Chair's Summary of Program Review of Ecosystem Science
NOAA Northeast Fisheries Science Center
Woods Hole, MA
June 6-10, 2016

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(minor revisions from June 17 communication)

Review Panel Members:

- Charles Stock, NOAA/Geophysical Fluid Dynamics Laboratory, Chair
- Jeremy Collie, University of Rhode Island
- Simon Jennings, Centre for Environment, Fisheries and Aquaculture Science, United Kingdom
- Jon Helge Vølstad, Institute of Marine Research, Norway
- Francisco Werner, NOAA/Southwest Fisheries Science Center

Background and Overview of Review:

The purpose of this review, as outlined in the final terms of reference dated September 16, 2015, was to evaluate the current scientific programs of the Northeast Fisheries Science Center (NEFSC) that provide information relative to the management, protection and restoration of resilient and productive ecosystems. The scope of the ecosystem related science discussed included efforts that investigate ecological, oceanographic, climate, and habitat-related processes linked to Living Marine Resources (LMRs) and done in accordance with NOAA's legislative and other mandates (e.g., Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, Marine Mammal Protection Act, the National Ocean Policy).

The ecosystem science efforts within NEFSC were communicated to the reviewers through three days of presentations, posters, roundtable discussions, and public comments. Supporting materials were also provided prior to the review and supplemented during the meeting as requested. Several reviewers singled out the poster session as a unique aspect of the review that allowed them to interact with a broader set of scientists involved in NEFSC's EBFM work. Overall, the review was exceptionally well organized in all respects and the panel would like to recognize all those involved in putting together the program and contributing to talks, posters and discussions.

The reviewers were asked to provide advice (observations and recommendations) on the direction of ecosystem science research programs across a progression of five themes: 1) management context and strategic planning; 2) ecosystem data; 3) ecosystem modeling and analysis; 4) incorporation into management; 5) communication and peer review. Reviewers were also asked to consider eight over-arching sets of questions that are linked to themes in this summary. The panel chair was tasked with summarizing review proceedings in this report, highlighting salient issues and recurring themes. This report, however, is not a consensus document.

Those attending all or part of the review included NEFSC leadership and staff, including director Bill Karp, deputy director Susan Gardner and Chief of staff Paula Fratantoni, and the heads of pertinent research divisions and programs (Mike Fogarty, Tom Noji, Jon Hare, Kevin Friedland, John Hoey, Mike Simpkins). Participants from headquarters included Richard Merrick, Jason Link, Kenric Osgood, and Stephanie Oakes. John Bullard, the administrator for the Greater Atlantic Regional Fisheries Office (GARFO) was also in attendance, along with representatives from the Mid-Atlantic Fisheries

Management Council (MAFMC), the New England Fisheries Management Council (NEFMC), the Atlantic States Fisheries Commission (ASFMC) and regional planning bodies (RPBs).

General Observations and Recommendations

The committee was impressed by the very high quality of the ecosystem science work at the NEFSC, extending across oceanographic, climate, habitat and ecosystem assessment foci, and from observational to modeling efforts. While differences in opinion on approach and prioritization within the ecosystem science endeavor were expressed (and are indeed healthy) the strong common commitment of NEFSC leadership and staff to providing the best possible science to inform the large range of decisions facing NOAA and its regional partners was clear throughout the review. This very positive assessment of the overall health and vitality of NEFSC ecosystem science should be borne in mind when considering the observations and recommendations that follow, which naturally emphasize improvements to consider. Comments by all reviewers highlight three over-arching challenges for the NEFSC to consider. These are described broadly here, with a finer parsing of recurrent observations and recommendations provided by theme and question below.

