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

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.

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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.

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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 agree[1] 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 CO_2 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 Cooperate 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 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 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.

References

DFO (2008) National Workshop on Modelling Tools for Ecosystem Approaches to Management; 22-25 October 2007. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2008/007.

FAO (2008) Fisheries management. 2. The ecosystem approach to fisheries. 2.1 Best practices in ecosystem modelling for informing an ecosystem approach to fisheries., FAO Fisheries Technical Guidelines for Responsible Fisheries. No. 4, Suppl. 2, Add. 1. Rome, FAO. 2008. 78p.

Fogarty, M. & O'Boyle, R. (2011) New ecosystem approach: space vs. species. *Commercial Fisheries News, February 2011. Volume 38 Number 6.*

Fogarty, M. J., Overholtz, W. J. & Link, J. (2008) Fishery production potential of the northeast continental shelf of the United States. GARM WP 3.5 GARM-III-BRP Meeting.

Guénette, S., Heymans, J. J., Christensen, V. & Trites, A. W. (2006) Ecosystem models show combined effects of fishing, predation, competition, and ocean productivity on Steller sea lions (*Eumetopias jubatus*) in Alaska. *Canadian Journal of Fisheries and Aquatic Sciences,* 63**,** 2495-2517.

Link, J., Col, L., Guida, V., Dow, D., O'reilly, J., Green, J., Overholtz, W., Palka, D., Legault, C. & Vitaliano, J. (2009) Response of balanced network models to large-scale perturbation: Implications for evaluating the role of small pelagics in the Gulf of Maine. *Ecological Modelling,* 220**,** 351-369.

Link, J. S. (2004) A general model of selectivity for fish feeding: A rank proportion algorithm. *Transactions of the American Fisheries Society,* 133**,** 655-673.

Link, J. S., Gamble, R. J. & Fogarty, M. J. (2011) An overview of the NEFSC's ecosystem modeling enterprise for the Northeast US shelf Large Marine Ecosystem: toward ecosystem-based management. MS for NEFSC Ecosystem Modeling Review, March 2011.

Link, J. S., Ihde, T. F., Townsend, H., Osgood, K., Schirripa, M., Kobayashi, D., Gaichas, S., Field, J., Levin, P., Aydin, K., Watters, G. & Harvey, C. (Eds.) (2010) *Report of the 2nd National Ecosystem Modeling Workshop (NEMoW II): Bridging The Credibility Gap – Dealing With Uncertainty In Ecosystem Models*, NOAA Tech. Memo. NMFS-F/SPO-102, 72p.

Overholtz, W. & Link, J. (2009) A simulation model to explore the response of the Gulf of Maine food web to large-scale environmental and ecological changes. *Ecological Modelling,* 220**,** 2491-2502.

Plagányi, É. E., Rademeyer, R. A., Butterworth, D. S., Cunningham, C. L. & Johnston, S. J. (2007) Making management procedures operational, innovations implemented in South Africa. *ICES Journal of Marine Science: Journal du Conseil,* 64**,** 626.

Rademeyer, R. A., Plagányi, É. E. & Butterworth, D. S. (2007) Tips and tricks in designing management procedures. *ICES Journal of Marine Science: Journal du Conseil,* 64**,** 618.

Sainsbury, K. J., Punt, A. E. & Smith, A. D. M. (2000) Design of operational management strategies for achieving fishery ecosystem objectives. *Ices Journal of Marine Science,* 57**,** 731-741.

The White House (2010) Stewardship of the oceans, our coasts, and the great lakes. Executive Order of July 19, 2010. http://www.whitehouse.gov/administration/eop/oceans/policy.

Townsend, H. M., Link, J. S., Osgood, K. E., Gedamke, T., Watters, G. M., Polovina, J. J., Levin, P. S., Cyr, N. & Aydin, K. Y. (Eds.) (2008) *Report of the NEMoW (National Ecosystem Modeling Workshop)*, NOAA Technical Memorandum NMFS-F/SPO-87. pp. 93.

Walters, C. (1986) *Adaptive management of renewable resources,* New York [Reprint edition available from Blackburn Press, 2001], McMillan.

Walters, C. J., Christensen, V., Martell, S. J. & Kitchell, J. F. (2005) Possible ecosystem impacts of applying MSY policies from single-species assessment. *ICES Journal of Marine Science,* 62**,** 558-568.

