participants then introduced themselves with brief descriptions of their background and work responsibilities.

Dr Jason Link described the logistics of the meeting (Appendix 1, #93, LogisticalInformation.pptx), including of the SharePoint site that was set up with background documents and all of the presentations for the modeling review. The program for the meeting had been changed, notably to include presentations all three days of the review, where the original program had most of the third day set aside for review panel considerations and discussion. The Terms of Reference for the review had also been modified from the version that the reviewers had received, but these differences were subsequently discussed between CIE, NEFSC-EAP and the reviewers, and it was agreed to use a slightly simplified version of the Terms of Reference as outlined below in this report.

Mike Fogarty next gave an overview of the introduction of EBFM on the Northeast US continental shelf (Appendix 1, #96, CIEModelReviewIntroductionv4b.ppt).

The new National Ocean Policy establishes EBM as the guiding principle and marine spatial planning as a primary tool for ocean resource management. But this is still to be done working under the existing legal framework of MSY optimization.

Mike Fogarty outlined the existing management framework in the NE, and focused on the need to include ecosystem considerations in the management. This may involve area-based management rather than species-based, and should consider how species and fisheries covered by different plans interact through for instance by-catch and predation. This should be done through a formal process for considering species interactions, while accounting for climate and environmental effects. The outcome should be a small number of ecosystem-based fishery management plans for the NE shelf. The discussion also focused on obtaining the economic and social information that is necessary for evaluating tradeoffs, for instance between competing fisheries. A close understanding of where the fisheries operate spatially is also of importance for any move toward spatially explicit management planning.

A critical issue for modeling relates to “the art of the soluble” or, how simple approaches can we get away with? There is a tradeoff between model complexity and the predictive capabilities of the models. Finding the optimal tradeoff, the Medawar zone, is an area of active concern for the NEFSC’s use of modeling for ecosystem-based management. Also, it is clear that EBM calls for extended focus on marine spatial planning, and while this of concern for the NEFSC planning, it has up to now not been an integral plan of the road map for ecosystem modeling. Ecosystem models can make important contributions to environmental impact assessments, which are of increasing concern, and this issue was also discussed.

Mike Fogarty continued with a review of empirical time series models (Appendix 1, #97, CIEreviewEmpiricalModelsv3.ppt). Papers describing this were not included in the review material, but briefly introduced in the white paper (Link et al., 2011), of which we, however, only received an incomplete draft at the start of the review.

Jason Link presented a review of energy transfer (or food web) models, which also are used for network analysis (Appendix 1, #103, NetworkModelsv2.ppt).

The exemplary work in connection with the EMAX initiative has served as a starting point for the Atlantis “full-system” modeling at the center, and while this work indeed incorporates much of the information that was gathered as part of EMAX, the long development time of the NEUS Atlantis model has called for a focus and prioritization of sparse resources, and the simpler food web approaches have only been sparsely followed up on.

Jason Link expressed in his presentation that it was worth considering further, dynamic use of food web models, but this remains an area where the Center has made little progress compared to other NMFS Centers and the scientific community at large.

Mike Fogarty next presented a review of fishery production potential models (Appendix 1, # 94, AggProdModels-v4.ppt). This represents a rather simple approach to estimate potential fishery production based on the level of primary production, basic knowledge of the food web, and transfer efficiencies.

Robert Gamble presented the work on multispecies production modeling at NEFSC (Appendix 1, #102, MS-PRODPRESENTATION_EMReviewv5.ppt). These models are well established, and the center is exploring new ways of using the models to address research questions.

After the day’s presentation Jason Link led a discussion among the participants. Tony Smith asked for an overview of how the Ecosim model of EwE can be tuned to time series data and the number of parameters fitted. Internationally, there is extensive experience with this, and it was clear that there is no major difference between what is required for MS-PROD and Ecosim modeling.

The meeting ended around 6 PM on the first day.

On Day 2 of the review, March 30, there also were around 20 persons in attendance. Jason Link started at 9 AM with a presentation giving a review of extended stock assessment models, ESAMs (extract from Appendix 1, #100, ESAMModelsv2.ppt). A key issue of this approach is to estimate consumption by predators based on evacuation rate studies, of which there are studies for many of the predators in the NEUS LME. It is

clear that predation mortality can be modeled directly for many forage species, and that biological reference points (BRPs) need to account for the higher total mortality, especially to properly consider the implications for predators of fisheries on forage species.

The Center has also developed an extended MSVPA (MSVPA-X) methodology, which has been applied to several areas in the region along with other multispecies modeling approaches. The approach is clearly capable, but also very data demanding. The MSVPA-X has, related to the demands, not been updated with data from after 2002, due mainly to resource limitations and a shift in priorities. The approach was subject to an external review in 2006, and it was therefore not a focal point for the current review.

Predation impact of marine mammals seems to be of less concern in the NEUS LME compared to many other places in the world, notably in northern temperate areas where marine mammal populations are rebounding after cessation of hunting. A graduate student at NEFSC is currently evaluating the impact of marine mammals in the region.

Mike Fogarty next presented an overview of the Center's use of aggregated production models (Appendix 1, # 94, AggProdModels-v4.ppt). An early application of aggregated surplus production models was implemented by ICNAF to set an upper cap on the total ecosystem extractions. The implementation was in form of a two-tier system, where a second layers allocated quotas between species.

To evaluate how an aggregate biomass measure can be used and the potential implications for the individual species, a MSE approach where the operating model included a species interaction term, while the harvesting was done based on aggregate species fishing, i.e. with same effort on all species. As expected, the effect of using the aggregate-species MSY was that a large proportion (0.3 – 0.4) of the total number of species would be collapsed at the MSY-effort level. This finding is similar to what has been found in corresponding studies elsewhere (including based on different methodologies), and illustrate that the finding may be of a general nature.

The question of modeling elimination of by-catch, as currently being strongly discussed in Europe, was raised. This also relates to modeling of the strong stock and weak stock problem, and it was pointed out that a combination of individual-species and system-level surplus production modeling could be used as a tool for evaluating impact of alternative regulations. To evaluate the implementation effects of this would, however, call for more detailed modeling of technical interactions, which can be done using dynamic simulation modeling, such as is possible through the MSE implementation that is available in both Ecosim and Atlantis.

Jason Link presented a review of “full system” models after lunch on Day 2 (Appendix 1, #101, FullSystemModelsv3.ppt). The model being developed at NEFSC is an Atlantis model, and there are two papers from the Center documenting the development of the model. Jason Link pointed out that the focus of the model was on the upper trophic levels, notably fish, but the development also included substantial effort allocated to model bio-physical processes and lower trophic levels, from detritus, bacteria to invertebrates.

The Atlantis model development has taken around five years and has called for considerable effort. It has now reached a state where the model can be run, and potentially used to evaluate robustness of alternative management scenarios. There was considerable discussion about the calibration procedures for the model, including calls for introduction of formal criteria for evaluating the fit of the model to time series data.

The run-time for the NEUS Atlantis model is around five hours, which in essence makes it impossible to do tuning that would call for any substantive number of model runs. The behavior of the model has, however, been tested for sensitivity to changes in fishing pressure, which may give some confidence in its overall behavior. Examples of this were presented in overview but not included in the documentation; therefore it is not possible to evaluate how well the NEUS Atlantis model can replicate “true” system behavior. It may, however, still be of use as an operating model for MSE, even if general recommendations for such include fitting to time series data (Plagányi et al., 2007, Rademeyer et al., 2007). A question remains though why to use a very complicated model (with little-known behavior) for this purpose when a much simpler model would do the same job (but with better-known behavior).

Management scenarios for the NEUS Atlantis include options for areal management, e.g., spatial closures, but these have to be aligned with the relatively coarse spatial resolution of the model. Use of the model for spatial closures was exemplified through a case study, where closing the eastern part of Georges Bank to fishing was demonstrated. It was pointed out that cod abundance was predicted to increase three times while a key sessile group (scallops) hardly changed, and this seemed peculiar. This led to a discussion on the impact of dispersal rates on the simulation results – it is clear that this is a crucial parameter for all spatial models, and it is one for which we in general have only very cursory information.

The meeting was rounded off for the day around 5.30 PM.

On the third day, March 31, the meeting started at 9 AM with a dozen people in attendance. Jason Link began the day with a presentation on multi-model inference – focus was on how to use multiple models with different parameterization and assumptions to evaluate given research/policy questions (Appendix 1, #98, Discussion1v1.pptx). The discussion focused on evaluation of cross-model comparisons, including on how to use formal statistical protocols for model evaluation.

The presentation next focused on uncertainty, and it was pointed out that the only feasible way to address this with complex models is by focusing on specific research/policy questions. For this, it is or should be made possible to evaluate the level of uncertainty, preferably through multi-model comparisons and within-model evaluation of uncertainty.

Fishery production potential values, e.g., to predict the impact of climate change, provide strategic advice for how the systems will be modeled. The approaches can be used to set total system caps on fisheries removals, which can serve as “ceilings” for overall fishery limits and which can be used in conjunction with “floors” based on single species modeling. The analysis can also be used to explore tradeoffs among alternative fishing regimes for given trophic levels, and for considerations of system level biological reference points (BRPs), and delineations of ecosystem overfishing (EOF).

This was followed by a discussion of model uses for developing and estimating ecological indicators, for defining and evaluating ecosystem overfishing, and for other reference points. This work is done to explore its potential for simplifying the management process, to more directly account for ecosystem constraints, and to add additional precautionary aspects to the management process.

The discussion focused on how realistic it is that ecosystem-level reference points and indicators can be developed to a level where they will be acceptable for use in actual management.

There was also discussion about the practicality of using a two-tier system to set overall harvest levels as tier one, then setting species-specific levels as tier two. One important aspect of this relates to analytical capabilities.

Jason Link described (Appendix 1, #99, Discussion2v1.pptx) the progress toward using MSE to address ecosystem-level issues at the NEFSC. Tony Smith mentioned that Ecosim also could be used for MSE and serve as an intermediate model between the production models and Atlantis. He also pointed out that with Atlantis it will not be possible to do the large number of runs typically performed with MSE in order to address uncertainty, but such would have to be focused on runs where parameters are “bracketed”, i.e. models are run using lower, mean, and upper levels for key parameters.

Jason Link estimated that it would take 2-3 person-years to bring the Atlantis model to a level where it can be convincingly used as an operating model. Additional time (years) will be needed to include additional use sectors. Tony Smith added, however, that Atlantis could be used as currently implemented to evaluate performance of alternative assessment methodologies. Personally, I question the value of this in general, and find it important to see a demonstration that the model behaves in accordance with general expectations before using a model as an operating model to evaluate performance of management procedures. The preferred way of evaluating model behavior, as I see it, is through retrospective analyses.

I also note that the intended use of MSE goes beyond evaluation of alternative assessment methodologies. The White Paper (Link et al., 2011, p. 45) thus states: “our expected use of MSE will likely be to evaluate tradeoffs”, which indeed calls for more stringent model evaluation.

The last afternoon session of the review was moved to the NEFSC building and held in the Director’s meeting room with 15 people in attendance. There were no afternoon presentations but the session was kicked off at 2 PM with a discussion about prioritization. Mike Fogarty outlined the capacity and functioning of the NEFSC-EAP, including of how it fits into the NEFSC structure. The group has a good cooperation with the NEFSC divisions, and involves close to a dozen people including support staff in its work. It was noted that EMAX was done before the EAP was established, which was two years ago. Outreach is considered important for the work with the EAP website serving as an illustration – though its actual impact in this regard was not presented or clear during the review. The commitment to outreach is also demonstrated by the very active engagement of the senior staff in a number of aspects of outreach, including council meetings and information to and public meetings with stakeholders.

Mike Fogarty also outlined an ongoing book project describing the ecology of the NE continental shelf, which can serve as a foundation for EBFM in the region, and which have the NEFSC Division Chiefs on the editorial board, writing chapters. The book project is expected to provide a nucleus for developing a fishery ecosystem plan for the NEFSC area of purview and to provide the background strategy for implementation of EBFM in the region.

The plenary meeting finished around 3.15, after which the review team interviewed Drs. Fogarty and Link mainly to clarify issues related to modeling capabilities and organizational issues. The review team then met in camera from 4 to 5 PM, followed by a further round of discussion with Fogarty and Link to revisit issues related to prioritization, notably with regard to spatial information, analysis, and modeling. The review closed late afternoon, March 31.

Summary of Findings

General

The scientists in NEFSC-EAP (and its precursors) have done an outstanding job on developing and applying approaches for EBFM; they are highly productive as scientists (see Table 1), their work is much cited in the literature, and they are by all measures doing an outstanding job to prepare NEFSC for EBFM and eventually EBM.

Table 1. Overview of publications supplied for the present review. Model type and year of publication are indicated. MS indicates unpublished documents, including those in print. Multi-authored publications are only included where NEFSC staff are lead authors. For details see listing in Appendix 1.

Model type	<2005	2005	2006	2007	2008	2009	2010	2011	MS	Sum
Aggregate	1			1	6				1	9
ESAM	1			4	3	3	3	3		17
Food web	4	3	1	1	2	3	2		2	18
Atlantis							1		1	2
IEA					3	2	1			6
Indicators	6	1	2			3	2			14
MSM	2		1		1	1	2			7
Overview	1						1	1	2	5
Total	15	4	4	6	15	12	12	4	6	78

It is also clear that there is considerable development that needs to be done at the NEFSC, and at NOAA in general, in order to fully implement EBM. Important parts of this relate to governance issues and legal frameworks, but there are also significant scientific contributions to be made, and the NEFSC-EAP group is in position to continue to be a major contributor to the NOAA-wide move to EBM. For this it is, however, necessary to focus the work in the group on activities of a strategic character while drawing on the wider network of the NEFSC (including external organizations) to cover disciplines beyond traditional fisheries science.

Moving to EBM calls for evaluation of tradeoffs, and these will unavoidably be of a social and economic character in addition to the ecological with which the NEFSC-EAP group has the most experience. Also, environmental conditions will continue to change, and this calls for involvement of climate and hydrographic science in predictions. It is important that the NEFSC is in position to provide the best possible science to evaluate tradeoffs and provide alternative future scenarios, and this calls for strong interaction

between the NEFSC-EAP and scientists from a range of disciplines, notably within the NEFSC, but also from elsewhere within NOAA, (e.g., GFDL) and from Academia.

I question the notion in the White Paper (Link et al., 2011, p. 57) that “EBFM is not apt to be an optimization exercise but rather an approach to avoid undesired ecosystem states and to identify those management approaches that are most robust for LMR management”. This statement indicates that the EAP is not ready to go beyond academic exercises, but rather will stick to the traditional and uncontroversial. Some of the key pieces of information we should be able to provide to decision-makers are the ecological, economic, and social tradeoffs of alternative management procedures. Quantification of such tradeoffs is closely related to optimization based on defined objectivity functions, and if government agencies do not take on the role of evaluating such tradeoffs, who can? Often, only such agencies have access to the economic and social information that is required.

Implementing EBM on the modeling side indeed calls for access to a wide variety of databases, and the NEFSC-EAP has considerable experience with extraction and evaluation of ecosystem-wide data, including of a spatial character. They have access to spatial databases that are ready for use and can contribute quickly to descriptive/GIS-analytic studies, and mapping to evaluate cumulative impact as well as visualization tools linked to Google Ocean, etc.