All reviewers observed that the ecosystem science effort at NEFSC has placed the science center in an excellent position to move in a concerted manner toward NOAA's EAFM, EBFM and EBM objectives and the robust management strategies that such advances should bring. The prioritization of this area was clear in the NEFSC's strategic plan that emphasizes "Ecosystem-based science supporting the stewardship of living marine resources under changing climate conditions". All reviewers further observed that rapid environmental changes, strong multi-species interactions, and growing demand for competing ocean uses in the region provide significant impetus for accelerated movement toward these objectives to ensure sustainable and optimal management choices. It was noted, however, that the large volume of immediate research demands/deliverables handled by NEFSC staff posed a significant strategic challenge to efforts aimed at improving the way NEFSC meets stakeholder needs through incorporation of ecosystem-based science. All reviewers thus emphasized the importance of:

- Streamlining and/or reduction of immediate stock assessment demands (which require a substantial fraction of NEFSC resources) to meet NEFSC stock assessment review recommendations and national recommendations to allow a minimum of 20% of stock assessment scientist time for research. This research should be focused on transitioning to EBFM in a manner consistent with the strategic plan as opposed to further refinement of existing methods.
- A symmetric/complementary shift in resources within the ecosystem dynamics and assessment group from model development to collaborative work connecting ecosystem science and management (e.g., expansion of multi-species, environmentally informed operating model MSEs such as the Hydra example presented at the meeting).
- Formal introduction of ecosystem-based estimates directly into management pathways, particularly SAW/SARC in a multi-model context. The committee observed immediate opportunities and reasons to prioritize climate effects on stock range and productivity, and consideration of prominent multi-species interactions. They also noted the potential value of a direct connection between the NEFSC and SSCs, agreed upon with the FMCs, for accelerating progress in this area.

Strategies for achieving increased resource allocations for these issues should be pursued in a manner consistent with the NEFSC strategic plan and NOAA fisheries prioritization and may require reallocations

from lower priority areas. These priorities also may require measured investment in additional mandates (e.g., RPBs) that do not bring additional resources. Executing these strategic resource changes will require strong leadership, coordination and shared and sustained commitment from the director, division, and appropriate group heads.

All reviewers highlighted the sustained, robust observational programs developed and maintained at NEFSC and their foundational role in EBFM. They stressed the high priority of protecting the integrity and quality of these data streams to the fullest extent possible while recognizing challenges in recent years posed by reductions in ship time and increased mission responsibilities. There is no way, however, to back fill critical time series once they are compromised. Reviewers encouraged cost efficient observational innovations and enhancements through technological, industry, and academic pathways. They also emphasized, however, the need to clearly map these activities onto NEFSC mandates and relative to NEFSC observational efforts to ensure the contribution of these efforts to management is fully realized and appreciated.

All reviewers noted substantial, and generally successful, efforts by NEFSC scientists to communicate ecosystem science and help various management bodies develop strategies for EAFM/EBFM implementation. These efforts were reflected in strong engagement of NEFMC, MAFMC, ASFMC, GARFO and RPB members throughout the review, including a particularly useful managers roundtable. Despite these overall strengths, however, the reviewers also noted communication gaps likely to impede the adoption of EBFM/EBM unless overcome:

- There was a tendency amongst stakeholders to equate EAFM/EBFM with wider uncertainty buffers and thus tighter regulation, rather than with more informed and effective management of systems where climate and ecosystem effects are inherent and unavoidable;
- EAFM/EBFM adoption was often perceived as an abrupt, high-risk shift rather than an evolutionary improvement of existing methods that should reduce risk and better achieve optimal yields;
- There seemed to be perceived division between statutory requirements and EBFM goals that negatively impacted EBFM prioritization. The review panel viewed EBFM pathways as the way to ensure application of best available science and achieve optimal yields in manner consistent with fisheries standards. This issue is in need of clarification at the national level.

The reviewer's encouraged rapid development of illustrative case studies to address the first two issues. Careful consideration of the second issue in EBFM strategy implementation (i.e., evolutionary versus revolutionary) is essential. All reviewers noted the value of industry partnerships (e.g., study fleets, the butterfish bycatch collaboration) for addressing this communication challenges and encouraged continued shared investments. These activities should be part of an overall NEFSC communication strategy to address these challenges.

Discussion of these over-arching challenges during the review debriefing with NEFSC and NOAA leadership suggested that the three issues above are national and indeed international issues. They should be elevated appropriately.

