

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

External Independent Peer Review  
Summary Reports

Prepared for the Center for Independent Experts

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

**External Independent Peer Review**

by

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**Prepared for the Center for Independent Experts**

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## **Executive Summary**

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

## Conclusions and Recommendations

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

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

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

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

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

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

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

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

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

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**External Independent Peer Review**

by

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**Prepared for the Center for Independent Experts**

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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.

## Conclusions and Recommendations

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

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

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

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

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

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

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

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

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

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

To guide the NEFSC toward implementation of EBM my most important recommendation is that the NEFSC-EAP takes on the role of an interdisciplinary unit that can foster broad modeling initiatives and cooperation. An important aspect of this

should be to define a clear and explicit policy-driven strategy for what modeling to conduct in order to implement EBM at the NEFSC. The strategy should include model selection criteria to ensure that the group stays abreast with the model development, (i.e. that the criteria are consulted when a task is planned). It is considered a crucial aspect of best modeling practices for EBM to include alternative modeling approaches in EBM analysis, and this is especially important given that uncertainty is difficult to model conclusively at the ecosystem level.

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

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

The NEFSC-EAP is a small and efficient group. Given the urgency that implementation of the new Ocean Policy Act calls for, and given the expanded scope of what is required to timely address key policy questions for spatial planning, EBM, and climate change, I strongly recommend that the NEFSC 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.

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**External Independent Peer Review**

**by**

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**Prepared for the Center for Independent Experts**

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## Executive Summary

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

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

Members of the NEFSC ecosystem modeling group are well connected to other parts of the NEFSC, to various stakeholders and to international colleagues. This is an important aspect of staying at the forefront of development to make the approaches scientifically sound, yet applicable to the tasks at hand, such as providing timely advice for an ecosystem approach to fisheries management or other issues regarding the ecosystem. Given the complexity of the food web one would not *a priori* expect reasonable results from the simplest models, which might for example simply consider pairs of species. This is in stark contrast with Arcto-Boreal systems where one can commonly isolate and focus on interactions between only two species at a time. Instead more complex models are needed.

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

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



## **Conclusions**

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

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

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

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

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

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

## Recommendations

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