It is important that there is a Center-wide meta-database and data-protocols to inform EBM, and the NEFSC-EAP could well take the lead on such an initiative. It is a major impediment for implementation of EBM that databases tend to be distributed between multiple research groups and disciplines, and often constructed to be of use only to the primary data holders. While it may well be counterproductive to centralize the development and upkeep of such databases, it is, however, important that they be made available beyond the primary, often disciplinary, users.

As an example, fisheries economic information is typically assembled by fisheries economists in NMFS Centers and used for economic reporting and analysis. It is also important to use such data when evaluating tradeoffs between fisheries as part of EBM, and it should be made available for such analysis. Who should ensure this? The modeling group that makes the EBM analysis is in the best position to do so; hence my suggestion that the NEFSC-EAP takes on the coordinating role of evaluating Center-wide database availability and access.

It is important in connection with model development, that consideration about implementation uncertainty (e.g., potential failures), especially with regard to MSE, is incorporated in consultation with stakeholders, notably managers and representatives from the fishing industry.

Findings specific to Terms of Reference (ToR)

The updated ToR, as received when the review started, called for consideration of the following for each model type (i.e. for ToR Sections B through F, see below):

- i. Review and agree¹ upon data requirements requisite for the model
- ii. Evaluate adequacy of input data as applied for the NEUS application of this model
- iii. Evaluate strengths and weaknesses of analytical methodologies
- iv. Evaluate if model structure, parameterization, calibration/tuning, validation/verification, and intended uses are adequately documented
- v. Evaluate strengths and weaknesses of assumptions, example estimations, and sources of uncertainties, especially with respect to known best practices in the field
- vi. Review types/levels of use for model outputs, especially with respect to adequacy of modeling relative to major topical issues
- vii. Recommendations

While this in principle is pertinent, it is not possible to evaluate the wide specter of models presented at the review to this level of details. This would have called for much more time to be available for the on-site review as well as access to more detailed documentation and specific analysis than what was made available or indeed what was possible given time constraints. Recognizing this, I evaluate each of the modeling approaches with the list above in mind, but do not necessarily address all of the topics for each model type.

If detailed reviews of individual models are called for this should be done through specific reviews of such models.

¹ Given that we are conducting independent reviews and that there is no summary report, we have made no attempt in the review panel to agree on data requirements (or any other aspects of the reports).

A. Overall review – synthesis & summary

a. Summarize evaluations, findings and recommendations of overall community-ecosystem level modeling strategy in practice for the NEUS LME system

Given inherent resource limitations it is important for any research group, and especially so in an agency like NOAA, that there is a clear strategy in place for its operation, the NEFSC-EAP being no exception. It does not appear, however, that such a strategy has been defined clearly for the group; it is for instance not apparent from the White Paper developed for the present review (Link et al., 2011). The modeling work in the group covers a very wide range of approaches, and as is clear from the more detailed comments in the following sections, the group has done an outstanding job with regard to scientific scope and productivity.

NEFSC-EAP is seeking to model the continuum from very simple models (such as aggregate surplus production models) to the most complex (Atlantis), and in doing so, it is spanning very wide for a small group. Where the use of alternative models is to be strongly encouraged in order to provide alternate view (and hence a glimpse of the associated uncertainty) of how systems may be impacted by anthropogenic factors, it is much to expect a small group to actually do this in practice. As such, the effort of the group is laudable. My main question is therefore if the group would have been better off by focusing on the simpler range of the model complexity specter; do they have the resources to fully develop the most complex model in our field?

To answer that question calls for a clear definition of modeling strategy, and I recommend that the NEFSC-EAP take on as an important task to clearly define their modeling strategy, including how they will operationalize it and be ready to deliver on EBM given actual resource constraints.

Regarding the strategy, Mike Fogarty expressed that “although a broad spectrum of modeling approaches is ... available to support EBM/EBFM, we have tailored our overall strategy to focus on familiar concepts centered on production processes,” (M. Fogarty, email to review team of March 15, 2011.) These are indeed familiar concepts, and they are well in line with the work traditionally performed at the Center.

It may, however, be time to move beyond the familiar given the emerging priorities that are called for in the new US Ocean Policy Act (The White House, 2010), which establishes EBM as the guiding principle and marine spatial planning as a primary tool for ocean resource management.

In moving toward EBFM the NEFSC-EAP has based its spatial planning on the assumption that this can be done by first defining spatial management units, and then concentrating the work of the group on fisheries production analysis within such, (Appendix 1, #96,

CIEModelReviewIntroductionv4b.ppt, Fogarty and O'Boyle, 2011). I question, however, if such an approach is sufficiently anticipatory when it comes to preparing the Center for EBM.

Some of the crucial questions that relate to implementation of EBM in the NEUS concern alternative sector uses of the marine environment, recently exemplified with regards to location of extensive offshore wind farms. The NEUS area is classified as “outstanding” with regard to wind potential by the US Department of Energy, and there is considerable pressure to implement numerous, extensive farms. Given the goodwill windmills enjoy in Washington and by the general public, it becomes a question of placement, placement, and placement; not of whether it will happen or not. Analyses are urgently called for that build on quantitative modeling of the ecological, economic, and social implications of placements, and this calls for relatively high-resolution spatially explicit modeling or zoning analysis. Such are possible based on, e.g., GIS, Marxan, and Ecospace analysis, but hardly using coarse predefined spatial management units as implemented in NEUS Atlantis. Also, such cases will require urgent analysis, so development time has to be short for the methodologies if the results are to be relevant.

I am also concerned about how the NEFSC-EAP prepares the Center for addressing climate change questions. The group has done an exemplary study on climate change impact for Atlantic croaker (*Micropogonias undulatus*), where temperature forecasts were obtained from 14 general circulation models simulating three CO₂ emission scenarios, and this was used to make prediction about future population recruitment. I find this study exemplary because it uses a simple model combined with alternative environmental models to give an idea of uncertainty in the predictions. The strength of the IPCC work is closely linked to the use of alternative models; where would we be today with the climate change debate if the IPCC had focused all resources on developing one atmospheric model and one ocean model?

In the spirit of using alternative models to explore issues, I find it noteworthy that the NEFSC-EAP has gambled a major proportion of its resources over the last five years on development of a single modeling approach, the NEUS Atlantis model. It appears from statements at the panel review that an additional number of person-years are required to bring the model to a state where it can actually be used credibly as an operating model, let alone the subsequent person-years that will be required to include additional sectors to make the model useful for addressing EBM questions. Even if this may be possible with such additional years of development added, it is unlikely that it will be possible to notably fit the “full system” model to time series data, to address questions of uncertainty beyond extreme parameter bounding, or that the model can be developed to have a spatial resolution that will make it useful for addressing the most

important questions for EBM, which are bound to be spatial and require a finer (or different) spatial resolution than what has been predetermined for the NEUS Atlantis model.

Also, what are the options of using the full system model for making predictions about the impact of climate change? A critical aspect of this is what underlying climate model to use, and the NEUS Atlantis model does not allow flexibility in using alternate climate models such as done in the Atlantic croaker study.

I also note that there are alternative modeling approaches with which it is possible to address the same EBM questions, building on the same data material, as is potentially anticipated for the NEUS Atlantis model, but with an order of magnitude less development time required. It is also possible to do this based on a range of climate models, not just one.

The project description for the present review (see page 42) states that the purpose is “to evaluate the appropriateness and performance characteristics of community-level and ecosystem models employed at NEFSC as operating models in support of the development of Ecosystem-Based Fishery Management (EBFM) strategies for the Northeast U.S. Continental Shelf.” This places a very strong emphasis on Management Strategy Evaluation (MSE) procedure development, which is only an element in the EBFM and EBM processes. While an important element of EBFM it is not a sufficient element on its own. It is important that the NEFSC-EAP keeps this in mind when defining their EBM modeling strategy.

Overall, what I am most concerned with regarding the (implicit) modeling strategy applied by the NEFSC-EAP is that it doesn't seem to be driven by policy questions. I recommend a procedure where a limited set of overarching policy questions are formulated, and the task becomes to select and implement the modeling tools that are required to address these questions. Having worked with the most complex of the kids on the block, the group has the capacity to do this. Preferably, and wherever possible this should be done using alternative modeling approaches rather than gambling all resources on one approach. This will, among others, make it possible to map the lower end of the Medawar zone – as advocated during the review, but not yet approached in practice at NEFSC-EAP.

b. Determine whether the science reviewed is considered to be the best scientific information available

This ToR item is pertinent to include in a review in connection with specific management actions, such as for an assessment that is conducted as part of a fisheries management process. It is much less constructive or even important a question when it comes to

evaluating the overall modeling strategy for a complete research group. From reading the background documents, from the review panel proceedings, from reflections while writing this report, and from general knowledge of the group members and their work over the last decades, I conclude that it is a very qualified group of scientists that constitutes the NEFSC-EAP.

When evaluating the individual models and their use, I find that some, e.g., the way the various production models have been conducted, fit under the category of best scientific information available. The same holds for the EMAX modeling for as far as the documentation of the model is concerned, but not for the way it has been used. The limited use (even with 18 food web publications, see Table 1) is representative of how such modeling was done in the mid-1990s, with the perturbation experiments for small pelagics serving as an example, and it grossly underutilizes the potential of the modeling approach as realized by many other research groups, including in institutes with mandates similar to that of the NEFSC.

The NEUS Atlantis model has not been developed to a degree where it can provide credible output – or at least this was not demonstrated to the review panel, we only heard about preliminary results, such as the rather peculiar outcome for scallops/cod in connection with area closures. It would therefore be a stretch to classify the outcome as the best scientific information available.

c. Determine if the intended uses of overall community-ecosystem level modeling that have been identified as priorities for the NEUS LME are being executed in accordance with global best practices

The international community has embraced the question of best practices for ecosystem modeling as part of EBFM/EBM (FAO, 2008, DFO, 2008, Townsend et al., 2008, Link et al., 2010), and the NEFSC-EAP is at the forefront of this development. My concern is therefore not as much related to whether the group lives up to the expectations of best practices. It has in general, and I am sure it will continue to do so. The few glitches I have noted during the review process relate to the group being overextended with regard to what it is trying to cover and achieve as compared to the resources at its disposal.

Overall, the group very much lives up to current standards for best practice with regard to ecosystem modeling, within the constraints of the chosen models. This was clear from the review as is it from the review White Paper (Link et al., 2011).

The NEFSC-EAP is a small group with a very extensive mandate, making it very critical that their resources are used efficiently. A key requirement for this is that there is a clear prioritization, and hence to some degree question if indeed an “overall

community-ecosystem level modeling [...] have been identified as priorities for the NEUS LME”, as stated in the ToR above. I suggest that the group revisits its priority setting in order to make the considerations more clear and specified.

d. Provide recommendations for further improvements

The NEFSC-EAP is a competent group with a strong scientific reputation. I recommend though that they widen their focus beyond fisheries production methodologies. Even if the Magnuson–Stevens Fishery Conservation and Management Act with its focus on optimum yield currently provides the guidelines for US fisheries management, and even if the focus of the NEFSC-EAP is well aligned with this act, it is time now to embrace the implications of the new US Ocean Act Policy (The White House, 2010), with its focus on implementation of EBM and marine spatial planning. EBM is wider than EBFM, and calls for multi-sector considerations going beyond what we so slowly are getting used to and comfortable with as part of EBFM.

An aspect of this relates to the expertise that is required within the NEFSC-EAP in order to be at the forefront of the EBM implementation for the NEUS. EBM calls for multi-disciplinary and multi-sectoral initiatives and analysis, and the group needs to have capacity to communicate and work efficiently with other disciplines and divisions. Such would be promoted if the group had staff with other disciplinary background than currently covered assigned, e.g., with regards to socio-economic and environmental modeling aspects.

To guide the NEFSC toward implementation of EBM my most important recommendation is that the NEFSC-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 strategy for what modeling to conduct in order to implement EBM at the NEFSC. The strategy should include modeling selection criteria to avoid the present seemingly *ad hoc* (or at least implicit) selection, and to ensure that the group stays abreast with the model development. It is considered a crucial aspect of best modeling practices for EBM (FAO, 2008) to include alternative modeling approaches in EBM analysis, and this is especially important given that uncertainty (be it process or observation-driven) is difficult to model conclusively at the ecosystem level.

The group can also serve an important role for guiding the Center in evaluating monitoring needs where clearly one of the important questions that needs to be addressed is what information that is needed for implementation of EBM.

e. Provide brief description on panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations

This is covered in the section Review Activities, starting on page 7, combined with the section Summary of Findings, starting on page 14.

B. Energy transfer models – production potential models

The fisheries production models build on readily available information, partly from remote sensing, partly from the literature though informed by local data and modeling. Information about primary productivity is important, and the center is making good use of satellite-derived information for this purpose. It builds on output from food web models for transfer efficiencies (including their variability between systems), and on N-15 analysis for trophic levels.

The applications for the NEUS, which include both deterministic and stochastic approaches, provide outcomes in the form of potential productivity with probability distributions, and a major research question relates to how this can be used to cap fisheries catches, e.g., at a fraction of the potential productivity.

On the uncertainty front, the transfer efficiencies depend on the production/biomass and consumption/biomass ratios that are used in the underlying food web models. Many models have rather poor input data for consumption/biomass ratios, so there is some uncertainty associated with these parameters. There is, however, no reason to believe that there is systematic inter-annual variation in the transfer efficiencies, and given that the fishery production is seen as a cap on potential fishery production, predictions for how the potential change over time may not be impacted.

The approach has an explicit way of dealing with uncertainty, so that the output is a probability distribution, taking care of precision. With regards to accuracy, my main concern is the use of a mean trophic level for the MSY harvest policy to estimate the potential fisheries production, along with the uncertainty in transfer efficiencies and potential exploitation levels discussed by the authors (Fogarty et al., 2008).

A key question related to the approach remains though; how important is it to provide an estimate of maximum potential fisheries production? Will it ever be used in practice for fisheries management in the NEUS?

It provides a biological reference point in the form of a potentially harvestable amount (with wide bounds), but I would for instance find it much more interesting to provide guidelines for how one could optimize the fisheries so as to obtain long-term maximum economic output (be it profit or value) for the system without jeopardizing the integrity of the ecosystem. Such analysis can be performed using various approaches for

ecosystem modeling, but for this it is necessary to formulate the objectives for management. Focusing on management objectives and associated tradeoffs seems to be an area that is not yet central to the work in the NEFSC-EAP; still it is one that will become increasingly important as the Center move towards EBFM.

My overall recommendation for the use of fisheries production potential modeling is that clear policy questions be formulated on which they can build, and that alternative modeling approaches be used to address those questions. This form for modeling, given its simplicity, minimal data requirements, and ease of application may well remain to serve a purpose in the toolbox of the NEFSC-EAP.

C. Energy transfer models – network models

The data requirements for these models are not extensive compared to the data availability in the region, and relate mainly to abundance, productivity, and diets. Indeed, food web models have been used in a rigorous, comparative manner at NEFSC, and this work is qualified. The EMAX process, especially, has been very thorough and the documentation for this is among the best among the hundreds I have seen for such models (Appendix 1, notably #46). It is remarkable how a large amount of information from throughout the Center is incorporated in the activity, and this bear witness to extensive cooperation across Divisions.