In the pages that follow, we summarized recurrent observations and recommendations by theme. Many, but not all of these map onto the three challenges summarized above. The present content reflects the final version of individual reviewer input sent along with this document. Please refer to these individual reports for the full scope of comments and insights.

Panel Member's Major Recurrent Observations and Recommendations (by theme)

Theme 1: Management context and strategic planning

The first three questions were most pertinent to this theme and emphasized by reviewers:

1. Does the NEFSC have clear goals and objectives for an ecosystem-related science program? Is ecosystem-related science integrated with the other science activities across Divisions within the NEFSC? Are NEFSC's ecosystem science and research activities appropriately prioritized and evaluated as part of an overall strategic plan?
2. Does the NEFSC's ecosystem-related science programs focus on information to address the priority needs of the Regional Offices, other NOAA managers, Fishery Management Councils and Commissions, and other partners that require ecosystem-related information to achieve their mission?
3. Has the NEFSC appropriately established a Regional Action Plan to identify the major climate threats to the ecosystem, identify major vulnerabilities of living marine resources with respect to climate, address the core science needs to address impacts from a changing climate, and integrate this information into management advice, congruent with the NOAA Fisheries Climate Science Strategy?

Recurrent Observations

1. The NEFSC 2016-2021 strategic plan prioritization of "ecosystem-based science supporting stewardship of living marine resources under changing climate conditions" is consistent with NOAA fisheries priorities, the EBFM roadmap and befitting of the climate and ecosystem challenges faced in the region. There is ambiguity, however, in the degree to which EBFM is required by legislative mandates. This can negatively impact prioritization of EBFM relative to other activities.
2. The habitat, oceanography and ecosystem-based assessment groups have strong relationships and work together effectively to conduct pioneering multi-faceted climate research. Cross-division steering and working groups are beneficial to this process, but there is some concern that divisional (i.e., chains of command/performance review) may trump committee structures and hinder EBFM efforts.
3. There is a shared desire for collaborative work between population dynamics and ecosystem-oriented groups, but this is hindered by large immediate management demands on the population dynamics groups, slowing incorporation into management (see theme 4).
4. The ecosystem science conducted at the NEFSC is consistent with and responsive to GARFO, NEFMC, MAFMC, and ASMFC EBFM strategies. Specifically, the ecosystem observations, indicators and models developed are well positioned to address alternative but complementary paths to EBFM outlined by the NEFMC and MAFMC and contribute to the broader EBM questions posed by the regional planning bodies. NEFSC scientists have effectively engaged with NEFMC, MAFMC, ASMFC and GARFO through the EBFM Plan Development Teams (PDTs) to formulate EBFM strategies, but there were some persistent negative impressions of EBFM within the fisheries representatives that need to be overcome (see general comments, theme 5)
5. NEFSC scientists have successfully completed immediate priorities of the NOAA Fisheries Climate Science Strategy, including the development of NOAA Fisheries' first vulnerability assessment and a draft climate "Regional Action Plan" that is currently in public comment. NEFSC scientists have also developed pioneering climate-LMR impacts assessment and continue

to leverage external funding, collaborations with NOAA/OAR and academic colleagues to quantitatively understand climate change impacts on LMRs.

6. The strategic priority of EBFM, together with already prominent climate and multi-species effects on LMRs with NEFSC's region argue for expanded investment that requires difficult choices in a resource limited environment. These choices, however, are critical for ensuring robust resource management/optimal yields in coming years, and present a national challenge that extends beyond NEFSC.