Appendix 1: Bibliography of materials provided for review

NEFSC Ecosystem Modeling Review
Background Readings

Modeling Overviews

1. Link, J.S., Bundy, A., Overholtz, W.J., Shackell, N., Manderson, J., Duplisea, D., x, J., Koen-Alonso, M. & Friedland, K. 2011. Northwest Atlantic Ecosystem Based Management of Fisheries. *in* Belgranno, A. and Fowler, C.W. (eds.) Ecosystem Based Management for Fisheries: Linking Patterns to Policy. pp. 32-112.
2. ICES. 2010. Report of the Working Group on Multispecies Assessment Methods (WGSAM), 4–8 October 2010, San Sebastian, Spain. ICES CM 2010/SSGSUE:05. 95 pp
3. Link, J.S., T.F. Ihde, H. Townsend, K. Osgood, M. Schirripa, D. Kobayashi, S. Gaichas, J. Field, P. Levin, K. Aydin, G. Watters, and C. Harvey (editors). 2010. Report of the 2nd National Ecosystem Modeling Workshop (NEMoW II): Bridging The Credibility Gap – Dealing With Uncertainty In Ecosystem Models. NOAA Tech. Memo. NMFS-F/SPO-102, 72p.
4. ICES. 2009. Report of the Working Group on Multispecies Assessment Methods (WGSAM), 5–9 October 2009, ICES Headquarters, Copenhagen. ICES CM 2009/RMC:10. 117 pp.
5. ICES. 2008. Report of the Working Group on Multispecies Assessment Methods (WGSAM), 6–10 October 2008, ICES Headquarters, Copenhagen. ICES CM 2008/RMC:06. 113 pp.
6. Townsend, H. M., J. S. Link, K. E. Osgood, T. Gedamke, G. M. Watters, J. J. Polovina, P. S. Levin, N. Cyr, and K. Y. Aydin (editors). 2008. Report of the NEMoW (National Ecosystem Modeling Workshop). NOAA Technical Memorandum NMFS-F/SPO-87. pp. 93.
7. ICES. 2007. Report of the Working Group on Multispecies Assessment Methods (WGSAM), 15–19 October 2007, San Sebastian, Spain. ICES CM 2007/RMC:08. 134 pp.
8. Whipple, S., Link, J.S. , L.P. Garrison & Fogarty, M.J. 2000. Models of predation and fishing mortality in aquatic ecosystems. *Fish. and Fisheries*. 1:22-40.
9. Hollowed, A.B., Bax, N., Beamish, R., Collie, J., Fogarty, M., Livingston, P., Pope, J. & Rice, J.C. 2000. Are multispecies models an improvement on single-species models for measuring fishing impacts on marine ecosystems? ICES Journal of Marine Science, 57:707-719.
10. Link, J.S. and Bundy, A. (In Press). Ecosystem Modeling in the Gulf of Maine Region: Towards an Ecosystem Approach to Fisheries. *AFS Gulf of Maine Symposium Proceedings*
11. Link, J.S., A. Bundy, W.J. Overholtz, N. Shackell, J. Manderson, D. Duplisea, J. Hare, M. Koen-Alonso, K.D. Friedland. (In Press). Northwest Atlantic Ecosystem-Based Fisheries Management. *Fish and Fisheries*

ESAMs & Influence on BRPs (MRMs 1)

12. Tyrrell, M.C., Link, J.S. & Moustahfid, H. 2011. The importance of including predation in some fish population models: implications for biological reference points. *Fisheries Research* 108-1-8.