The work has also contributed to development of the discipline through contributions to comparative studies as well as to methodology development, especially with regard to the importance of data use and evaluation. The donut-methodology developed at the Center is noted as an example of a significant research contribution from NEFSC-EAP to the research field (Link, 2004).

Overall, however, the NEFSC-EAP has not capitalized on the investment the Center has made through the EMAX activity. The analyses are basically limited to network analysis and simple perturbation experiments, and vastly underutilize the potential of the approach. There are only a few analyses building on EMAX, e.g., the small pelagics perturbation study (Link et al., 2009), which I cannot consider a very meaningful application.

With regards to estimation of MSY based directly on the static EMAX food web model as reported by Link et al. (Appendix 1, #58), I am highly skeptical. Estimation of B_{MSY} from a static network model is not meaningful, and again there are much better ways of doing this that build on such models, but estimate MSY using a dynamic model and after fitting to time series (see, e.g., Walters et al., 2005 for a good example).

So, in conclusion about the use of the EMAX model for addressing fisheries management and EBFM questions, it should not be done on the static food web model directly, but based on dynamic simulations. Such can be performed with very limited resource allocation given that the food web model has been constructed and documented.

This is neatly illustrated with a cursory Gulf of Maine dynamic model building on EMAX (Overholtz and Link, 2009). The model is a simplified version of the Ecosim model, but I note though that the argumentation in the Overholtz paper, “Ecosim, however, was not designed to address other scenarios such as climate change or large increases in predator biomass, nor can it readily address simultaneous major system changes” was dated by perhaps a decade by the time it was written, as demonstrated by many other prior applications. I notice for instance that the time and spatial-dynamic model Ecospace, which build on Ecosim, has been coupled (i.e. with exchange of spatial parameters for each time step) to three different bio-geochemical models and that there are numerous applications that evaluate the relative role of fisheries, environmental, and ecological parameters on Ecosim models based on extensive fitting to time series data (e.g., Guénette et al., 2006).

This being said, it would indeed be interesting to compare results from the Overholtz and Ecosim models, notably with regard to how they can be made to fit to all available time series data and make policy predictions. Such fitting should be an integral part of dynamic model development, before they are used in any serious manner for EBFM, in line with best practices for ecosystem modeling (FAO, 2008).

With regard to network analysis, I actually don't think I have ever seen any substantial results from such studies being used for fisheries management or EBFM, (and I made my PhD in network analysis and have contributed a bit to the development of the field, so I'm not speaking out of total ignorance). I have, however, seen other research groups in comparable institutions make substantial contributions to EBFM based on time- and spatial-dynamic modeling building on the underlying food web models, such as documented through EMAX.

It is also possible and indeed straightforward to further develop the EMAX model to address questions related to ecosystem state and services. I note for instance that including more detailed species-definitions would open for use of the model as part of environmental impact assessments (EIA), an area gathering increasing importance – and an area where the Alaska Fisheries Science Center successfully has demonstrated how food web models can be used for EIA as a regular part of the fisheries assessment process.

D. Aggregate production models

Aggregate production models are simple, classic models, which, based on biomass and catches/effort time series, estimate growth rates and carrying capacity and notably MSY. They differ from the traditional forms mainly by modeling a diverse species assemblage instead of individual species or functional groups (ecologically similar species).

The aggregated production modeling can be used as a scoping tool for evaluating impact of levels in overall fishing mortality. The model describes the extreme situation where the fisheries are completely unselective, this is indeed an extreme, but it is useful as a bounding exercise. More detailed analysis based on individual-species modeling can and should, naturally, go hand in hand.

The approach can also be used to give exploratory estimates for system level MSY, which can be compared to the summed single species MSY (and which will be lower). Given the advanced level of the single species assessments in the region, I doubt though that it will be of any real use for fisheries management or for EBFM. Still, it helps to make it clear that all species cannot be managed simultaneously to produce MSY, and it does indeed provide an estimate for how much below the summed single-species MSY the multi-species MSY may be.

The aggregated production models are of special interest for a potential move toward a simpler management system, which may open for modeling/assessment also being made based on simpler approaches than the currently very detailed single species population modeling. In the spirit of “being prepared” this is thus a topic that should be explored more fully if inline with the group priority setting, (which it may well be). Of interest is, notably, how to use fitting techniques to improve the parameterization of production models.

In the spirit of using alternative models, I notice that it will be straightforward to make a parallel calculation of potential fishery production directly from a fitted, dynamic model building on the EMAX model.

E. Multispecies production models

These models rely on biomasses by species or populations, which generally are available in the region. More difficult is estimates of carrying capacity by species, as well as competition and interaction strength coefficients. With some assumptions, these parameters may, however, be informed based on data from notably diet data. The models serve as a simplistic tool for exploratory evaluations so it is a possibility to evaluate how predictions are impacted about uncertainty in the input parameters.

A primary usage of these models is as a simulation tool in connection with MSE to explore alternative harvest strategies. They are also useful to explore the effects of aggregate reference points on individual stocks and to test a variety of interaction and predation term constellations.

In evaluating output from the approach, (notably Appendix 1, #32) I cannot help wondering how different the results would be if the model had been fitted to time series data. The approach would indeed benefit – especially with regard to credibility for use as an operating MSE model, if it were fitted to data, e.g., from the MSVPA-X in line with general recommendations for operating models (Rademeyer et al., 2007).

Overall, I find the modeling approach neat and worthwhile; it builds on available data supplemented with input parameters for which one can make qualified estimates, and it produces an alternate view on how the system performs. Given its simplicity and potential, I indeed think it should be part of the modeling toolbox of the Center.

F. Full system models – Atlantis

The data requirements for Atlantis models are very extensive, and the NEUS Atlantis model illustrates this through its extensive reliance on default parameter settings, i.e. by using parameter setting from the original Australian models.

The NEUS Atlantis is potentially a “full system” model as it was termed in connection with this review, but it is not developed to a degree where it lives up to this designation. As implemented, it only deals with a subset of the full system capabilities and is focused on fisheries biology, while socio-economic aspects of fisheries as well as notably other ocean-use aspects (such as are involved in EBM) are still to be considered and implemented, calling for years of development time. Also the implementation for the low trophic levels leans very heavily on parameter settings from the original, Australian Atlantis model.

Using Atlantis as a “gaming tool” to evaluate model reactions to alternative parameters settings (such as notably density dependence and dispersal rates) is not practical due to the long run time of the model (5 hours). That is one reason why the use of the model is focused on use as an operating model as part of MSE where the research focus is on developing management procedures that are robust to uncertainty irrespective of whether the operating model performs realistically or not. One can question, however, if such a complex model really is needed or even preferable for testing management procedures.

Atlantis has a spatial resolution that largely is informed by fisheries statistical/ecological boundaries and border conditions, and cannot be easily modified to consider spatial

management that does not correspond to this, rather coarse, pre-defined spatial scale. This, in combination with the long model runtime quite considerably reduces its potential use as a zoning tool.

Climate change can be considered in the Atlantis framework through temperature changes, ocean acidification/chemistry, and loading levels of nutrients. I find, however, more desirable an approach that builds on several IPCC ocean models (such as are available to NEFSC-EAP through ROMS and its cooperation with the NOAA GFDL and the Princeton Cooperative Lab) in order to consider the uncertainty inherently involved in future predictions. This will be difficult to implement in practice for the NEUS Atlantis given the long development time of the approach as implemented. An approach that linked to alternative ocean models would break this limitation.

To evaluate tradeoff in the fleet dynamics module of Atlantis (not yet activated but developed by CSIRO) requires socio-economic information. Such information is available at NEFSC and cooperation between the NEFSC-EAP and the relevant NEFSC Divisions on this is clearly warranted – both for use with NEUS Atlantis and alternative models. I believe, however, that Jason Link mentioned at the review that implementation of the fleet dynamics module in NEUS Atlantis was a considerable development task.

Uncertainty can partly be handled by setting bounds on parameters, but formal sensitivity analysis or evaluation of uncertainty is not feasible. The applied parameter calibration procedure with its subjective “within an order of magnitude” does not seem overly convincing.

It is indeed difficult to develop an Atlantis model, and the development of the NEUS Atlantis model has been a five-year process, which has taken a substantial part of Jason Link and Robert Gamble’s time, and which has called for critical involvement of CSIRO colleagues, notably Dr Fulton who has been an integral part of all Atlantis model development.

The NEUS Atlantis development is thus a very considerable investment for the Center, and it is only now that the model is reaching a level where it can at least be run and potentially be useful. It is, however, also clear that there still is major development necessary to establish credibility for its use. The main use is therefore likely to be as a virtual world and a scoping tool to evaluate tradeoffs in alternative management scenarios. While of scientific interest, does this represent an optimal use of sparse resources?

The NEFSC-EAP has to some extent painted itself in the corner through its implicit prioritization and resource investment in the “full system” NEUS Atlantis model. The visible results from this activity are minor, and I doubt there will be results from the

approach within the next few years that can be of immediate use for the Center in its move toward EBM.

So what do to? Wait for the paint to dry, i.e. finish the development, or walk out? I do not know the answer to this question. Atlantis is a very neat model when fully implemented, and the modelers implementing it are very capable. Whether it is realistic to get to the point of full implementation and what it will take can best be judged by those who actually know the details of how far advanced it is now, what the cost has been, and what is needed to get to the full level, which I presume should include alternative use scenarios.

What I do know is that the questions that it is intended to ask of NEUS Atlantis, as well as its use as an operating model for evaluating alternative management strategies, and all other uses I have heard suggested, can be addressed using alternative and much simpler ecosystem modeling approaches.

I suggest an evaluation as part of a formal strategy setting for how NEFSC-EAP implements its modeling scheme in support of the Center's move toward EBM. Evaluate alternative modeling approaches (such exist), and put together a package that can be implemented so as to deliver on EBFM/EBM within a reasonable time frame. There is a demand for this now with the new Ocean Policy Act knocking on the door, calling for modeling methodologies as an important part of EBM implementation.

G. Other models

i. Empirical multivariate time series

Mike Fogarty made a presentation (Appendix 1, #97, CIEreviewEmpiricalModelsv3.ppt) of empirical multivariate models and a page about this was included in the white paper for the review (Link et al., 2011). Papers describing the approach were not included in the documents made available prior to the review, and I do not have specific information that allows me to properly evaluate this form for modeling. Given its relative simplicity and easy of interpretation it may, however, well be a part of the NEFSC-EAP toolbox.

ii. MRMs

1. ESAMs

Discussions at the review focused on the effect of environmental parameters, notably the implications of adding temperature impacts to the stock-recruitment relationship for Atlantic croaker (Link et al., 2011). The way this study used a simple approach combined with a range of IPCC climate models is exemplary and serves as a neat

example of how to integrate climate change impact into fisheries research. I especially find the use of output from a range of IPCC models important, given the uncertainty associated with each of these individually. The important question to address is indeed what can be learned from using a range of IPCC models to feed the climate change predictions. Such an approach should be followed in general when addressing questions related to climate change.

Overall, the ESAM models, fit well into the current stock assessment processes, which serves to underline that there should be an immediate interest and use for the results from the studies. But the ESAM models are not useful for exploring tradeoffs between species. Given the intended focus of the NEFSC-EAP group on evaluating tradeoffs, one may therefore question the role ESAMs in the future should play for the EAP group. I do not find they should be (nor have they been) a focal point, whether they are included as a minor tool in the toolbox is a matter of resources.

2. Other MS models

iii. Others

No comments required.

Conclusions and Recommendations

The group of scientists in the NEFSC-EAP is very productive and capable. They have, almost heroically, developed a very diverse modeling portfolio, and they are active locally, nationally, and internationally in developing and promoting ecosystem approaches to fisheries. They enjoy international reputation as scientists, and they are clearly well positioned to lead NEFSC as it prepares to implement EBFM and EBM.

As the NEFSC-EAP has been preparing the move to, initially, EBFM they have been in the reverse of the “Australian situation”. In Australia, legislation moved ahead of science a decade ago, when making a quick move to implement EBM for its marine areas. So while NEFSC-EAP (and its key scientists before the program was established) has worked on developing a diverse toolbox with the aim of “being prepared”, the policy implementing bodies, such as notably the regional fisheries management councils have, naturally, been focused on management based on the existing, productivity-oriented legislation.

As a result of the science being ahead of the legislation, (which indeed should be the case), progress toward EBM has been slow, and the EAP has spread itself thin, spanning from the simplest approaches for EBFM to the most complicated, and working without defined milestones.

The White Paper developed for this review illustrates this (Link et al., 2011, p. 61-62). Overall the paper is a clear, comprehensive, and important overview of the EBFM-related modeling activities at the Center, but it does not provide a strategy nor is it clear that there is an underlying, defined strategy. While the EAP certainly needs to have a modeling toolbox, the key issue is not what tools to develop for that *per se*, but that the modeling, each time, takes the key policy questions as the starting point, and then uses alternative modeling approaches for addressing the questions.

It is time for a new, explicit strategy. The situation in the US changed last July with President Obama’s Executive Order announcing the new Ocean Policy Act (The White House, 2010) and with its focus on implementation of ecosystem-based coastal and marine spatial planning. The NEFSC-EAP is now in a unique situation to guide the Center as it prepares for the new Act. This will, however, call for the EAP to widen its scope beyond EBFM to embrace EBM, and, notably, to clearly define the program’s modeling strategy and from this clarify the resource allocation and requirements.

Noting that spatial planning will be a focus for the Ocean Policy, and noting that there is considerable urgency to include alternative sector use scenarios in the modeling, (such as notably wind farms); I stress the need for the EAP to consider higher-resolution spatial modeling that will be of use for zoning. For this, and indeed for evaluating tradeoffs of EBFM and of EBM in general, it is important that the group incorporates economic and social aspects into the modeling.

EBM modeling has to be data-driven to be credible, which calls for access to and inclusion of a very wide variety of ecosystem-level information. The economic and social aspects as mentioned above are but examples of this. The EAP already has access to a variety of spatial databases at the NEFSC as well as considerable expertise for analyzing such data. This is an important part of the foundation for EBM, and it should be expanded, in cooperation with other organizations as required, to encompass the full specter of what is required for implementation of EBM.

I also emphasize that climate change is becoming an ever-increasing factor for ocean productivity, and that specific consideration of this should be built into the strategic planning of the work of the NEFSC-EAP. Preparing for the future, notably with regard to adaptive measures, calls for the Center to take initiative. A key to this is to build on the suite of ocean circulation models that have been prepared for the IPCC, and notably so by the NOAA GFDL/Princeton Cooperative Laboratory. Using a variety of models is important to acknowledge and express the range of uncertainty in the forward projections. Linking such climate models to ecosystem models, describing how the environment impacts life in the oceans and in consequence fisheries, is important for NEFSC as it prepares to embrace EBM and be in position to give advice for the future.

Jointly, the need for EBFM, EBM, spatial planning, and incorporation of climate change consideration in the work of the NEFSC, calls for the EAP to rethink and indeed clearly define its modeling strategy. Emphasis should be on using alternative modeling approaches, spanning from very simple to more data-intensive and complex. It should also be on developing tools that are available for use in the foreseeable future, which to me is one of the shortcomings of the current implementation in the group.

Developing modeling capacity for the sake of “being prepared” is, however, not a viable strategy. It is inefficient, and it leads to model development for the sake of modeling. It is important that the strategy is defined based on very clear and specified policy questions, and that this is done with a realistic estimation of the resources that are needed for efficient and timely implementation.