Recommendations to address issues

1. Ambiguities between the statutory versus "soft" mandate for EBFM should be clarified at the national level, and the objectives of EBFM aligned with governing acts (e.g., best available science to produce optimal yields). Prioritization of EBFM within work plans should be consistent with strategic prioritization in aspirational documents.
2. In a steady or declining resource environment, a combination of efficiencies (e.g., gained by following recommendations arising from NEFSC's stock assessment review) or reduced funding of lower priority areas (in accordance with annual guidance on fisheries priorities) should be found to accelerate progress toward EBFM. Please refer to theme 4 for additional recommendation relevant for accelerating the transition of EBFM to management.
3. NEFSC should consider developing a communications strategy that would clarify the transitional process from single-species management to EBFM to address misconceptions (see general comments, theme 5).
4. The strategic plan defines a challenging set of EBFM priorities, new investments (e.g., regional planning bodies) must be carefully weighed against these priorities in the absence of new resources, with an emphasis on efficient synergies between priority EBFM goals and expanding mandates.
5. Cross-divisional action through steering/work groups should be encouraged and extended through incentives and prioritization of cross-divisional/group work in high priority EBFM areas.
6. There were many regional action plan priorities. Some additional prioritization may be required. A Gantt chart, for example, was suggested by one reviewer. Developing initial climate-driven EBFM operating models seemed to be a pressing need given the magnitude of recent changes and could serve multiple purposes in this respect (i.e., improving management toward EBFM and helping dispel communication gaps).
7. A long-term strategy for recruiting and hiring scientists spanning the range of expertise needed for EBFM is needed to ensure continued success.

Theme 2: Ecosystem Data

Over-arching question 4 was most pertinent: What is the status of oceanographic, habitat, climate and ecological data required to fulfill ecosystem-related science needs? Has the NEFSC developed strategies to obtain and manage such data?

Recurrent observations:

1. Through sustained investment over many decades, the NEFSC has developed exceptional time series of fish, hydrographic, plankton, food web, and habitat surveys that provide the observational foundation for EBFM goals and broadly support activities within the NEFSC and the broader research community. The NEFSC's ability to maintain these has been challenged by budgetary pressures and new demands. The scientists involved in NEFSC data collection efforts

had a clear sense of purpose and understood their role in assessment and management processes.
2. NEFSC scientists have also successfully leveraged data from ocean observing systems and satellites, often in near real-time, to fill in gaps in the resolution of LMR-environment relationships.
3. Innovate industry partnerships/cooperative research has substantively augmented environmental data collection and helped build industry relationships (see theme 5), but outcomes of this work (i.e., impact on management and associated uncertainties) did not always filter back to the fisherman.
4. New user interfaces are making large NEFSC databases available to NOAA scientists and their research partners in a way that would not have been feasible even 10 years ago. The main outlet for public access was the Ecosystem Considerations website, which had a logical, clear structure.
5. Laboratory-based efforts undertaken at the NEFSC are providing essential constraints for understanding LMR resilience to impending acidification and warming of NEFSC waters.

Recommendations to address issues:

1. Ecosystem data provide the foundation for EBFM and robust funding for core observational activities - including maintenance of critical time series that cannot be "backfilled" once missed – observations should be prioritized appropriately.
2. Cooperative data collection with the industry plays a key role in developing trust and augmenting NEFSC data sets, but tighter integration/clarification of how these data streams fit into the management process and/or industry operations is needed. One reviewer suggested that the utility of this data could be enhanced by agreeing on a limited number of fixed stations, or intentionally random sampling, targeted to reduce by-catch or uncertainty buffers.
3. NEFSC should consider surveying the users of their Ecosystem Considerations website or holding small workshops with key stakeholder groups to identify targeted improvements (e.g., mapping thermal ranges based on temperature ranges provided by the user).
4. Analyses should be conducted to evaluate whether long-standing survey designs are in need of modification and to prioritize survey elements to a) continue to improve surveys; b) minimize impacts if cuts are unavoidable.

Theme 3: Ecosystem modeling and analysis

Over-arching question 5 was most pertinent to this theme and emphasized by reviewers: Is the NEFSC appropriately analyzing and modeling ecosystem-level processes? Are cumulative and integrative ecosystem-level analyses being conducted? If not, is there a plan in place to initiate or contribute to the science needed to address cumulative impacts?