13. NEFSC. 2011. 51st Northeast Regional Stock Assessment Workshop (51st SAW) Assessment Report. Northeast Fisheries Science Center Reference Document 11-02; 856 p.
14. NEFSC. 2011. 51st Northeast Regional Stock Assessment Workshop (51st SAW): Assessment Summary Report. Northeast Fisheries Science Center Reference Document 11-01, part A, B, C.
15. Debroba, J., G. Shepherd, F. Grégoire, J. Nieland, and J. Link. 2010. Stock Assessment of Atlantic Mackerel in the Northwest Atlantic - 2009. TRAC Reference Document - 2010/01. 59pp.
16. DFO. 2010. Proceedings of the Transboundary Resources Assessment Committee (TRAC) Spiny Dogfish Review. Proceedings 2010/01. 57 pp.
17. NEFSC. 2010. 50th Northeast Regional Stock Assessment Workshop (50th SAW) Assessment Report. Northeast Fisheries Science Center Reference Document 10-17, part A, C.
18. NEFSC. 2010. 49th Northeast Regional Stock Assessment Workshop (49th SAW) Assessment Report. Northeast Fisheries Science Center Reference Document 10-03. Appendix B1.
19. Link, J.S. & J.S. Idoine. 2009. Predator Consumption Estimates of the northern shrimp *Pandalus borealis*, with Implications for Estimates of Population Biomass in the Gulf of Maine. *N. Amer. J. Fish. Manag.* 29:1567-1583.
20. Moustahfid, H., Tyrrell, M.C. & Link, J.S. 2009. Accounting explicitly for predation mortality in surplus production models: an application to longfin inshore squid. *N. Amer. J. Fish. Manag.* 29:1555-1566.
21. Moustahfid, H., Link, J.S., Overholtz, W.J. & Tyrell, M.C. 2009. The advantage of explicitly incorporating predation mortality into age-structured stock assessment models: an application for Northwest Atlantic mackerel. *ICES J. Mar. Sci.* 66: 445-454.
22. Fogarty, M. L. Incze, K. Hayhoe, D.Mountain and J. Manning. 2008. Potential Climate Change Impacts on Atlantic Cod (Gadus morhua) off the Northeastern United States. Mitig. Adapt. Strat. Glob.Change. 13:453-466.
23. Overholtz, W.J., Jacobson, L.D. & Link, J.S. 2008. Developing an ecosystem approach for assessment advice and biological reference points for the Gulf of Maine-Georges Bank herring complex: adding the impact of predation mortality. *N. Amer. J. Fish. Manag.* 28:247-257.
24. Link, J.S. & Sosebee, K. 2008. Estimates and implications of Skate Consumption in the northeastern US continental shelf ecosystem. *N. Amer. J. Fish. Manag.* 28:649-662.
25. NEFSC. 2007. Assessment Report (45th SARC/SAW). Section A.10. [TOR 6]. Northeast Fisheries Science Center Reference Document, 07-16. pp 13-138.
26. NEFSC. 2007. Assessment Report (44th SARC/SAW). Section B.8. [TOR 6]. Northeast Fisheries Science Center Reference Document, 07-10. pp 332-344, 504-547.
27. Tyrrell, M.C., Link J.S., Moustahfid, H. & Smith, B.E. 2007. The dynamic role of pollock (Pollachius virens) as a predator in the Northeast US Atlantic ecosystem: a multi-decadal perspective. *J. Northwest Atl. Fish. Sci.* 38:53-65.
28. Overholtz, W.J. & Link, J.S. 2007. Consumption impacts by marine mammals, fish, and seabirds on the Gulf of Maine-Georges Bank Atlantic Herring (*Clupea harengus*) complex during 1977-2002. *ICES J. Mar. Sci.* 64:83-96.
29. Overholtz, W.J., Link, J.S. & Suslowicz, L.E. 1999. Consumption and harvest of pelagic fishes in the Gulf of Maine-Georges Bank ecosystem: Implications for fishery management. Proceedings of the 16th Lowell Wakefield Fisheries Symposium- Ecosystem Considerations in Fisheries Management. AK-SG-99-01: 163-186.

Multispecies Models (MRMs 2)

30. Link, J.S., B.A. Megrey, T.J. Miller, T. Essington, J. Boldt, A. Bundy, E. Moksness, K.F. Drinkwater & R. I. Perry. 2010. Comparative Analysis of Marine Ecosystems: International Production Modelling Workshop. *Biol. Lett.* doi: 10.1098/rsbl.2010.0526
31. Garrison, L.P., Link, J.S., Cieri, M., Kilduff, P., Sharov, A., Vaughan, D., Muffley, B., Mahmoudi, B., & Latour, R. 2010. An Expansion of the MSVPA Approach for Quantifying Predator-Prey Interactions In Exploited Fish Communities. *ICES J. Mar. Sci.* 67: 856-870.
32. Gamble, R.J. & Link, J.S. 2009. Analyzing the Tradeoffs Among Ecological and Fishing Effects on an Example Fish Community: a Multispecies (Fisheries) Production Model. *Ecol. Model.* 220:2570-2582.
33. Tyrrell, M.C., Link, J.S., Moustahfid, H. & Overholtz, W.J. 2008. Evaluating the effect of predation mortality on forage species population dynamics in the Northwest Atlantic continental shelf ecosystem: an application using multispecies virtual population analysis. *ICES J. Mar. Sci.* 65:1689-1700.
34. Hall, S.J., Collie, J.S., Duplisea, D.E., Jennings, S., Bravington, M. & Link, J. 2006. A length-based multi-species model for evaluating community responses to fishing. *Can. J. Fish. Aquat. Sci.* 63:1344-1359.
35. NEFSC 2006. 42nd Northeast Regional Stock Assessment Workshop (42nd SAW). Northeast Fisheries Science Center Reference Document, 06-09b, 308 pp.
36. Garrison, L. and Link, J. 2004. An Expanded Multispecies Virtual Population Analysis Approach (MSVPAX) to Evaluate Predator-Prey Interactions in Exploited Fish Ecosystems. VERSION 1.1. Users Manual and Model Description. Atlantic States Marine Fisheries Commission, Washington, D.C.
37. White, G.C., Kline, L.L., Garrison, L.P. & Link, J.S. 2003. Expansion of multispecies modeling assessment approach for management of coastal fisheries for Atlantic menhaden, bluefish, striped bass and weakfish. Annual Report to the NOAA Chesapeake Bay Office.