To guide the NEFSC toward implementation of EBM my most important recommendation is that the NEFSC-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. The strategy should include model selection criteria to ensure that the group stays abreast with the model development, (i.e. that the criteria are consulted when a task is planned). It is considered a crucial aspect of best modeling practices for EBM to include alternative modeling approaches in EBM analysis, and this is especially important given that uncertainty is difficult to model conclusively at the ecosystem level.

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 EAP could be,

- How do 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? What additions will there be to the ESA?

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 evaluate the resource allocation that implementation of the recommended NEFSC-EAP modeling strategy will call for.

The current resource level is insufficient given the expanded scope. For the EAP to successfully take the initiative on implementation of EBM calls for interdisciplinary expertise that goes beyond what is currently covered by the group, and hence for additional resources. As examples, I can mention expertise on environmental productivity/climate/hydrography, socio-economic, implementation, and governance issues. Having such expertise in the group will serve to facilitate cooperation with the more disciplinary NEFSC Divisions as well as with other institutions.

It is a very strong side of the EBM implementation that it opens for, even calls for a strong cooperation across traditional disciplinary boundaries as well as for cooperation with diverse stakeholder groups. Strong cooperation is indeed necessary as evaluation

of tradeoffs is required, and tradeoffs must be evaluated based on data-rich information, transparent analysis, and with strong stakeholder involvement throughout the process.

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Appendix 1: Bibliography of materials provided for review

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Presentations

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94. A review of aggregate production models; 47 slides. File: AggProdModels-v4.ppt
95. CIE Model Review, overview, 1 slide. File: CIE Model Review Mar 15.ppt.
96. Toward ecosystem based fishery management on the Northeast US Continental shelf, 63 slides. CIEModelReviewIntroductionv4b.ppt.
97. A review of empirical time series models; 29 slides. File: CIEreviewEmpiricalModelsv3.ppt.
98. Discussion of multi-model inference; a comment on addressing other sources of EM uncertainty; discussion of model uses for estimating fisheries production potential; discussion of model uses for ecological indicators, ecosystem overfishing & related BRPs; 60 slides. File: Discussion1v1.pptx.
99. Discussion on model uses for MSE; discussion on model uses for evaluating tradeoffs; discussion on model uses for multi sector uses; 32 slides. File: Discussion2v1.pptx.
100. A review of extended stock assessment models; 83 slides. File: ESAMModelsv2.ppt
101. A review of full system models; 92 slides. File: FullSystemModelsv3.ppt.
102. A review of multispecies production models; 49 slides. File: MS-PRODPRESENTATION_EMReviewv5.ppt.
103. A review of energy transfer (network) models; 65 slides. File: NetworkModelsv2.ppt

Appendix 2: CIE Statement of Work

External Independent Peer Review by the Center for Independent Experts

Review of Modeling Approaches in Support of Ecosystem-Based Fishery Management

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description: The purpose of this review is to evaluate the appropriateness and performance characteristics of community-level and ecosystem models employed at NEFSC as operating models in support of the development of Ecosystem-Based Fishery Management (EBFM) strategies for the Northeast U.S. Continental Shelf. NMFS strongly endorsed the concept of Ecosystem-Based Management and the related need for the development of Integrated Ecosystem Assessment in support of EBFM. Although this review is directed at efforts in the NEFSC, the findings will be more broadly applicable throughout the agency. The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**. The tentative agenda of the panel review meeting is attached in **Annex 3**.

Requirements for CIE Reviewers: Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein.

CIE reviewers shall have working knowledge and recent experience in the application of community-level and ecosystem models for EBFM. The CIE reviewers shall have expertise with a broad spectrum of complexity and mechanistic detail from static energy flow models to detailed simulation models, and familiarity with the ATLANTIS model is desirable. Our objective is to employ multi-model inference to assess options for EBFM. We are particularly interested in the question of tradeoffs between model complexity and predictive skill in meeting the needs for scientific advice in support of EBFM. Operating models lie at the heart of the development of Integrated Ecosystem

Assessments (IEAs). IEAs have been strongly advocated at the agency level as the principle vehicle for developing and evaluating scientific advice in support of EBFM. It is essential that a rigorous review of modeling activities be undertaken to meet this need.

CIE reviewers shall have experience in different approaches to modeling exploited marine ecosystems. The approaches currently employed in this region include mass balance energy flow models, aggregate-species production models with implicit consideration of species interactions, multispecies production models with explicit consideration of interspecific interactions, state-space multispecies models, multispecies delay-difference models, and the ATLANTIS modeling framework. Reviewers shall have direct experience in model development with EBFM application.

Each CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein.

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review during the panel review meeting scheduled in Woods Hole, Massachusetts during 29-31 March 2011.

Statement of Tasks: Each CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Upon completion of the CIE reviewer selection by the CIE Steering Committee, the CIE shall provide the CIE reviewer information (full name, title, affiliation, country, address, email) to the COTR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contact is responsible for providing the CIE reviewers with the background documents, reports, foreign national security clearance, and other information concerning pertinent meeting arrangements. The NMFS Project Contact is also responsible for providing the Chair a copy of the SoW in advance of the panel review meeting. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When CIE 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 CIE reviewers who are non-US citizens. For this reason, the CIE 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/sponsor.html>).

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE Lead Coordinator on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

The reviewers will be supplied with a review document describing ongoing modeling efforts at NEFSC in support of ecosystem-based fishery management:

Community and Ecosystem Models in Support of Ecosystem-Based Fishery Management for the Northeast U.S. Continental Shelf. Projected length 125-150 pp maximum

Panel Review Meeting: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. **Modifications to the SoW and ToRs can not be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COTR and CIE Lead Coordinator.** Each CIE reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the ToRs as specified herein. The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The NMFS Project Contact is responsible for ensuring that the Chair understands the contractual role of the CIE reviewers as specified herein. The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

The CIE peer reviewers will provide a critical evaluation of the community-level and ecosystem modeling conducted at NEFSC in support of EBFM. The adequacy of the overall modeling framework to meet the needs of EBFM in this region will be assessed and recommended changes to modeling strategies will be provided. The reviewers will contribute individual perspectives on the findings and recommendations for each ToRs. The panel Chair will be responsible for overall compilation of the report of the peer review and in the development of a summary statement of the adequacy of the modeling effort in relationship to the requirements for EBFM in this region.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Other Tasks – Contribution to Summary Report: Each CIE reviewer may assist the Chair of the panel review meeting with contributions to the Summary Report, based on the terms of reference of the review. Each CIE reviewer is not required to reach a

consensus, and should provide a brief summary of the reviewer’s views on the summary of findings and conclusions reached by the review panel in accordance with the ToRs.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

- 1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
- 2) Participate during the panel review meeting at the Northeast Fisheries Science Center in Woods Hole, Massachusetts during 29-31 March 2011.
- 3) At the Northeast Fisheries Science Center in Woods Hole, Massachusetts during 29-31 March 2011 as specified herein, conduct an independent peer review in accordance with the ToRs (**Annex 2**).
- 4) No later than 14² April 2011, each CIE reviewer shall submit an independent peer review report addressed to the “Center for Independent Experts,” and sent to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and to Dr. David Sampson, CIE Regional Coordinator, via email to david.sampson@oregonstate.edu. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

22 February 2011	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
15 March 2011	NMFS Project Contact sends the CIE Reviewers the pre-review documents
March 29-31 2011	Each reviewer participates and conducts an independent peer review during the panel review meeting
14 ³ April 2011	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
28 April 2011	CIE submits CIE independent peer review reports to the COTR
5 May 2011	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

² The date of the report submission to CFI was subsequently moved to April 25, 2011.

³ This date of delivery was moved to April 25, 2011.

Modifications to the Statement of Work: Requests to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on substitutions. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the CIE reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards:

- (1) each CIE report shall be completed with the format and content in accordance with **Annex 1**,
- (2) each CIE report shall address each ToR as specified in **Annex 2**,
- (3) the CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the CIE reports to the NMFS Project Contact and Center Director.

Support Personnel:

William Michaels, Contracting Officer's Technical Representative (COTR)
NMFS Office of Science and Technology
1315 East West Hwy, SSMC3, F/ST4, Silver Spring, MD 20910
William.Michaels@noaa.gov Phone: 301-713-2363 ext 136

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Key Personnel:

NMFS Project Contact:

Michael Fogarty
Northeast Fisheries Science Center, 166 Water St. Woods Hole, MA, 02543
mfogarty@mercury.wh.who.edu Phone: 508-495-2352

Annex 1: 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.

**Annex 2.1: Terms of Reference for the Peer Review provided in advance of Meeting
Review of Modeling Approaches in Support of Ecosystem-Based Fishery Management**

1. Evaluation, findings and recommendations of overall community-ecosystem level modeling strategy
2. Evaluation of strengths and weaknesses, and recommendations of analytic methodologies
3. Evaluation and recommendations of model assumptions, estimates, and uncertainty
4. Evaluation, findings, and recommendations of result interpretation and conclusions
5. Determine whether the the science reviewed is considered to be the best scientific information available.
6. Recommendations for further improvements
7. Brief description on panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations

Annex 2.2: Terms of Reference for the Peer Review provided at Meeting

Review of Modeling Approaches in Support of Ecosystem-Based Fishery Management

- A. Overall Review- Synthesis & Summary
 - a. Summarize evaluations, findings and recommendations of overall community-ecosystem level modeling strategy in practice for the NEUS LMR system
 - b. Determine whether the science reviewed is considered to be the best scientific information available.
 - c. Determine if the intended uses of overall community-ecosystem level modeling that have been identified as priorities for the NEUS LME are being executed in accordance with global best practices.
 - d. Provide recommendations for further improvements.
 - e. Provide brief description on panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations

- B. Energy Transfer Models (*Fogarty*)- *Production Potential Models*
 - i. Review and agree upon data requirements requisite for the model
 - ii. Evaluate adequacy of input data as applied for the NEUS application of this model
 - iii. Evaluate strengths and weaknesses of analytical methodologies
 - iv. Evaluate if model structure, parameterization, calibration/tuning, validation/verification, and intended uses are adequately documented
 - v. Evaluate strengths and weaknesses of assumptions, example estimations, and sources of uncertainties, especially with respect to known best practices in the field
 - vi. Review types/levels of use for model outputs, especially with respect to adequacy of modeling relative to major topical issues
 - vii. Recommendations

- C. Energy Transfer Models (*Link*)- *Network Models*
 - i. Review and agree upon data requirements requisite for the model
 - ii. Evaluate adequacy of input data as applied for the NEUS application of this model
 - iii. Evaluate strengths and weaknesses of analytical methodologies
 - iv. Evaluate if model structure, parameterization, calibration/tuning, validation/verification, and intended uses are adequately documented
 - v. Evaluate strengths and weaknesses of assumptions, example estimations, and sources of uncertainties, especially with respect to known best practices in the field
 - vi. Review types/levels of use for model outputs, especially with respect to adequacy of modeling relative to major topical issues
 - vii. Recommendations

- D. Aggregate Production Models (*Link/Fogarty*)
 - i. Review and agree upon data requirements requisite for the model
 - ii. Evaluate adequacy of input data as applied for the NEUS application of this model

- iii. Evaluate strengths and weaknesses of analytical methodologies
- iv. Evaluate if model structure, parameterization, calibration/tuning, validation/verification, and intended uses are adequately documented
- v. Evaluate strengths and weaknesses of assumptions, example estimations, and sources of uncertainties, especially with respect to known best practices in the field
- vi. Evaluate levels, methods and ramifications for aggregation and compare to single species summaries
- vii. Review types/levels of use for model outputs, especially with respect to adequacy of modeling relative to major topical issues
- viii. Recommendations

E. Multispecies Production Models (*Gamble/Fogarty*)

- i. Review and agree upon data requirements requisite for the model
- ii. Evaluate adequacy of input data as applied for the NEUS application of this model
- iii. Evaluate strengths and weaknesses of analytical methodologies
- iv. Evaluate if model structure, parameterization, calibration/tuning, validation/verification, and intended uses are adequately documented
- v. Evaluate strengths and weaknesses of assumptions, example estimations, and sources of uncertainties, especially with respect to known best practices in the field
- vi. Review types/levels of use for model outputs, especially with respect to adequacy of modeling relative to major topical issues
- vii. Recommendations

F. Full System Models (*Link/Gamble*)- *ATLANTIS*

- i. Review and agree upon data requirements requisite for the model
- ii. Evaluate adequacy of input data as applied for the NEUS application of this model
- iii. Evaluate strengths and weaknesses of analytical methodologies
- iv. Evaluate if model structure, parameterization, calibration/tuning, validation/verification, and intended uses are adequately documented
- v. Evaluate strengths and weaknesses of assumptions, example estimations, and sources of uncertainties, especially with respect to known best practices in the field
- vi. Evaluate levels, methods and ramifications for aggregation
- vii. Review types/levels of use for model outputs, especially with respect to adequacy of modeling relative to major topical issues
- viii. Recommendations

G. Other models (*Fogarty/Link*)

- i. Briefly review and comment upon other community and ecosystem models for the NEUS ecosystem. For each:
 - 1. Review simple summaries
 - 2. Evaluate examples of intended/extant uses
 - 3. Identify any gaps in model uses
- ii. Empirical multivariate time series

- iii. MRMs
 - 1. ESAMs
 - 2. Other MS models
- iv. Others
- v. Recommendations

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

The review panel consisted of,

- Professor Gunnar Stefansson from The University of Reykjavik, Reykjavik, Iceland,
- Dr Anthony D.M. Smith from CSIRO, Hobart, Australia, and
- Professor Villy Christensen from The University of British Columbia, Vancouver, Canada.

Further, Dr Mike Fogarty served as the main contact person for NEFSC-EAP. He, along with Dr Jason Link and Dr Robert Gamble made the presentations to the review panel.

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

1. Ingrid Biedson – Cornell
2. Tom Hoff – MAFMC
3. Wendy Gabriel – NEFSC
4. Kiersten Curti – NEFSC
5. Rich Bell – URI/NMFS
6. Anne Richards – NEFSC
7. Sean Lucey – NEFSC
8. Steve Sutton – NEFSC
9. Ron Schlitz – NEFSC
10. Burton Shank – NEFSC
11. Linda Deegan – MBL
12. Hui Liu – NEFSC
13. Rob Gamble – NEFSC
14. Tony Smith – CSIRO Australia
15. Villy Christensen - UBC
16. Gunnar Stefansson – University of Iceland
17. Frank Almeida – NEFSC
18. Jon Hare – NEFSC – Narragansett
19. Michael Jones – NEFSC
20. Kimberly Murray – NEFSC
21. David McElroy
22. Laurel Col – NEFSC
23. Deborah Hart – NEFSC

24. Mike Fogarty – NEFSC

25. Jason Link - NEFSC

The proceedings of the review are detailed in the Review Activities section of this report, starting on page 7.

There was no formal Chair of the review, and a summary report was neither requested nor produced. Because the program left only very little time for the review panel to meet *in camera*, and because a summary report wasn't requested, we have only a general sense of the team being in consensus of the broad lines of our evaluations, but we cannot comment on alternate views within the panel, given that our reports are produced independently.