Recurrent observations:

1. Scientists in the NEFSC are engaged in diverse analyses of the rich data sets described in theme 2. Such projects are often carried out by graduate, postdoctoral and visiting scientist under the direction of NEFSC scientists and leveraging support from NOAA (e.g., FATE, CPO, IEA) and other sources. This is beneficial to the lab, the research community, and often underpins ecosystem indicator development and EBFM strategies (e.g., empirical regime shift research).
2. The Ecosystem Assessment group has consistently produced innovative ecosystem models and modeling applications spanning a range of complexity to support both incremental and more revolutionary advances toward EBFM. These models integrate diverse data sets from theme 2

and continue to push methodological and ecosystem science frontiers in a manner consistent with the previous CIE review. Accomplishments in this area are impressive given the small size of the group and are internationally recognized.

3. In accordance with the previous CIE review, substantial progress has been made in integrating socioeconomic considerations (e.g., portfolio science) to improve assessment of the socioeconomic implications of different natural and management scenarios.
4. Critical groundwork for incorporating ecosystem models with management has been laid via recently published management strategy evaluations (MSEs) using multi-species models (Hydra) led by ecosystem assessment scientists and collaborators.
5. To date, there has been limited uptake of multispecies models or single-species models with environmental drivers into the assessment and management process. Contributing factors include: a) heavy stock assessment workload that provides little time for innovation; b) an emphasis on precision over accuracy in stock assessments; c) a reluctance to consider multiple models.

Recommendations to address issues:

1. Continue leveraging external grants and visiting scientists for analysis of existing data sets. This task seems well suited for this mode of funding and we would encourage national NOAA programs to maintain funding opportunities in this area through programs like FATE and IEA funding.
2. Integrative modeling efforts should focus efforts more squarely on transitioning models developed under this theme toward management via expanded MSEs and providing results directly to management processes (see theme 4). This should be reciprocated by allocation of additional effort to EBFM from the stock assessment side gained via streamlining or prioritizing improvement through EBFM over further refinement of existing methods.
3. Global sensitivity analysis with modeling frameworks may be useful in understanding the parameters determining model accuracy and to refine/prioritize observations to constrain these.

Theme 4: Incorporation into management

Over-arching question 6 was most pertinent to this theme 4: Is the NEFSC's oceanographic, habitat, climate and ecological advice sufficiently included into living marine resource management advice? Are there suitable mechanisms to determine when such inclusion is warranted?

Recurrent observations:

1. NEFSC scientists are heavily engaged in the management system through their membership on EBFM plan development teams within the councils/commission and the SSCs. This has led to the development of EBFM transition plans by the MAFMC (an incremental approach) and NEFMC (a more marked yet ultimately deliberate and evidence-based transition) that NEFSC scientists have taken substantive steps to develop the tools to meet.
2. Provision of the ecosystem status report to the FMCs was noted as a foundational information transfer to management and industry operations.
3. Accelerating the transfer of ecosystem information to management was identified as a major challenge for the center over the next 5 years. While there are examples of ecosystem and climate considerations supporting advice (e.g., butterfish/squid study) multispecies models or single species models with environmental covariates are not considered in core assessments. Progress to incorporate such factors has been slowed significantly by the demands of single

species stock assessment requests in the region and other immediate advice needs and exacerbated by the perception that EBFM and statutory requirements are distinct.
4. There is a reluctance to pass the results of multiple models to the fishery management councils in a risk assessment framework. There is a need for SSCs to consider multiple models meeting skill criteria to accurately assess risk and minimize the potential of failed reviews.
5. The pace of EBFM incorporation needs to be accelerated to meet NOAA aspirations and preserve yield/avoid sub-optimal management in a rapidly changing climate.

Recommendations

1. Continue concerted efforts to streamline the stock assessment process in accordance with the findings of the stock assessment review (move from a vicious spiral to a virtuous circle).
2. Aggressively pursue 20% research targets for Population Dynamics scientists and prioritize advancing EBFM assessments over further refinements in single species/no environment approaches, in a manner analogous to the recommendation that modeling work within the ecological applications group shift emphasis to the transfer to management.
3. Continue to use MSE approaches to identify those models that are ready to be considered for tactical decisions and provide these as part of the SAW/SARC and other management processes in a multi-model context. Inclusion should be based on similar or improved skill as standard approaches relative to defined criteria. Introduction of EBFM into the process could be facilitated by direct collaboration between SSCs and the NEFSC agreed upon by the management councils/commissions.
4. NEFSC should prioritize the priority actions in the climate RAP (e.g., a Gantt Chart) to ensure robust management under highly dynamic climate changes, including expanded inclusion of manageable but meaningful ecosystem terms of reference in stock assessments to stimulate movement toward FMC EBFM plans.
5. Assess the present value of the ecosystem status report to the management process through conversation with the council and identify ways to further improve its utility.
6. Continue EBFM PDT engagement.