Food Web & Network Models

38. Link, J.S. 2010. Adding Rigor to Ecological Network Models by Evaluating a Set of Pre-balance Diagnostics: A Plea for PREBAL. *Ecol. Model.* 221:1582-1593.
39. Byron, C., D. Bengtson, J. Link, B. Costa-Pierce, R. Rheault, D. Beutel. and D. Alves. 2010. Modeling Carrying Capacity for Bivalve Aquaculture Using Mass-Balance Modeling and Stakeholder Collaboration. ICES CM 2010/J:03, 31p.
40. Overholtz, W.J. & Link, J.S. 2009. A simulation model to explore the response of the Gulf of Maine food web to large scale environmental and ecological changes. *Ecol. Model.*220:2491-2502.
41. Gaichas, S., Skaret, G., Falk-Petersen, J., Link, J.S., Overholtz, W., Megrey, B.A., Gjoesaeter, H., Stockhausen, W., Dommasnes, A. & Aydin, K. 2009. A comparison of community and trophic structure in five marine ecosystems based on energy budgets and system metrics. *Prog. Oceanogr.* 81:47-62.
42. Link, J.S., Col, L., Guida, V., Dow, D., O'Reilly, J., Green, J., Overholtz, W., Palka, D., Legault, C., Vitaliano, J., Griswold, C., Fogarty, M. & Friedland, K. 2009. Response of Balanced Network Models to Large-Scale Perturbation: Implications for Evaluating the Role of Small Pelagics in the Gulf of Maine. *Ecol. Model.* 220: 351-369.
43. Link, J., Overholtz, W., O'Reilly, J., Green, J., Dow, D., Palka, D., Legault, C., Vitaliano, J., Guida, V., Fogarty, M., Brodziak, J., Methratta, E., Stockhausen, W., Col, L., Waring, G., & Griswold, C. 2008. An Overview of EMAX: The Northeast U.S. Continental Shelf Ecological Network. *J. Mar Sys.* 74:453-474.