Appendix 4: List of abbreviations

Atlantis Center	Modeling approach and software, originally developed at CSIRO NEFSC
CIE	Center for Independent Experts
CSIRO	The Commonwealth Scientific and Industrial Research Organisation, Australia
EAP	NEFSC's Ecosystem Assessment Program
EBFM	Ecosystem-based fisheries management
EBM	Ecosystem-based management
EMAX	Energy Modeling and Analysis eXercise
ESA	Endangered Species Act
ESAM	Extended Stock Assessment Models
EwE	Ecopath with Ecosim (modeling approach and software)
GFDL	NOAA Geophysical Fluid Dynamics Laboratory at Princeton University
ICNAF	International Commission for the Northwest Atlantic Fisheries, now replaced by NAFO
IEA	Integrated Ecosystem Assessment
LMR	Living Marine Resources
MRM	Minimum Realistic Models; not a pre-definable term
MSE	Management Strategy Evaluation (Also known as Management Procedures)
MSVPA-X	eXtended MultiSpecies Virtual Population Analysis
MSY	Maximum Sustainable Yield
NAFO	Northwest Atlantic Fisheries Organization
NEFSC	Northeast Fisheries Science Center of NOAA/NMFS
NEUS	Northeast U.S. Continental Shelf
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
ROMS	Regional Ocean Modeling System
ToR	Terms of Reference

**Modeling Approaches in Support of Ecosystem-Based Fishery
Management at the Northeast Fisheries Science Center,
Woods Hole MA**

External Independent Peer Review

by

Gunnar Stefansson

Prepared for the Center for Independent Experts

April 2011

Executive Summary

An independent peer review panel met with several participants at a workshop at the Northeast Fisheries Science Center (NEFSC) in Woods Hole, March 29-31 2011 where approaches to ecosystem modeling were presented. The models comprise several of the best currently available and the fundamental data used with these models are data collected by the NEFSC, also appropriate for this purpose.

Overall, the work conducted by the group is exceptional in breadth and in fact the number of approaches, developed or tested, is quite unusual. When developing models it is indeed important to consider several approaches as the group has done, not only to avoid bias and errors but also to see the data and ecosystem through different looking glasses to gain new insights. Having done this, however, it becomes important to put some limitations on how to move forward: The number of approaches to be used in the future needs to be restricted to fewer, more select models. These models need to be developed in greater depth than before.

Members of the NEFSC ecosystem modeling group are well connected to other parts of the NEFSC, to various stakeholders and to international colleagues. This is an important aspect of staying at the forefront of development to make the approaches scientifically sound, yet applicable to the tasks at hand, such as providing timely advice for an ecosystem approach to fisheries management or other issues regarding the ecosystem.

Given the complexity of the food web one would not *a priori* expect reasonable results from the simplest models, which might for example simply consider pairs of species. This is in stark contrast with Arcto-Boreal systems where one can commonly isolate and focus on interactions between only two species at a time. Instead more complex models are needed.

The immediate issue facing the ecosystem group at NEFSC is, however, not simply one of a choice of model or modeling environment. Rather, the immediate issue is to find or participate in a venue for deciding on what kind of management should or is likely to ensue as a result of the decisions to move towards ecosystem based management. That venue will inevitably include a dialogue with stakeholders. This dialogue will define how ecosystem based (fishery) management should proceed and that again will determine which models are needed, some of which are already in the ecosystem modeling toolbox at NEFSC.

There is clearly a need to increase the number of individuals directly involved in developing models, as the current number is too low to be able to both develop and use the highly complex models that will inevitably be needed.

Background

This review is based principally on information (material and presentations) made available at a meeting held at the Northeast Fisheries Science Center (NEFSC) in Woods Hole, March 29-31 2011. The material is listed in Appendix 1 and the formal statement of work is given in Appendix 2 (including terms of reference in App. 2.2 and tentative meeting agenda in App. 2.3). The meeting was conducted with presentations on the topics given in App. 2.3 along with considerable and useful discussions among the participants (App. 3) on most topics.

This reviewer has a background in fisheries management and advice based mainly on statistical stock assessment methods, both single- and multispecies models. The review necessarily reflects this background to some extent.

The formal project description for this review (from Appendix 2) is as follows: *The purpose of this review is to evaluate the appropriateness and performance characteristics of community-level and ecosystem models employed at NEFSC as operating models in support of the development of Ecosystem-Based Fishery Management (EBFM) strategies for the Northeast U.S. Continental Shelf. NMFS strongly endorsed the concept of Ecosystem-Based Management and the related need for the development of Integrated Ecosystem Assessment in support of EBFM. Although this review is directed at efforts in the NEFSC, the findings will be more broadly applicable throughout the agency.*

A paper, “the overview paper¹”, provides an overview of the entire ecosystem modeling enterprise at the NEFSC. As such it is the single most important reference for this review. Most presentations at the March meeting corresponded to expanding on a part of that document. A “white paper”, on ecosystem-based fishery management, has also been prepared by the New England Scientific and Statistical Committee (SSC)². These two documents give a clear description of the importance of taking ecosystem considerations into account in general, e.g. referring to national policy in a White House Executive Order as well as recommendations by the Commission on Ocean Policy.

¹ Link *et al.* (2011) – to be referred to as “the overview paper” throughout.

² See NEFMC SSC, 2010 in the list of documents.

Similar issues were raised by Dr. F. Almeida in his introduction to the workshop, in particular that although the single species assessments may be very good as such they do not generally take ecosystem considerations into account nor are they a natural part of an ecosystem approach to fishery management (EAFM).

Much of this review refers to the “fish-part” of the various models. Of course there are many ocean uses other than fishing and the ecosystem group is likely to become tasked with questions related to more general and conflicting uses of the marine ecosystem, i.e. questions relating to general ecosystem based management (EBM). This has happened in the past through a variety of questions put to the group but such requests can only increase in numbers as society steadily invents more novel ways of using the marine environment, whether for windmill farms, subsurface cables or other uses. In these cases there will be requests for advice, usually spatially oriented and usually across the entire ecosystem. When ecosystem models are under discussion, one must bear in mind not just fisheries but also these potential applications, some of which have extended far beyond traditional fishery science.

This move to requests for advice on ocean policy outside traditional single-species issues is global and the number and diversity of such requests will only increase. Responding to these requests requires a battery of models and analyses, of the types which have been addressed within the ecosystem group at the NEFSC as well as some which will require completely new approaches.

Model uses vary in general and multispecies or ecosystem models are no exception. One particular use of such a model may be to function as an operating model for testing EBFM **strategies**. These contrast with models for **tactics** that form a part of the typically annual assessment-to-advice cycle. The types of models available for consideration as operating models alone form quite a large class, ranging from holistic models which attempt to describe the entire system (i.e. starting from hydrography, energy transfer and/or microbial activity up to fisheries harvests, economic yield and/or employment rates as the case may be) to models which only take into account the population dynamics of a single species (possibly slightly modified to take the species’ role as predator or prey into account). At these two extremes are Atlantis and the extended (single species) stock assessment (ESAM). In between is a plethora of models that may consider only a few fish species in detail (typical of Gadget models³) or one may model a

³ For a background to models with Gadget, see Stefansson and Palsson (1998); Begley and Howell (2004); Begley (2004); Taylor et al. (2007) and Taylor (2011).

large number of fish species but only take a few important processes into account (typically predation mortality as with MSVPA)⁴.

An exercise in modeling may arise simply as a research proposal out of academic interest or it may arise as a response to requests from stakeholders. In the context of this review it is important to realize that the main purpose of the present ecosystem modeling undertakings at the NEFSC is to form a basis for advice to stakeholders⁵. Discussions during the meeting, issues raised within the overview paper and further discussions with the users/developers of the ecosystem models have made this clear and hence the terms “*appropriateness and performance characteristics*” in the above project description will be interpreted in that light.

One way to classify modeling approaches is by how rigorously they incorporate data. An exploratory tool may, in principle, be developed without any data. A simple mathematical model may thus shed some light on questions of general interest. Usually this does not meet the needs of any stakeholder, who want (quantitative) directions on how to proceed on a given topic. A next step is therefore to make sure that the model behaves at least roughly like the ecosystem (or part thereof) that it is intended to mimic, and this may be done by simple eyeballing to verify overall trends predicted by the model. Statistically speaking, however, one should set up formal criteria (e.g. likelihoods) that describe the data and how well the model can predict the available data. Most single species stock assessment models continue this process to the bitter end. However many multispecies/ecosystem models really only take a cursory glance at data but rely on hand-tuning parameters to obtain what the investigator interprets as a decent or “good-enough” description, “tuning” or fit to the data. This may be appropriate when describing in general how a marine protected area (MPA) may work or how sets of ecosystem indicators may reflect the state of the resources, i.e. to give informed advice on strategy.⁶ It is unlikely, however, that such broad-brush model fits

⁴ References to all models discussed in this report, except Gadget, can be found in Link et al., 2011.

⁵ See Link et al., 2011 and NEFMC SSC, 2010.

⁶ See Stefansson and Rosenberg (2005, 2006) for simple MPA models developed only with a cursory glance at reality and Fulton et al. (2005) for fairly generic tests of ecosystem indicators, in both cases using specific ecosystems only as guideposts.

will be adequate descriptions of any given system and it is therefore also unlikely that they will be found to be an appropriate basis for tactical decisions. In spite of their problems as tactical models, they may be very useful as operating models for testing harvest strategies, i.e. a model reflecting roughly the ecosystem in question will be a potential candidate as an operating model. Nonetheless, unless these models describe the data sets reasonably well they will always be subject to criticism and may not be accepted as e.g. a primary operating model.

These are of course only some of the reasons why multispecies models have not generally replaced single species models. Rather, single species models have been fitted *ad nauseam* to data⁷ and then augmented by incorporating simple ecosystem considerations.⁸ This pretty much ensures that the earlier single-species fit to the data is maintained while taking the (apparently) most important ecosystem considerations into account.

Needless to say, members of the NEFSC ecosystem group are fully aware of these issues and many of them were discussed during the meeting. They are (re-) stated here to provide background for several of the methods-specific comments that appear below.

⁷ Where we nonetheless need to acknowledge that such fits are often less adequate than desired, *cf* common retrospective patterns, trends in catchability etc.

⁸ In a general sense, whether technical interactions, effects of predation on predator growth or prey mortality, effect of temperature on the stock-recruit curve or on catchability, *etc.*

Summary of Findings

General

From presentations to the panel, it is clear that the ecosystem group sees its mandate in the light of stakeholder requirements, with notable reference to the US Commission on Ocean Policy, the National Ocean Policy, the NOAA Strategic Plan and the SSC white papers on ecosystem approaches to fisheries.⁹ It is not at all clear, however, how these official guidelines can be used to drive the research within the ecosystem group. The guidelines in many cases first need to be interpreted and implemented as management action. This is by its nature a chicken-and-egg problem: one can not implement an ecosystem approach to fisheries (EAF) without the science, which can not take direction without knowing where the EAF is going.

Given the number of tasks undertaken, the Ecosystem Assessment Program of the NEFSC (or “ecosystem group”, below) at Woods Hole contains only a small number of permanent “model-oriented” employees. In addition to these the group does have several support staff, with a particular emphasis on access to databases. In spite of the low numbers, the group has managed to convincingly evaluate a wide range of models, most for the purpose of providing EAF directions. Further, this development is done in the appropriate international context. Thus, publications go through the normal peer-review process, contact is maintained to international professional groups (one of the chairs of the ICES Multispecies Assessment Working Group is within the ecosystem group) and contact is maintained with stakeholders through participation in the appropriate Science and Statistical Committees (SSCs). The last connection is particularly important since it links the ecosystem group with stakeholders in a natural manner as seen below.

There is clearly a need to increase the number of individuals directly involved in developing models: The modeling subgroup simply needs to include more individuals with a background in modeling (i.e. to have simultaneous expertise in applied mathematics, statistics, computer programming and database access).

⁹ See references in the overview paper, Link et al. 2011.

Very many different models have been set up and tested by the ecosystem group. This is important up to a point, not only to verify results but also to capture different ecosystem aspect or processes not all captured within a single model or modeling framework. On the other hand one must at some stage focus on the way forward and select a reduced set of models satisfying a few specific criteria:

- They should describe the system “adequately” by being able to predict measurements, i.e. they should *relate to data*.
- They should relate to quantities or issues of interest to the stakeholders.

These criteria will be discussed in general terms first and some will then be followed up on within the model classes. Data fitting in particular is discussed in some detail below, since this is an important aspect of obtaining reliable model fits and outputs.

Management strategies and their evaluations were discussed repeatedly during and between presentations at the meeting. A particular issue is how ecosystem concerns can be built into management strategies, how they can then be evaluated and whether such strategies can be implemented. Examples are discussed below, with reference to issues regarding implementation.

The panel was presented with several models and analyses where species had been grouped into e.g. “species groups” or “taxonomic groups” or “guilds”. This is often very useful and important, whether for understanding total consumption by ecosystem components, energy transfer between groups or the potential for managing harvests from a group caught by a fleet. As always however, one must eventually evaluate whether the analyses should terminate (with scientific publications as appropriate) or be carried forward to become a part of the toolbox for answering stakeholder questions, whether in an EBM or EBFM context.

Relating to data

As noted above, some of the models developed by the group give outputs differing considerably from single species results, with specific examples given below. That is of course not an issue unless the output actually deviates considerably from what measurements imply (i.e. it is not an issue *per se* if models differ in things which can not be measured directly such as the natural mortality rate or absolute abundance in a given year), or can easily be questioned on general biological grounds. Whether these various issues are serious or not depends on the application. Importantly however, an

immediate problem with not being able to predict e.g. the overall shape or trend reflected in a survey time series reasonably well is the lack of credibility within stock assessment circles, which of course may affect credibility among a considerable portion of the stakeholders who will be familiar with survey results or single species stock assessments. Thus one may be faced with a credibility issue even if a model is only to be used as one of several operating models and even if the model is only being used for simple exploratory analyses. Such issues need to be thought of beforehand and tackled in some way.

In the setting of a management strategy evaluation one may alternatively simply want to specify different parameter sets which correspond to different biological assumptions in cases when these come under obvious debate. This is common practice anyway when developing operating models, as these have to cover a wide range of plausible assumptions (see also section on databases below).

No matter which way is taken forward with a given multispecies model, there is a need to make sure that it either explains data series reasonably well or that there is some other mechanism to make sure that the properties of the actual data series can be captured for the purpose of the task at hand.¹⁰ Whether the task is an important MSE or “simply” uncovering the effects of sharks it is always important to try to ensure that the output is not merely a result of discrepancies between the model and some important features of the data.

In cases when there are no formal measures of the goodness of fit to data available, but only outputs from different models without indications of which fit “best”, there is an obvious problem of comparing the models. The NEFSC ecosystem group has addressed this in part through a process of inter-model comparisons. This is needed in any case, when there is a multitude of models to choose from, regardless of the fitting methods. Having the models first formally verified by comparisons to actual data merely reduces the likelihood of some models performing inconsistently with the observations.

¹⁰ A single issue may be solved e.g. by adding appropriately correlated variation to a predicted recruitment series, outside the model (if that is the issue). Alternatively one may simply want to acknowledge the fact that e.g. an appropriate fitting method is needed and either modify the approach accordingly or abandon the model as the case may be.