Theme 5: Communication and Peer Review

Over-arching questions 7 and 8 were most pertinent to theme 5 and emphasized by reviewers:

7. Are the NEFSC's ecosystem-related science programs and products adequately peer-reviewed relative to their purpose and use? If not, has the NEFSC developed a strategy for peer-review?
8. Does the NEFSC appropriately communicate research results and resource needs to conduct ecosystem-related science to various managers, partners, stakeholders and the public?

Recurrent Observations:

1. The NEFSC has made major strides in communicating ecosystem status and trends through the development of web-based products and data sharing with research partners and stakeholders, including, but not limited to, the ecosystem considerations website and the state of the ecosystem report. Data and model visualization tools are also being used to engage stakeholders.
2. NEFSC scientist actively engage with the FMCs, RPBs, GARFO, and other stakeholders/partners in diverse ways to communicate science, develop workable solutions to stakeholder needs (e.g., EBFM strategy development through PDTs), and spur collaboration with scientific partners.

3. The NEFSC is heavily engaged in education and outreach, including work with a consortium of minority-serving undergraduate institutions and with fishermen through the Marine Resource Education Program.
4. The cooperative research partnerships with industry were enthusiastically praised by management roundtable participants as producing both useful science and building trust (though see theme 2 suggestions for ways to improve).
5. The ecosystem science within the NEFSC is world class and meets scientific peer review standards but, for numerous reasons, models supporting EBFM have not been entered into the SAW/SARC process.
6. Despite much progress in this area, several reviewers detected communication gaps that must be overcome to achieve EBFM objectives.
    a. Investment in ecosystem-based management seemed to be viewed by some as requiring degradation of management advice via reduced single species stock assessments rather than a pathway towards improved advice. It is also often separated from statutory requirements.
    b. EBFM was often viewed as synonymous with enhanced uncertainty buffers (i.e., an EBFM tax).
    c. The transition to EBFM was often portrayed with analogies (e.g., jumping from one plane to another) that implied high risk.

Recommendations to address issue:

1. Begin providing data streams from EBFM approaches to the SAW/SARC process (i.e., see theme 4).
2. Continue to augment and improve website and data serving in manner consistent with theme 2 recommendations (i.e., survey users and allow user manipulation of mapping and analysis tools).
3. NEFSC should consider developing a communications strategy that would clarify the transitional process from single species management to EBFM (i.e., a progressive and evidence-based operationalization of EBFM rather than a high-risk transition). The most effective means may ultimately be by demonstrating the potential benefits of EBFM through case studies.
4. As in theme 2, targeted investment in industry partnerships that address key uncertainties influencing fish catch and also builds understanding/confidence in EBFM approaches. NEFSC should, however, make greater efforts to highlight the added value of industry data relative to core NEFSC datasets.

Conclusions

The NEFSC's strong commitment to high quality science in support of core NOAA mandates was evident throughout the review. Sustaining this commitment over many years has enabled NEFSC to advance the frontiers of ecosystem science and laid the groundwork for concerted advances in ecosystem-based management. Such advances are consistent with NOAA fisheries and NEFSC strategic plans and aspirations, and should ensure maintenance of healthy ecosystems and productive fisheries despite impending challenges. There are significant obstacles to overcome to fully transition to EBFM and the benefits it will provide, but accomplishments to date, the skill and dedication of NEFSC scientists and staff, and invested stakeholders, suggest that these challenges can and will be met.