44. Link, J.S., O'Reilly, J., Dow, D., Fogarty, M., Vitaliano, J., Legault, C., Overholtz, W., Green, J., Palka, D., Guida, V. & Brodziak, J. 2008. Energy Flow on Georges Bank revisited: the energy modeling and analysis eXercise (EMAX) in historical context. *J. Northwest Atl. Fish*. *Sci.* 39:83-101.
45. Steele, J.H., Collie, J.S., Bisagni, J.J., Gifford, D.J., Fogarty, M.J., Link, J.S., Sullivan, B.K., Sieracki, M.K., Beet, A.R., Mountain, D.G., Durbin, E.G., Palka, D. & Stockhausen, W.T. 2007. Balancing end-to-end budgets of the Georges Bank ecosystem. *Prog. Oceanogr*. 74:423-448.
46. Link, J.S., Griswold, C.A. Methratta, E.M. & Gunnard, J. (eds). 2006. Documentation for the Energy Modeling and Analysis eXercise (EMAX). Northeast Fisheries Science Center Reference Document, 06-15. 166 pp.
47. Steele, J., Bisagni, J., Collie, J., Fogarty, M., Gifford , M., Link, J., Sieracki, M., Sullivan, B., & Beet, A. 2005. Constructing end-to-end budgets for the Georges Bank ecosystem. ICES CM 2005/M08 16 pp.
48. Link, J., W. Overholtz, J. O'Reilly, J. Green, E. Methratta, D. Dow, D. Palka, C. Legault, S. Edwards, G. Waring, W. Stockhausen, D. Mountain, J. Vitaliano, V. Guida, J. Kane, J. Jossi, M. Fogarty, J. Brodziak, C. Griswold, C. McCandless, N. Kohler, S. Fromm, L. Col, T. Smith, C. MacKenzie, and R. Goldberg. 2005. An Overview of EMAX: The Northeast U.S. Continental Shelf Ecological Network. ICES CM 2005/L02 40 pp.
49. Link, J.S., Stockhausen, W.T. & Methratta, E.T. 2005. Food web theory in marine ecosystems. pp. 98-113 *in* Belgrano, A., Scharler U.M., Dunne, J. & Ulanowicz, R.E. (eds.) Aquatic Food Webs: an Ecosystem Approach. Oxford Univ. Press, Oxford.
50. Link, J.S. 2004. A general model of selectivity for fish feeding: a rank proportion algorithm. *Trans. Amer. Fish. Soc.* 133:655-673.
51. Link, J.S. 2002. Does food web theory work for marine ecosystems? *Mar. Ecol. Prog. Ser.* 230:1-9.
52. Link, J. 1999. (Re)Constructing Food Webs and Managing Fisheries. Proceedings of the 16th Lowell Wakefield Fisheries Symposium- Ecosystem Considerations in Fisheries Management. AK-SG-99-01: 571-588.
53. Link, J. & Keen, R. 1999. A model of salmonid planktivory: Field test of a mechanistic approach to size-selection. *Ecol. Model.* 117:269-283.
54. Byron, C., J. Link, D. Bengston, B. Costa-Pierce. (in press). Modeling Carrying Capacity of Shellfish Aquaculture in Highly Flushed Temperate Lagoons. *Aquaculture.*
55. Byron, C., J. Link, D. Bengston, B. Costa-Pierce. (in press). Calculating Carrying Capacity of Shellfish Aquaculture Using Mass-Balance Modeling: Narragansett Bay, Rhode Island. *Ecol. Model.*

Aggregate (Production) Models

56. NEFSC 2008. Assessment of 19 Northeast Groundfish Stocks through 2007 Report of the 3rd Groundfish Assessment Review Meeting (GARM III), Northeast Fisheries Science Center, Woods Hole, Massachusetts, August 4-8, 2008. Section 2.1. Northeast Fisheries Science Center Reference Document, 08-15. pp. 855-865.
57. Overholtz, W.J., J.S. Link, M.J. Fogarty, L. Col, and C. Legault. 2008. US Northeast Shelf LME Biomass, target biological reference points for fish and worldwide cross-system comparisons. GARM WP 3.1 GARM-III-BRP Meeting
58. Link, J.S., W.J. Overholtz, C. Legault, L. Col, M.J. Fogarty. 2008. Energy budget contextualization of fish biomasses at B_MSY. GARM WP 3.2 GARM-III-BRP Meeting
59. Overholtz, W.J., M.F. Fogarty, J.S. Link, C. Legault, and L. Col. 2008. Estimates of aggregate surplus production for the GARM and other stock groups for the US Northeast Shelf LME. GARM

WP 3.3 GARM-III-BRP Meeting
60. Link, J.S., R. Gamble, W.J. Overholtz, C. Legault, L. Col, and M.J. Fogarty. 2008. An Aggregate and MS Production Model: A Simulator Tool GARM WP 3.4 GARM-III-BRP Meeting
61. Fogarty, M.J., W.J. Overholtz, and J. Link. 2008. Fishery Production Potential of the Northeast Continental Shelf of the United States. GARM WP 3.5 GARM-III-BRP Meeting
62. Overholtz, W.J., J.S. Link, M. Fogarty, L. Col, and C. Legault. 2008. Target Biological Reference Points, Worldwide Cross System Comparisons, and Aggregate Production Model Results for GARM Stocks. GARM WP 2.1 GARM-III-Final Meeting
63. Link, J.S. 2003. A Model of Aggregate Biomass Tradeoffs. ICES Annual Science Conference. Theme Session on Reference Point Approaches to Management within the Precautionary Approach. ICES CM 2003/Y08 28 pp.
64. Overholtz, W.J., M.J. Fogarty and J.S. Link. (In review). Using aggregate surplus production models to assess the overall production potential of the demersal fish resources of the Northeast U.S. Shelf Large Marine Ecosystem.