While it is clear that formal fitting to data is difficult when nonlinear models have parameter sets which number in the hundreds or even thousands, it is more important than ever to make sure that approaches to determining these parameters is objective and can be repeated. Traditional methods for determining values for large sets of parameters range used to be *ad-hoc*, such as those originally used for making MSVPA consistent with stomach content data but many current ADMB models may include many more parameters than the earlier MSVPA models: The fact that the ADMB models can be fitted “properly” is a consequence of improved methods and improved computer performance.

One alternative approach includes transforming the data (using some model) in order to have an information source comparable with output from the model in question. This was e.g. done with MULTSPEC where stomach content data were first converted to consumption estimates and subsequently the model fitting mechanism compared the internal estimates of consumption to these values.¹¹

An extreme version of this approach, which pretty much ignores the original data, is to fit the parameters of one model to reflect the outputs from another.¹²

These methods basically correspond to fitting the model to a function of the data and in general this is not a recommended procedure since important properties of the data may be lost. In terms of fitting methods, this is similar to going back to the now-outdated methods of transforming proportions using a logistic transform and then fitting a straight line to the data. With the advent of the generalized linear model these transformations have largely been abandoned, the whole point of the GLM exercise being to adapt the model to fit to the original data, not *vice versa*.

Given the problems of fitting complex models to large data sets one may nevertheless be forced to resort to such less-than-optimal methods. At a minimum, the approach should be made objective and repeatable. Before resorting to such methods, however, it is important to at least consider alternative formal model-fitting approaches since they have advanced considerably in the past few decades. For example, Bayesian models are used to describe fMRI data, which make both fisheries data and models minute in comparison.

¹¹ See e.g. Tjelmeland and Bogstad (1989, 1998); Bogstad et al. (1992).

¹² Pope (1989) used this approach to obtain parameters in a (simple) multispecies production model based on output from a more complex model.

For multispecies fisheries models specifically methods have been developed to use formal model fitting to stomach content data instead of transforming to consumption and to use formal methods to verify consistency of the model fits.¹³ These particular methods were developed for simpler ecosystems and may not be plausible approaches to the intertwined NE US ecosystems but one should at least investigate whether current approaches to parameter estimation can be improved.

The problem of fitting overly complex models to data, using chronically inadequate computers, is a very old one. Recent methods typically use several phases of model fitting, estimating parameters one group at a time, possibly only using a portion of the data at each stage. At the extreme this corresponds to picking up some estimates from the literature (e.g. consumption estimates obtained from stomach content data and not modified further), but a more deliberate approach is usually preferred. This is pretty much the method used in age-old methods for age-disaggregating a length distribution¹⁴ and is routine in both ADMB and Gadget¹⁵ work.

In addition to data-driven methods to evaluate model quality, there is a need to compare in some manner widely different models (*inter*-model comparisons). This field has been developed considerably within climate models, in some cases using Bayesian approaches to compare an array of different models.¹⁶ One can not avoid noting, however, that if neither of two models fit data well then it is very hard to state why they differ. In general, if two models fit well to abundance series and are in accordance with

¹³ See e.g. Stefansson and Palsson (1998) for a Gadget-approach to modeling, Taylor (2003) and Taylor (2011) for model-fits to single/multi-species models and Stefansson (1998) for model diagnostics.

¹⁴ Users of the MIX program of MacDonald and Pitcher (1979) typically first estimated proportions, then mean lengths followed by standard deviations, repeating the process as needed.

¹⁵ Within the Gadget environment models are typically developed parameters estimated for each stock component separately, see e.g. Taylor (2011). Once an adequate model fit is obtained for each component these are combined and linked to more data (e.g. stomach content data). Even then parameters may be estimated in phases at each stage.

¹⁶ See e.g. Berliner and Kim (2008) for an example.

stomach content data and catches, then one does not expect a major discrepancy between them. Thus improved fitting to data should reduce the need for inter-model comparisons.

Relating to stakeholders

For a modeling exercise to have relevance in the context of an institute such as the NEFSC it must usually provide some input to discussions with stakeholders. If this is not the case then the models are usually considered an academic exercise and downgraded in importance accordingly. Given the limits on resources this approach is often appropriate (though sometimes short-sighted). The modeling exercise may be more than just a model of course, particularly in the context of a management strategy evaluation (MSE).

Some of the models presented to the panel can be considered candidates for use in a management strategy evaluation. The devil is in the detail, however, and it is nowhere nearly enough just to have decent underlying models. In particular, the MSE is largely irrelevant unless it is done in tight collaboration with stakeholders and uses a strategy which can be implemented. Put bluntly, an evaluation of irrelevant strategies is a largely irrelevant exercise, though it may be of some theoretical interest.

An important aspect of the ecosystem group is the participation of two group members in Science and Statistical Committees, that forum being appropriate to advise stakeholders on e.g. management strategies.

In the single-species framework management strategies usually aim to limit the fishing mortality for the species and use some biomass level as a target or lower bound. In an ecosystem context these individual values may not make much sense, usually because the single species BMSY values may add up to more than the ecosystem has seen before.¹⁷

¹⁷ See earlier work by the ICES Multispecies Assessment Working Group, which led to revised natural mortality vectors being used in many ICES single species assessments, or Walters *et al.* 2005 for a more recent reference.

Although it may seem imminently sensible to go ahead and suggest alternatives to the single species harvest control rules (HCR), this can really only be done within a forum that is set up by stakeholders with a mandate to evaluate and propose such rules.

For example, one might easily envisage a 2-tier system for demersal fish, where an overall ecosystem quota is first set, followed by allocating this to species. Experience in many countries indicates that this is really only feasible as a part of a dialogue with stakeholders. Otherwise it is highly likely that the evaluation of the new ecosystem harvest control rule becomes an academic exercise of little interest to decision makers. Thus the appropriate way forward is for a body such as a SSC, which already has the appropriate mandate of suggesting a new HCR, to set terms of reference and nominate a subgroup to formulate or evaluate revised ecosystem-based harvest control rules. Such terms of reference (or the process as a whole) will specify rules that have the potential to be implemented and are not just theoretical.

In light of the somewhat uncertain procedure it is not clear when additional input will be required from economists or social scientists. On the one hand for an “ecosystem MSY” it is clear that it makes little sense to simply add up tons of mussels, lobster, mackerel and cod without at least multiplying by the unit price. On the other hand simple economics (first-hand value) can fairly easily be added to an ordinary multispecies model. In terms of the EBFM a much more pressing need is to start the dialogue with stakeholders in order to define just what general kind of framework is needed.

Notes on databases

The ecosystem group appears to have good access to NEFSC databases and the expertise to extract data from these as required to feed the models. Naturally this is an essential part of any modeling exercise.

Some modeling environments (e.g. Atlantis) can be very data-hungry and it is a major task to set up the input files for such models. Some analyses may be based on data from satellites, trawl surveys, acoustic surveys, hydrographic measurements, biological samples from catches, surface sightings or price information. These data sets are on different time scales and variable spatial resolution implying that care must be taken at all stages of analysis.

It is common practice to set up input files manually for programs such as Atlantis. It follows that it is a major hassle to revisit the input data. For example converting input data from 1cm groups to 5cm groups may require many man-months of work in some

instances. In principle this should be attainable by merely changing the extraction command from the original database, but it rarely is.

The modeling group may want to consider generic alternatives by defining a single interface to all the databases. Such an interface is typically a new database but could be a collection of specific views into the present systems. Once the interface is defined the next step is not to extract data for a given model but to write extraction routines (whether in perl, python or php) to give input data for the modeling environment in a syntactically correct format. At the same time the extraction routines output the metadata which the modeling environment needs, be they spatial scales, information on length groupings etc. If this is done correctly then a lot of time can be saved later if different spatial, temporal or other scales are to be evaluated. If the new databases are generic (and not hard-linked into NEFSC databases) then the extraction routines can be made applicable to other areas as well.¹⁸

These databases may in principle be used to generate different data combinations to evaluate models using bootstrapping (or the jackknife). The issue involves setting up a resampling procedure which avoids the usual problems with the *intra*-haul correlation, but in a much more general sense since all the different data sources collected in a small spatial-temporal cell tend to be correlated. Although such methods have only been tested for a few cases, initial results are quite promising.¹⁹

Common issues of the general “ecosystem” type are the various gear conflicts. In many (most) cases these are at a finer resolution than that used in most models. Thus, although commonly posed by management, these questions usually fall outside the range which can be answered by the models. Rather than try to operate models on the

¹⁸ This approach was used in the EU-funded *dst*² project for setting up input files for Gadget, see <http://www.hafro.is/dst2/> or Taylor (2003); Kupca (2005, 2004a); Kupca and Sandbeck (2003). Given a standardized data base, the same extraction routines have been used to extract data for Gadget models for various areas in the North-East Atlantic including Icelandic waters, the Irish Sea, North Sea as well as the Bay of Biscay and Tyrrhenian Sea.

¹⁹ This kind of bootstrapping has been done for entire tagging experiments in Hannesson et al. (2008) but Kupca (2004b) developed a formal method for bootstrapping from a data base system and this was tested and used in Taylor et al. (2011) (or see <http://arXiv.org/abs/0807.3677>)

very fine scales required to describe gear interactions it is often more appropriate to base responses on catch data (logbooks) or survey information, possibly using geographical information systems (but see below).

A note on geographical information systems

It has become customary to use a geographical information system (GIS) to layer different pieces of information and even to obtain plots of species distributions. Unfortunately there is no guarantee that these systems will use appropriate (statistical) methods to provide such plots and the methods may not even be documented. It is usually more appropriate to obtain such plots using a mapping sub-package within a statistical package – the plots themselves can then be outputs of a GAM, GLM or combinations of multiple such models.²⁰

²⁰ Typical examples can be seen in Stefansson (1996) or Stefansson and Palsson (1997) but alternative zero-inflated distributions are also common.

Findings specific to Terms of Reference (ToR)

1. Evaluation, findings and recommendations of overall modeling strategy

A. *Summarize evaluations, findings and recommendations of overall community-ecosystem level modeling strategy in practice for the NEUS LME system*

Only a few bullet points will be given here, with more detail given on each topic below.

- The overall strategy has led to understanding of many important issues in the ecosystem under investigation.
- Data analyses and models clearly demonstrate the skills of the members of the ecosystem group.
- Spatial areas have been defined in order to have “relevant” areas e.g. for geographic management. General ecosystem questions are most likely to have a spatial component. “Space” is therefore a particular component and models incorporating this should be given a particular emphasis.
- The modeling strategy has tested many different approaches. At this time it is appropriate to reduce the total number of models and approaches, moving focus to fewer models and trying to emphasize those most likely to be beneficial to answering stakeholder queries, yet not completely omitting those analyses likely to further enhance understanding of this complex ecosystem.

B. *Determine whether the science reviewed is considered to be the best scientific information available.*

As documented in several places in this report, the individuals are seen to be active in the local and global scientific community and publish their results in internationally peer-reviewed journals – as is expected from a group at the forefront of model development and applications. The models and analyses used and developed are certainly at the forefront worldwide. As always, these models can be enhanced and suggestions on how to move the models towards stakeholder interest, increased reliability and increased credibility are given below.

C. *Determine if the intended uses of overall community-ecosystem level modeling that have been identified as priorities for the NEUS LME are being executed in accordance with global best practices.*

The New England Scientific and Statistical Committee (SSC) has produced a white paper on ecosystem-based fishery management. This white paper is the outcome of work initiated with a 2009 workshop “with over 60 participants providing a cross section of Council members, scientists, managers, invited experts, NGOs and fishing industry involved in EBFM.”²¹ This type of dialogue forms an integral part of the decision making process which ultimately ends up in an implementation of the EBFM. This SSC will need to be involved in taking this work one step further, namely to map out the actual types of harvest control rules or management strategies which are implementable and in accordance with the guidelines in the white paper. In many international fora this is not done by groups of scientists but by special groups that have a mandate to suggest strategies. The panel has been informed that the SSC has such a mandate and is therefore ideally suited to suggest e.g. that a body such as (or with ties to) the ecosystem group evaluate different types of management strategies with an EBFM focus.

²¹ See the white paper, NEFMC SSC. 2010

Several of the models developed by the ecosystem group have the potential to become a part of such work.

The models considered and presented to the panel have been developed, set up, tested and verified using fairly standard methods, much along the lines recommended as “best practice” international standards.²² Overall, the breadth of models that have been used is overwhelming. Details on each model type, along with recommendations, are given below.

The way each type of model applies to EBM or EBFM varies considerably. Some are seen to be highly applicable to e.g. becoming an operating procedure but this does not apply to all of them.

D. *Provide recommendations for further improvements.*

See recommendations at the end of this document (p. 30).

2. Evaluation of strengths and weaknesses, and recommendations for specific methodologies

A. *Energy Transfer Models (Fogarty)- Production Potential Models*

Results from production potential and network models were demonstrated to the panel. In the case of production potential models uncertainty estimates were also demonstrated. These types of models are of considerable interest for a number of reasons, one of which is to have some idea about the total potential production from the system and another being how that is likely to change in response to predicted global warming. Apart from such one-off questions, these models are however, unlikely to answer many questions of interest to stakeholders.

Interestingly, several results were given where an overall fishing mortality multiplier was applied to the entire collection of fisheries to demonstrate how yields did not reduce much by decreasing fishing mortality from an overall FMSY, but the proportion of collapsed stocks declined considerably.

Suggestions have been put forward that these methods may be used as a part of

²² But note that the FAO-defined “best practice” does involve formal fitting to data: “Fitting to data is best practice, and this requires careful specification of likelihoods “, *cf* p. 59 of FAO Technical Guidelines for Responsible Fisheries, ISSN 1020-5292, Suppl. 2, Add. 1 at <http://www.fao.org/docrep/011/i0151e/i0151e00.htm>.

management. For example one might design a 2-tier approach to setting quotas where some sort of overall quota is initially set at the ecosystem level, subsequently followed by a disaggregation to the species level. The exact implementation can be envisioned in a variety of ways – the overall ecosystem level could be based on an overall fishing mortality rate or could be based on the current or new production relative to some baseline or total production (the “f-ratio”).

Several concepts have emerged from these investigations, many useful but some require more work. For example it is not clear how stable the numbers in the f-ratio are but this is crucial if such a number is to be used.

The idea of estimating total production potential using energy transfers, one way or another, is certainly a process which is useful in principle and is something that has to be done at least once for a given system. It is not as clear whether such work can or should form a basis for fisheries management in the long or short term, other than as a reference.

Investigations using an overall fishing mortality have been done as part of other work, some under this heading of production potential. This topic needs to be given considerably more attention.

One could of course simply investigate the effect of using a single fishing mortality across species. In practice this would at best apply within a complex such as groundfish, since it is quite far-fetched that one would ever want to use the same fishing mortality for a pelagic species and a groundfish species. Since the species will have age- (or length-) dependent selection patterns, the fishing mortality is not strictly constant across components of the ecosystem anyway.

A more appropriate method would therefore be to use an underlying fishing mortality vector and scale this by some number k . The scaling factor k then replaces the constant fishing mortality in the analyses. The underlying vector of fishing mortalities needs to be “sensibly” chosen. One approach is to set it to the FMSY values for each species separately.²³ When modeling without interactions the FMSY values will most naturally be chosen as the single-species FMSY values. However in the present, multispecies setting, the most natural approach would be to first find the vector of fishing mortalities that maximizes the total yield (possibly economic yield), i.e. the FMSY vector in the multispecies sense. This vector forms a natural

²³ This is done by Walters et al. 2005.

vector for scaling the results.