Reviewer 1 - Report on Program Review of Ecosystem Science
Science Center: Northeast Fisheries Science Center (NEFSC)
Address: Wood Hole Laboratory, Woods Hole, MA
Dates: 6-10 June 2016

Background

The objective of this review is to evaluate the current scientific programs of the NEFSC that are directed to provide information relative to the management, protection and restoration of resilient and productive ecosystems. For this purpose, ecosystem-related science programs are defined as those that elucidate ecological, oceanographic, climate and habitat-related processes as they are linked to living marine resources. This review is based on briefing documents provided by the NEFSC prior to the review, oral and poster presentations during the review, panel discussions and individual conversations with NEFSC scientists. The review panel greatly appreciated the high level of organization, including the electronic agenda with web links, the briefing book and two-page summaries of the research programs.

General Observations and Recommendations

Ecosystem science permeates many, if not most, of the activities of the NEFSC. The 2016-2021 Strategic Plan is broadly centered on supporting ecosystem based fisheries management. In addition, the NEFSC provides ecosystem data and scientific expertise to support other missions, including the conservation of protected resources and the Regional Planning Bodies, through the Marine Life Data and Assessment Team. Since 1995, overfishing has been reduced for most federally managed species in New England and the Mid-Atlantic regions. As fishing mortality is reduced and stocks begin to rebuild, other sources of mortality become more important. The three most important ecosystem considerations for fisheries management are, in descending order: climate, multispecies interactions, and fish habitat. Since 2000, climate change has been a major driver of fish population dynamics, interacting with fishing mortality in ways that are just beginning to be understood. Natural mortality rates change over time in relation to the relative abundance of prey and predator species—predation mortality is especially important for forage species like Atlantic herring and menhaden. Finally, the pelagic and benthic habitats ultimately define the productivity of NOAA trust species.

Specific Findings and Recommendations

Theme 1 – Management Context and Strategic Planning

Observations

The NEFSC is primarily responsive to the mandates of the Magnuson-Stevens Fishery Conservation and Management Act, the Endangered Species Act, the Marine Mammal Protection Act, and the National Environmental Policy Act. None of these acts specifically mandates EBFM. The mandate for EBFM comes from the President's (2010) National Ocean Policy. At the agency level, NOAA Fisheries is committed to EBFM and the ecosystem approach has been formally adopted by the NEFMC, MAFMC, and ASMFC. However, the absence of a clear legal mandate makes it challenging to develop EBFM in parallel with existing statutes and funding priorities.

The new organization of the NEFSC science programs is driven primarily by the requirements of the governing acts and to respond to demands of the regional fishery management councils (for example a large amount of effort is devoted to stocks assessments by the Population Dynamics

Branch). Ecosystem science is integrated into the four divisions. It is unclear what level of support is provided for each of these activities. At least in the organizational diagram, the division structure still appears to be "stove-piped". Efforts are underway to form cross-cutting committees (Climate, Ecosystem, Habitat and Assessment Steering Group, MSE Working Grouph) but the dotted lines are not apparent in the organizational diagram. When it comes to staff workloads, solid lines (chains of command) usually trump dotted lines (committee structures).

Ecosystem scientists at the NEFSC are highly qualified. They are conducting cutting-edge research that is published in primary fisheries journals. A challenge exists regarding how to best channel this expertise to balance the objectives of EBFM with other staff demands, while providing opportunities for professional growth and advancement.

Recommendations

The Strategic Science Plan clearly defines the priority science themes. The NEFSC should resist "mission creep" by carefully considering new demands and evaluating how they fit with the primary science themes. To the extent possible, the objectives of EBFM should be aligned with requirements of the governing acts to provide a harmonious organizational structure with adequate base support of ecosystem science.

Theme 2 – Ecosystem Data

Observations

The NEFSC supports several long-running ecosystem surveys, including the bottom-trawl survey, Ecosystems Monitoring (EcoMon), longline surveys, and marine mammal surveys. The bottom-trawl survey has long been the "backbone" for stock assessments and is becoming increasingly important as fishing mortality rates decline and fisheries-dependent data provide a weaker signal about stock status. Likewise, the EcoMon survey is becoming increasingly important for developing indices of larval abundance and understanding ecosystem effects on the early life history of principal commercial species.