Full System Models

65. Link, J.S., E.A. Fulton, and R.J. Gamble. 2010. The Northeast US Application of ATLANTIS: A full system model exploring marine ecosystem dynamics in a living marine resource management context. *Progress in Oceanography.* 87:214-234.
66. Fulton, E.A., J.S. Link, I. Kaplan., M. Savina-Rolland, P. Johnson., C. Ainsworth, P. Horne, R. Gorton, R.J. Gamble, A.D.M. Smith, D.C. Smith. (In Press). Lessons in modelling and management of marine ecosystems: The Atlantis experience. *Fish and Fisheries*
67. Link, J.S., Gamble, R.J., and Fulton, E.A. (In press). NEUS – ATLANTIS: Construction, Calibration and Application of an Ecosystem Model with Ecological Interactions, Physiographic Conditions, and Fleet Behavior. NOAA Tech. Memo. NEFSC

Ecological Indicators & Ecosystem Overfishing

68. Patrick, W.S., P. Spencer, J. Link, O. Ormseth, J. Cope, J. Field, D. Kobayashi, T. Gedamke, E. Cortés, K. Bigelow, W. Overholtz, & P. Lawson. 2010. Assessing the vulnerability of U.S. fisheries to becoming overfished or undergoing overfishing through the use of productivity and susceptibility indices. *Fish. Bull.* 108:305-322.
69. Shin, Y.-J., L.J. Shannon, A. Bundy, M. Coll, J.L. Blanchard, M.-F. Borges, J. Cotter, P.M. Cury, J.J. Heymans, D. Jouffre, J.S. Link, C. Möllmann, H. Ojaveer, K.O.M. Abdallahi, M.-J. Rochet, & D. Yemane. 2010. Using indicators for evaluating, comparing and communicating the ecological status of exploited marine ecosystems. Part 2: Setting the scene. *ICES J. Mar. Sci.* 67: 692-716.
70. Shin, Y.-J., A. Bundy, L.J. Shannon, M. Simier, M. Coll, E.A. Fulton, J.S. Link, D. Jouffre, H. Ojaveer, S. Mackinson, J.J. Heymans, T. Raid. 2010. Can simple be useful and reliable? Using ecological indicators for representing and comparing the states of marine ecosystems. *ICES J. Mar. Sci.* 67: 717-731.
71. Blanchard, J.L., Coll, M., Cotter, J., Link, J., Trenkel, V., Vergnon, R., Yemane, D., & Shin, Y-J. 2010. Trend analysis of indicators: a comparison of recent changes in the status of marine ecosystems around the world. *ICES J. Mar. Sci.* 67: 732-744.