The problem with any of these methods is that it may not be feasible for the fleets to target the species in this manner, i.e. the ratios of fishing mortalities induced by the fleets may be such that the vector of overall FMSY levels can not be attained. Likely examples of this scenario include cases where a vulnerable species is a bycatch with a less vulnerable species (e.g. Atlantic halibut with plaice or most skates with most demersal (teleost) fish).

It follows that to make these kinds of analyses credible one must first evaluate the vector of fishing mortalities per species as actually induced by the combined fleets. Scaling this vector (e.g. to unit length) provides a standard vector of (relative) fishing mortalities, which has been achieved in the real world. The annual variation in these vectors provides a measure of what kind of deviations can be reasonably implemented. The ecosystem is harvested by many fleets so the partial fishing mortalities inflicted by each fleet form components which can in principle be combined in any manner by placing limits on individual fleets. If the ecosystem FMSY vector is within such ranges of plausible values (done separately for the different components such as demersal vs pelagic) then it can be used as mentioned above.

Otherwise the exercise would appear merely academic since it can probably not be implemented.

It follows that to make these kinds of analyses credible one must first evaluate the vector of fishing mortalities per species as actually induced by the combined fleets. Scaling this vector (e.g. to unit length) provides a standard vector of (relative) fishing mortalities, which has been achieved in the real world. The annual variation in these vectors provides a measure of what kind of deviations can be reasonably implemented. The ecosystem is harvested by many fleets so the partial fishing mortalities inflicted by each fleet form components which can in principle be combined in any manner by placing limits on individual fleets. If the ecosystem FMSY vector is within such ranges of plausible values (done separately for the different components such as demersal vs pelagic) then it can be used as mentioned above. Otherwise the exercise would appear merely academic since it can probably not be implemented.

Finally, and most importantly, although the idea of managing with respect to overall ecosystem measures is very appealing, it can only be done as a part of a dialogue with stakeholders. Basically, the concepts need to be introduced at meetings that

have the mandate to decide or recommend harvest control rules and feedback from such meetings needs to be used to further develop the concepts.

B. Energy Transfer Models (Link)- Network Models

Most of the comments on the Energy Transfer Models in (A) above also apply here but are not repeated.

The network models have been used for understanding at several levels. One such is to obtain estimates of transfer efficiencies between trophic levels. The intention is to use these in other models.

Considerable attention has been given to “tune” the different models, thus e.g. obtaining fairly consistent results in Ecopath and Econetwrk.

This reviewer is not an expert in Ecopath, Ecosim, Ecospace or Econetwrk, but one particular general comment is in order: The single species stock assessment methods (whether extended to account for some ecosystem concerns or not) have been extensively developed to take uncertainty into account. Model diagnostics are routinely used to evaluate whether the models appropriately fit to the data sets (and often these tests fail even in the final assessments). Basically, the development over the past 3 decades has been away from *ad-hoc* fitting methods to formal nonlinear statistical models in most cases. It is hard to envisage that these models will be scrapped in favor of other models that do not have these statistical underpinnings – even if the new ones are more likely to capture important ecosystem concerns. It is not lost on this reviewer that it is easier said than done to enforce objective statistical methods on the very high dimensional multispecies models under consideration. It is merely hard to see *ad-hoc* data fitting methods or outputs with no uncertainty estimates replacing current (extended single species) methods – and as mentioned above, it is FAO-defined best practice to fit formally to data.

On the same note, the use of species groups, whether called guilds or taxonomic groups, is useful for understanding many concepts but it is not quite clear how these can be translated into management. Possible exceptions may be cases such as a demersal fishery in a given area. If a considerable portion of the catch taken by that fleet consists of species that form a “guild” then one might see a way forward in providing “ecosystem advice” for that species group in that particular area, for example by overall effort control for that particular fleet.

C. Aggregate Production Models (Link/Fogarty)

A class of aggregate production models was presented where, instead of fitting to a population, fitting was done to a group of species. Although this is in many ways different from fitting production models based on individual species, there are enough commonalities that this is discussed with the multispecies production models below (D).

D. Multispecies Production Models (Gamble/Fogarty)

The MS-PROD model, as presented, is a “multispecies extension of the Schaefer model”. The various production models (items C and D) have interesting aspects and potential use in several ways. They are, however, bulk biomass models, which implies certain limitations on their usefulness in terms of advice to stakeholders.

As a start it should be noted that, just as the single species Schaefer model is a very useful tool, so can the multispecies versions be useful. In particular a well-designed quadratic model like this is very useful to quickly investigate the effects of harvest control rules and to get a first idea about likely directions when the certain components change.

One concern is reflected in the description of how parameters were set: “r’s were **informed** by using $2 \times F_{MSY}$ as a starting point, and modified as necessary” and similarly for Ks, competition interaction strengths, spatial overlap etc. What this means, basically, is that no formal method was used to estimate any parameters in these models. Further, the multispecies production models contain parameters describing “competition” as well as “availability” of prey to predator. *A priori* one would expect these parameters to be confounded and it is not at all clear whether their use can be justified from a model-fitting point of view (*i.e.* whether in fact using all of these parameters merely adds noise).

Further, these models have no explicit spatial components, arguably the most important component of models to be used for ecosystem based assessments or modeling.

There have been many uses of multispecies bulk models, some theoretical and some with applications. At least one of these appears to have been fitted in an objective manner by fitting to output from an age-disaggregated multispecies

prediction model (MSFOR, for the North Sea).²⁴

In addition to these issues, which arise from this debatable parameterization and method of assigning values to parameters, other issues arise when considering some of the simulations undertaken. For example, it is not clear to this reviewer that it can be completely logical to (1) taking the single-species F_{MSY} as an (even initial) basis to give r or (2) setting interaction terms to zero without re-“fitting” the remaining parameters. In general, one would expect the same effects here as in multiple regression where parameters need to be modified as others are dropped from or inserted into the model. For example if the initial parameters were indeed obtained from a formal (nonlinear regression) fit to a (very large) data set, then one would always re-estimate the parameters after inserting any assumption on certain interactions being zero etc.

These models are not spatially disaggregated so they are not likely to be amenable to EBM. Further, at present they probably do not provide a description of the fish part of the system adequate to make them credible to stock assessors or stakeholders so it is not clear whether they can be used directly for EBFM. It is therefore recommended that they be downgraded in terms of modeling emphasis and relegated to become a less-used part of the toolbox, e.g. only for occasional studies such as the effects of serious overfishing a certain species group, and then only with comparisons to other models.

In spite of this, there are several examples of aggregate biomass production models that have found their way into being a part of a management strategy evaluation. Such cases typically involve systems where age readings are hard to come by and one would normally not think of a biomass production model as being optimal for a data-rich scenario such as the area off the New England coast.

E. Full System Models (Link/Gamble)- ATLANTIS

The Atlantis model, in the form set up by the group, has considerable potential since this modeling environment can encompass almost any aspect of the ecosystem handled by any other ecosystem model. Naturally, this does not come without problems. In particular Atlantis does not incorporate any statistical estimation

²⁴ See Pope (1989), but note that this ignores the stock-recruitment curve and also here there are issues with the method of fitting, although it appears to be a formal (objective) fitting mechanism.

method but is adjusted to reflect more-or-less the overall behavior of the ecosystem in question. This is quite adequate for obtaining an overall view of a system and for answering a variety of what-if questions. If Atlantis is to be used as an operating model various error terms need to be added to the output and this can in principle be done externally. Atlantis has in fact been used for evaluating a range of very different management methods where these approaches have been developed and described.²⁵

The implementation of Atlantis presented to the panel is a promising first attempt at an Atlantis model for the region. The model is general enough in principle to answer a wide range of EBM-based questions.²⁶

On the other hand it must also be noted that there are some problems with the Atlantis approach and these will be serious in certain scenarios. The primary issue (from this reviewer's point of view) is the complete lack of a method to objectively estimate parameters, evaluate goodness of fit, compare different models quantitatively or obtain uncertainty estimates for parameters. The problem stems from the run times, i.e. it is infeasible to attach numerical estimation routines to a computer program as unwieldy as Atlantis.

This computer program does not automatically provide sums of squares or other measures of goodness-of-fit (and in particular survey indices etc are not even input into Atlantis). It would certainly be possible to automate some of the „tuning“ process, e.g. by selecting a set of important parameters and important time series and computing sums of squared deviations outside Atlantis, followed by a battery of runs to obtain a better fit. Given the run times however, this would need to be run on a computer cluster, even for only a handful of parameters – and the entire set of parameters will probably not be estimated in this manner in a single human lifetime. In spite of these problems, if a model of this order of complexity is to be completed to any level of confidence (even just to be used as a primary operating model) then some such fitting process needs to be invoked. Given the excessive run times, that can only reasonably be done by running different Atlantis parameterizations simultaneously on a large computer cluster and evaluate fits to some of the more

²⁵ See e.g. Fulton et al. (2005) for a complex example.

²⁶ For the narrower EBFM questions, MSVPA would go a long way as might Gadget but the choice is not at all clear.

important parameters. However, if using Atlantis is to be taken to the logical conclusion with the associated costs in man-hours, then purchasing or getting access to a 50 or 500-core computer cluster may not be the biggest worry.

As explained in the background section, however, these issues do not preclude Atlantis from being a very useful tool in the toolbox. In particular one can see Atlantis as one of the tools for answering fairly general spatial questions. Similarly, Atlantis can in principle be an operating model for evaluation of management strategies (or one of many such models).

Thus, even without any fitting procedure, Atlantis is clearly a candidate for an operating model for management strategy evaluations and for simple what-if analyses. Further, since this model is designed to include more detail than any other, it can be used as a basis to generate data for pretty much any other model under consideration and thus explore consistency between other estimation methods.

One typical problem regarding “realism” or “credibility” is that recruitment bursts are generally not picked up (certainly not in the implementation presented to the panel) since annual recruitment deviations from e.g. an underlying Ricker curve are not estimated. Deviations from a stock-recruit curve would need to be implemented in some manner if e.g. the typical variation in haddock recruitment is to be captured. In principle this could be kick-started by using as input the observed time series of recruitment from single species assessments (with the obvious caveats related to trying to maintain consistent natural mortality assumptions and thus scaling of stock size between the single species and multispecies versions). Since observed (apparent) autocorrelation in recruitment deviations are not uncommon these stocks can easily have “red noise” which is not captured (*cf.* the gadoid outburst).

This contrasts a minimally realistic model (MRM) where one would typically select a handful of important factors (whether species or processes) and make sure that these are modeled so that they appropriately reflect the underlying data sources. This is not just the case for extended single species models but also the suggested method with some multispecies models.²⁷

In the case of using Atlantis as an operating model one would presumably (more naturally) split the process of obtaining a credible result into the two parts of (1) obtaining a “reasonable” overall description and (2) generating data with properties

²⁷ See for example the 2-area, 2-species Gadget example in Taylor 2011.

similar to those measured.

Atlantis appears to be the most promising generally applicable model with the suite of models tested by the group, for general EBM applications and EBFM in particular (though alternatives exist).²⁸

This begs the question of what is needed to conduct serious modeling work using an environment such as Atlantis. The same applies to MSVPA, Gadget or similar modeling environments. In order to maintain any of these environments it is important to have a user, which has one of them as a primary responsibility. If there is only one individual then that user needs to be able to take on all tasks from extracting data through modifying the computer code and implementing appropriate statistical estimation methods. Quite commonly this implies more than one individual. It is important that the person who is mainly involved in model runs also has these as a primary responsibility, i.e. does not get swamped in other activities. Experience based on Gadget work seems to imply that one needs to continually have 2-3 staff members working mainly tasks related to that single model. One of these persons needs to be a “user” who actually applies the model to the ecosystem in question.

F. *Other models (Fogarty/Link)*

A variety of “other” models and analysis were presented to the group. All of these are useful, but usually only in a rather limited way. For example, an analysis indicating that (many components of) the ecosystem may behave in a “nonlinear” manner (so as not to be predictable) raises many more questions than it answers. Within a single species framework this kind of effect (almost only) arises if the right-hand limb of the stock-recruit curve is too steep and this is almost never seen from data. If this kind of effect is estimated to be common across a system, then there must be other causes and the questions raised range from doubt (“is the methodology biased in some manner?”) to queries on what can give rise to these effects (species interactions, migrations, fisher behavior or combinations thereof). If the analysis does not answer these questions then it is probably best relegated to

²⁸ In terms of EBFM alone one could presumably use Gadget to get the same results but with somewhat more objective data fitting, more piecemeal modeling and possibly a less daunting overall modeling exercise. Gadget does come with its own set of problems and this is not intended to indicate that Gadget should be adopted.

the status of a scientific curiosity, to be analyzed as such with a low priority. Methods designed to either directly answer stakeholder concerns or provide explanations of ecosystem behavior should take precedence.

Extensions of single species models have been developed in the “usual” way, taking natural mortality from MSVPA into single species assessments, including environmental effects into various processes etc. In other regions many such analyses are conducted by an ecosystem group, others as a part of a stock assessment process or management strategy evaluation.²⁹ These extensions will not go away: Even with improved ecosystem models there will still be a need to investigate simpler single species models, which may better capture the essential dynamics of the species in questions – yet taking into account the main interactions through simple methods.

The various analyses (single-species or otherwise) have clearly implied that there are many important “ecosystem effects”.³⁰ Many of these will need to be taken into account when management strategy evaluations are undertaken. At a minimum one will need to consider how not including these will affect outputs.

Conclusions

The group has demonstrated a capability to set up state-of-the art models, test them and implement them – for a very wide range of models. The primary need at this stage is to reduce the number of models and go from the “breadth” to “depth”, i.e. to select only a few models (which should be clearly applicable to providing advice relevant to stakeholders), but develop these in sufficient detail to provide more confidence in each one.

As an example of why this is important one can mention an application presented at the workshop. This particular application demonstrated the effect of reducing dogfish in the system, implemented both in Atlantis and MS-PROD. The inter-model

²⁹ Such as the ICES Multispecies Assessment Working Group on the one hand and species-oriented working groups on the other, whether in the North Sea, Barents Sea or off Iceland.

³⁰ In the general sense of technical interactions, effects of predation on predator growth or prey mortality, effect of temperature on the stock-recruit curve or on catchability.

comparison in this case demonstrated that some of the more important effects were estimated to be comparable in the two models, thus giving confidence in the results. The flip side of this is that without the comparison one could not have had confidence in either result: While it is true that it is generally important to compare model output across models, it is also true that such comparisons are essential when one lacks trust in either model! In the simplest case of linear regression with data clearly on the line there is no need to doubt a prediction made within the observed range of x values. The present situation is at the other extreme, when one is extrapolating outside the range of the data using models, which do not fit or explain the data well.

The need for inter-model comparisons should be considerably reduced when more effort is put into making each model better match the observations.