72. Link, J.S., Yemane, D., Shannon, L.J., Coll, M., Shin, Y-J., Hill, L., Borges, M.F., Bundy, A. & Aydin, K. 2010. Relating Marine Ecosystem Indicators to Fishing and Environmental Drivers: An Elucidation of Contrasting Responses. *ICES J. Mar. Sci.* 67: 787-795.
73. Coll, M., Shannon, L.J., Yemane, D., Link, J., Ojaveer, H., & Shin, Y-J. 2010. Ranking ecological relative status of exploited ecosystems using multiple indicators. *ICES J. Mar. Sci.* 67: 769-786.
74. Ecosystem Assessment Program. 2009. Ecosystem Status Report For the Northeast U.S. Continental Shelf Large Marine Ecosystem. Northeast Fisheries Science Center Reference Document, 09-11. 34 p.
75. Patrick, W.S., P. Spencer, O. Ormseth, J. Cope , J. Field, D. Kobayashi, T. Gedamke, E. Cortés, K. Bigelow, W. Overholtz, J. Link, and P. Lawson. 2009. Use of productivity and susceptibility indices to determine the vulnerability of a stock, with example applications to six U.S. fisheries. NOAA Tech. Memo. NMFS-F/SPO-101, 90p.
76. Pranovi, F. & Link, J.S. 2009. Ecosystem exploitation and trophodynamic indicators: a comparison between the Northern Adriatic Sea and Southern New England. *Prog. Oceanogr.* 81:149-164.
77. Methratta, E.T. & Link, J.S. 2006. Evaluation of Quantitative Indicators for Marine Fish Communities. *Ecol. Indicators* 6:575-588.
78. Link, J. S. 2006. Northeastern United States. Pp. 65 in Kruse, G.H., Livingston, P., Overland, J.E., Jamieson, G.S., McKinell, S. and Perry, R.I. (eds). Report of the PICES/NPRB Workshop on Integration of Ecological Indicators of the North Pacific with Emphasis on the Bering Sea. PICES Scientific Report No. 33.
79. Link, J.S. 2005. Translation of Ecosystem Indicators into Decision Criteria. *ICES J. Mar. Sci.* 62:569-576.
80. Link, J.S. & Brodziak, J.K.T. 2003. Discussion Group Report for Defining Ecosystem Overfishing. Proceedings of the 7th National Stock Assessment Workshop: (Re)Building Sustainable Fisheries and Marine Ecosystems. NOAA Tech. Memo. NMFS-F/SPO-62. pp. 29-32.
81. Link, J. & Brodziak, J. (eds.). 2002. Report on the Status of the NE US Continental Shelf Ecosystem. NEFSC Ecosystem Status Working Group. Northeast Fisheries Science Center Ref. Doc. 02-11, 245 pp.
82. Link, J.S., Brodziak, J.K.T., Edwards, S.F., Overholtz, W.J., Mountain, D., Jossi, J.W., Smith, T.D. & Fogarty, M.J. 2002. Marine Ecosystem Assessment in a Fisheries Management Context. Can. J. Fish. Aquat. Sci. 59:1429-1440.
83. Link, J.S., Brodziak, J.K.T., Edwards, S.F., Overholtz, W.J., Mountain, D., Jossi, J.W., Smith , T.D. & Fogarty, M.J. 2001. Ecosystem status in the Northeast United States Continental Shelf Ecosystem: Integration, synthesis, trends and meaning of ecosystem metrics. Or Getting to the brass tacks of ecosystem based fishery management. ICES Annual Science Conference. Theme Session on the Use and Information Content of Ecosystem Metrics and Reference Points. ICES CM 2001/T10 41 pp.
84. Murawski, S.A. 2000. Definitions of overfishing from an ecosystem perspective. ICES J. Marine Science 57:649-528.
85. Overholtz, W.O., Link, J.S. & Murawski, S.A. 2000. Working group report: ecosystem indicators. Proceedings of the 6th National Stock Assessment Workshop: Incorporating Ecosystem Considerations into Stock Assessments and Management Advice. NOAA Tech. Memo. NMFS-F/SPO-46. pp. 51-53.

IEAs, MSE and associated context

86. ICES. 2010. Report of the Working Group on the Northwest Atlantic Regional Sea (WGNARS), 20–22 April 2010, Woods Hole, USA. ICES CM 2010/SSGRSP:03. 63 pp.
87. NEFMC SSC. 2010. White Paper On Ecosystem – Based Fishery Management For New England Fishery Management Council. Newburyport, MA. 25 pp.
88. ICES. 2009. Report of the Working Group on Holistic Assessments of Regional Marine Ecosystems (WGHAME), 12-16 October 2009, ICES Headquarters, Copenhagen. ICES CM 2009/RMC:13. 76 pp.
89. Levin P.S., M.J. Fogarty, S.A. Murawski, and D. Fluharty. 2009. Integrated Ecosystem Assessments: Developing the Scientific Basis for Ecosystem-Based Management of the Ocean. PLoS Biol 7(1): e1000014. doi:10.1371/journal.pbio.1000014
90. Levin, P.S., M.J. Fogarty, G.C. Matlock, and M. Ernst. 2008. Integrated ecosystem assessments. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-92, 20 p.
91. NAFO. 2008. Report of the NAFO SC Working Group on Ecosystem Approach to Fisheries Management (WGEAFM). SCS08-24. 19 pp. Dartmouth, NS.
92. NAFO. 2008. Report of the WGEAFM Meeting May 26-30, 2008. NAFO SCS 08/10, Serial No. N5511, 70 p. Dartmouth, NS.

Presentations

93. Logistical information; 10 slides. File: LogisticalInformation.pptx.
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 14[2] 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 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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10600 SW 131st Court, Miami, FL 33186
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Roger W. Peretti, Executive Vice President
Northern Taiga Ventures, Inc. (NTVI)
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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.whoi.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	Modeling approach and software, originally developed at CSIRO
Center	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