Most of the above has placed an emphasis on the fisheries part of the ecosystem but it seems reasonable to assume that general EBM-related questions will come forth at an increasing pace in the future, even more so than EBFM-related questions. Most of the EBFM issues will almost certainly need to take spatial issues into account and it is not at all unlikely in the future that these will involve issues such as considering overall effort targeted at a system or overall harvests. In principle many of these can be handled using management strategy evaluations using models such as Atlantis as an operating model (but noting the incredible attention which need to be given to detail). The EBM issues are wider-ranging, will likely also mainly be of a spatial nature and it is not clear that any single toolbox will be generally useful for answering such questions. Familiarity with all available databases and capabilities in data analysis will be very important, however: Log-books, satellite information and other data sources of widely variable nature have and will need to be analyzed to answer these questions. Thus the primary capability needed may not be as much ecosystem modeling as database extractions and statistical analyses.

Several of the ideas presented in different documents relating to changes in fishery management, i.e. moving from species-directed management towards area-based management, need to be considered in detail. Given that there is a current management scheme it is not clear, however, just how such changes can be implemented. At the very least they will need to be developed within appropriate fora, i.e. in dialogue with stakeholders. Even the ideas for such changes need to originate in dialogue since otherwise one is unlikely to select appropriate models to cover the various aspects that will crop up in subsequent debates.

Recommendations

- Regarding fisheries, as a matter of priority, a dialogue should be set up (probably through the two SSCs) to advance discussions with (fisheries) stakeholders on how ecosystem issues can best be taken into account (in accordance with the various mandates relating to EBFM) with the intent of bringing discussions to the stage where revised and implementable management procedures can be formalized for evaluation purposes.
- The dialogues will define more clearly the types of toolboxes needed but at present it would seem that spatially disaggregated models are the most likely candidates. The focus of these discussions needs to be on what general forms of revised management strategies are feasible in terms of implementation and in accordance with how management needs to be moving towards the EBFM.
- Regarding other uses of ocean resources (EBM) it may not be possible to develop toolboxes to answer generic stakeholder questions. Development of skills in database extractions, spatial analyses and statistical modeling will always be important however and this should be continued.
- Among the models that have been developed and tested by the group, Atlantis appears to have the greatest potential as an operating model for management strategy evaluations in an ecosystem context. Other candidates are not obvious for this task (but see the text).
- The number of models in use and development should now be reduced and depth rather than breadth should be the priority.
- More modelers with simultaneous expertise in statistics and computer modeling should be added to the group.
- A general move should be made to always attempt to incorporate data in models in a statistical (and objective) manner (only).
- Non-spatial (aggregated) biomass production models, time-series analyses and other models which are not seen to be clearly linked to spatial issues or stakeholder questions should be downgraded in terms of modeling emphasis and relegated to become a less-used part of the toolbox.
- Methods and models designed to either directly answer stakeholder concerns or provide actual explanations of ecosystem behavior should take precedence.

Finally, as a critique of process, this reviewer would like to note that this particular review consists of reviewing more modeling approaches than is usually done during a review process. Future reviews need to concentrate on “smaller” questions such as choosing an operating model OR evaluating the implementation and value of energy transfer models OR evaluating the Atlantis approach as implemented at the NEFSC OR how one can suggest harvest control rules in the multispecies setting. Any one of these would be more than enough for one review.

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Appendix 2: CIE Statement of Work for Gunnar Stefansson

External Independent Peer Review by the Center for Independent Experts

Review of Modeling Approaches in Support of Ecosystem-Based Fishery Management

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description: The purpose of this review is to evaluate the appropriateness and performance characteristics of community-level and ecosystem models employed at NEFSC as operating models in support of the development of Ecosystem-Based Fishery Management (EBFM) strategies for the Northeast U.S. Continental Shelf. NMFS strongly endorsed the concept of Ecosystem-Based Management and the related need for the development of Integrated Ecosystem Assessment in support of EBFM. Although this review is directed at efforts in the NEFSC, the findings will be more broadly applicable throughout the agency. The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**. The tentative agenda of the panel review meeting is attached in **Annex 3**.

Requirements for CIE Reviewers: Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein.

CIE reviewers shall have working knowledge and recent experience in the application of community-level and ecosystem models for EBFM. The CIE reviewers shall have expertise with a broad spectrum of complexity and mechanistic detail from static energy flow models to detailed simulation models, and familiarity with the ATLANTIS model is desirable. Our objective is to employ multi-model inference to assess options for EBFM. We are particularly interested in the question of tradeoffs between model complexity and predictive skill in meeting the needs for scientific advice in support of EBFM. Operating models lie at the heart of the development of Integrated Ecosystem Assessments (IEAs). IEAs have been strongly advocated at the agency level as the principle vehicle for developing and evaluating scientific advice in support of EBFM. It is essential that a rigorous review of modeling activities be undertaken to meet this need.

CIE reviewers shall have experience in different approaches to modeling exploited marine ecosystems. The approaches currently employed in this region include mass balance energy flow models, aggregate-species production models with implicit consideration of species interactions, multispecies production models with explicit consideration of interspecific interactions, state-space multispecies models, multispecies delay-difference models, and the ATLANTIS modeling framework. Reviewers shall have direct experience in model development with EBFM application.

Each CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein.

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review during the panel review meeting scheduled in Woods Hole, Massachusetts during 29-31 March 2011.

Statement of Tasks: Each CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Upon completion of the CIE reviewer selection by the CIE Steering Committee, the CIE shall provide the CIE reviewer information (full name, title, affiliation, country, address, email) to the COTR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contact is responsible for providing the CIE reviewers with the background documents, reports, foreign national security clearance, and other information concerning pertinent meeting arrangements. The NMFS Project Contact is also responsible for providing the Chair a copy of the SoW in advance of the panel review meeting. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When CIE 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 CIE reviewers who are non-US citizens. For this reason, the CIE 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/sponsor.html>).

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE Lead Coordinator on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

The reviewers will be supplied with a review document describing ongoing modeling efforts at NEFSC in support of ecosystem-based fishery management:

Community and Ecosystem Models in Support of Ecosystem-Based Fishery Management for the Northeast U.S. Continental Shelf. Projected length 125-150 pp maximum

Panel Review Meeting: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. **Modifications to the SoW and ToRs can not be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COTR and CIE Lead Coordinator.** Each CIE reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the ToRs as specified herein. The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The NMFS Project Contact is responsible for ensuring that the Chair understands the contractual role of the CIE reviewers as specified herein. The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

The CIE peer reviewers will provide a critical evaluation of the community-level and ecosystem modeling conducted at NEFSC in support of EBFM. The adequacy of the overall modeling framework to meet the needs of EBFM in this region will be assessed and recommended changes to modeling strategies will be provided. The reviewers will contribute individual perspectives on the findings and recommendations for each ToRs. The panel Chair will be responsible for overall compilation of the report of the peer review and in the development of a summary statement of the adequacy of the modeling effort in relationship to the requirements for EBFM in this region.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Other Tasks – Contribution to Summary Report: Each CIE reviewer may assist the Chair of the panel review meeting with contributions to the Summary Report, based on the terms of reference of the review. Each CIE reviewer is not required to reach a consensus, and should provide a brief summary of the reviewer’s views on the summary of findings and conclusions reached by the review panel in accordance with the ToRs.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

- 1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
- 2) Participate during the panel review meeting at the Northeast Fisheries Science Center in Woods Hole, Massachusetts during 29-31 March 2011.
- 3) At the Northeast Fisheries Science Center in Woods Hole, Massachusetts during 29-31 March 2011 as specified herein, conduct an independent peer review in accordance with the ToRs (**Annex 2**).
- 4) No later than 14 April 2011, each CIE reviewer shall submit an independent peer review report addressed to the “Center for Independent Experts,” and sent to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and to Dr. David Sampson, CIE Regional Coordinator, via email to david.sampson@oregonstate.edu. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

22 February 2011	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
15 March 2011	NMFS Project Contact sends the CIE Reviewers the pre-review documents
March 29-31 2011	Each reviewer participates and conducts an independent peer review during the panel review meeting
14 April 2011	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
28 April 2011	CIE submits CIE independent peer review reports to the COTR
5 May 2011	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: Requests to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on substitutions. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the CIE reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards:

- (1) each CIE report shall be completed with the format and content in accordance with **Annex 1**,
- (2) each CIE report shall address each ToR as specified in **Annex 2**,
- (3) the CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the CIE reports to the NMFS Project Contact and Center Director.

Support Personnel:

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Appendix 2.1: 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

Appendix 2.2: Terms of Reference for the Peer Review – as presented to the Review Panel in advance

Review of Modeling Approaches in Support of Ecosystem-Based Fishery Management

1. Evaluation, findings and recommendations of overall community-ecosystem level modeling strategy
2. Evaluation of strengths and weaknesses, and recommendations of analytic methodologies
3. Evaluation and recommendations of model assumptions, estimates, and uncertainty
4. Evaluation, findings, and recommendations of result interpretation and conclusions
5. Determine whether the science reviewed is considered to be the best scientific information available.
6. Recommendations for further improvements
7. Brief description on panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations

Appendix 2.3: Terms of Reference for the Peer Review – as presented at the Meeting

Review of Modeling Approaches in Support of Ecosystem-Based Fishery Management

- A. Overall Review- Synthesis & Summary
 - a. Summarize evaluations, findings and recommendations of overall community-ecosystem level modeling strategy in practice for the NEUS LMR system
 - b. Determine whether the science reviewed is considered to be the best scientific information available.
 - c. Determine if the intended uses of overall community-ecosystem level modeling that have been identified as priorities for the NEUS LME are being executed in accordance with global best practices.
 - d. Provide recommendations for further improvements.
 - e. Provide brief description on panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations

- B. Energy Transfer Models (*Fogarty*)- *Production Potential Models*
 - i. Review and agree upon data requirements requisite for the model
 - ii. Evaluate adequacy of input data as applied for the NEUS application of this model
 - iii. Evaluate strengths and weaknesses of analytical methodologies
 - iv. Evaluate if model structure, parameterization, calibration/tuning, validation/verification, and intended uses are adequately documented
 - v. Evaluate strengths and weaknesses of assumptions, example estimations, and sources of uncertainties, especially with respect to known best practices in the field
 - vi. Review types/levels of use for model outputs, especially with respect to adequacy of modeling relative to major topical issues
 - vii. Recommendations

- C. Energy Transfer Models (*Link*)- *Network Models*
 - i. Review and agree upon data requirements requisite for the model
 - ii. Evaluate adequacy of input data as applied for the NEUS application of this model
 - iii. Evaluate strengths and weaknesses of analytical methodologies
 - iv. Evaluate if model structure, parameterization, calibration/tuning, validation/verification, and intended uses are adequately documented
 - v. Evaluate strengths and weaknesses of assumptions, example estimations, and sources of uncertainties, especially with respect to known best practices in the field

- vi. Review types/levels of use for model outputs, especially with respect to adequacy of modeling relative to major topical issues
- vii. Recommendations

D. Aggregate Production Models (*Link/Fogarty*)

- i. Review and agree upon data requirements requisite for the model
- ii. Evaluate adequacy of input data as applied for the NEUS application of this model
- iii. Evaluate strengths and weaknesses of analytical methodologies
- iv. Evaluate if model structure, parameterization, calibration/tuning, validation/verification, and intended uses are adequately documented
- v. Evaluate strengths and weaknesses of assumptions, example estimations, and sources of uncertainties, especially with respect to known best practices in the field
- vi. Evaluate levels, methods and ramifications for aggregation and compare to single species summaries
- vii. Review types/levels of use for model outputs, especially with respect to adequacy of modeling relative to major topical issues
- viii. Recommendations

E. Multispecies Production Models (*Gamble/Fogarty*)

- i. Review and agree upon data requirements requisite for the model
- ii. Evaluate adequacy of input data as applied for the NEUS application of this model
- iii. Evaluate strengths and weaknesses of analytical methodologies
- iv. Evaluate if model structure, parameterization, calibration/tuning, validation/verification, and intended uses are adequately documented
- v. Evaluate strengths and weaknesses of assumptions, example estimations, and sources of uncertainties, especially with respect to known best practices in the field
- vi. Review types/levels of use for model outputs, especially with respect to adequacy of modeling relative to major topical issues
- vii. Recommendations

F. Full System Models (*Link/Gamble*)- *ATLANTIS*

- i. Review and agree upon data requirements requisite for the model
- ii. Evaluate adequacy of input data as applied for the NEUS application of this model
- iii. Evaluate strengths and weaknesses of analytical methodologies
- iv. Evaluate if model structure, parameterization, calibration/tuning, validation/verification, and intended uses are adequately documented

- v. Evaluate strengths and weaknesses of assumptions, example estimations, and sources of uncertainties, especially with respect to known best practices in the field
- vi. Evaluate levels, methods and ramifications for aggregation
- vii. Review types/levels of use for model outputs, especially with respect to adequacy of modeling relative to major topical issues
- viii. Recommendations

G. Other models (*Fogarty/Link*)

- i. Briefly review and comment upon other community and ecosystem models for the NEUS ecosystem. For each:
 - 1. Review simple summaries
 - 2. Evaluate examples of intended/extant uses
 - 3. Identify any gaps in model uses
- ii. Empirical multivariate time series
- iii. MRMs
 - 1. ESAMs
 - 2. Other MS models
- iv. Others
- v. Recommendations

**Appendix 2.3: Tentative Agenda – as presented to the Review Panel in advance
Review of Modeling Approaches in Support of Ecosystem-Based Fishery Management
Northeast Fisheries Science Center, Woods Hole MA 02543
March 29-31 2011**

March 29 2011

- 900 Welcome to Workshop and Overview of Objectives for the Review
- 930 Review of Overview Modeling Strategy and Philosophy for Multi-Model Inference
- 1030 Break
- 1100 Review of Data Sources in Support of Community-Ecosystem Modeling
- 1230 Lunch
- 1400 Review of Data Sources Continued
- 1530 Break
- 1600 Review of Community/Ecosystem Model Applications
- 1730 Adjourn

March 30 2011

- 0900 Review of Community/Ecosystem Model Applications Continued
- 1030 Break
- 1100 Review of Community-Ecosystem Modeling Applications Continued
- 1230 Lunch
- 1400 Review of Community-Ecosystem Modeling Applications Continued
- 1530 Break
- 1600 Discussion
- 1730 Adjourn

March 31 2011

- 0900 Discussion/Questions Continued
- 1030 Break
- 1100 Panel Deliberations
- 1230 Lunch
- 1400 Panel Deliberations Continued
- 1730 Adjourn

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

Panel members: Dr A. Smith, Dr G. Stefansson and Dr V. Christensen

Meeting participants in the Review of Modeling Approaches in Support of EBFM, 3/29 - 3/31/2011

1. Ingrid Biedson – Cornell
2. Tom Hoff – MAFMC
3. Wendy Gabriel – NEFSC
4. Kiersten Curti – NEFSC
5. Rich Bell – URI/NMFS
6. Anne Richards – NEFSC
7. Sean Lucey – NEFSC
8. Steve Sutton – NEFSC
9. Ron Schlitz – NEFSC
10. Burton Shank – NEFSC
11. Linda Deegan – MBL
12. Hui Liu – NEFSC
13. Rob Gamble – NEFSC
14. Tony Smith – CSIRO Australia
15. Villy Christensen - UBC
16. Gunnar Stefansson – University of Iceland
17. Frank Almeida – NEFSC
18. Jon Hare – NEFSC – Narragansett
19. Michael Jones – NEFSC
20. Kimberly Murray – NEFSC
21. David McElroy
22. Laurel Col – NEFSC
23. Devorah Hart – NEFSC
24. Mike Fogarty – NEFSC
25. Jason Link - NEFSC