At the same time that EBFM has created additional data demands, budget constraints have made it necessary to balance funding of surveys with other center activities. In some years the frequency of the EcoMon survey has been reduced. An ongoing challenge is how to design an ecosystem survey given existing constraints on ships, personnel, and funding. It is difficult to prioritize which variables to measure not knowing exactly how they will be used.

Existing cooperative research programs provide constructive engagement of the fishing industry in ecosystem research. However, participating fishermen have been frustrated when results of these programs are not used directly for management purposes.

There is an increasing ability for real-time collection of environmental and fisheries data. These data can be used for operational fisheries. The temporal and spatial scales for operational fisheries oceanography, fish-stock assessment and management may differ. Real-time data are not necessarily required for assessment and management, although they can stream-line data collection and data-base management. There is a need for near real-time data for assessing short-lived species such as squid (annual or sub-annual life cycles). Cooperative research could have a large role in the assessment of these species.

Basic scientific expertise in field such as taxonomy, ichthyology, plankton and benthic ecology has been lost through retirements. Yet this expertise is increasingly needed to support NEFMC. Much of the ecosystem research presented to the review panel is being conducted by a talented group of postdoctoral fellows who are well versed in modern methods of statistics and spatial analyses.
Ecosystem data are being widely used for spatial analyses of fish distributions, and to parameterize multispecies and ecosystem models. New user interfaces are making these large databases available to NOAA scientists and their research partners in a way that would not have been feasible even 10 years ago.

Recommendations
The NEFSC should maintain ecosystem survey effort in the Northeast US Shelf Ecosystem. Given the observed and anticipated shifts in species distributions, analyses should be conducted to evaluate whether the original survey strata remain appropriate or whether post-stratification is needed.
Strategic hires are needed to provide expertise in the fundamental fields such as oceanography, plankton and benthic ecology in order to enhance the institutional capacity of the NEFSC. A balance should be sought among permanent positions, temporary FTEs, and postdoctoral fellows.
Given increasing demands for ecosystem data, the NEFSC should try to avoid duplication of data portals in order to make most efficient use of staff time and provide version control.
Cooperative Research should complement core data collection programs, not duplicate or compete with them. Cooperative research projects need to have clear goals to ensure that industry objectives are aligned with the science themes of the Strategic Plan. Such alignment will help to ensure that the results of cooperative research are more fully integrated in science advice.

Theme 3 – Ecosystem Modeling and Analysis

Observations
Scientists at the NEFSC are well versed in ecosystem analysis and modeling. They are developing a range of models, including multispecies production, delay-difference, and age-structured models, length-based models (Hydra), network models and dynamics ecosystem models (Atlantis). Presently Hydra is being used as an operating model to test the performance of simpler multispecies models in a simulation context. Network models based on satellite derived primary production estimates are being used to propose and ecosystem limit reference point for fishery removals from the northeast shelf.
The first two priorities of the Northeast Regional Action Plan are to give greater emphasis to climate-related terms of reference and to develop stock-assessment models that include environmental terms. In principle this should help to align existing stock assessment duties with the objectives of EBFM. The climate vulnerability analysis and a project lead by the Environmental Defense Fund have identified stocks for which climate considerations could be important in stock assessments.

To date there has been limited uptake of multispecies models or single-species models with environmental drivers into the assessment and management process. One reason is that the heavy stock-assessment workload provides little time for research and innovation. Another reason is that existing stock-assessment review procedures stress model precision over accuracy. Recently, the assessments for several important stocks have failed, creating additional management uncertainty and pressure on stock assessment scientists to provide alternative models. The result is a vicious cycle of increasing scrutiny and demands on the scientists' time.

Management Strategy Evaluation (MSE) has been broadly proposed as a tool to assess risk in the stock assessment process, to test the performance of relatively simple multispecies models, and to examine the effect of different management strategies under climate change (Priority Action 5). While MSE is certainly an appropriate tool, it can be time consuming and somewhat open ended. Therefore, the NEFSC should carefully target MSEs to answer specific questions so that it does not become a "cottage industry". In some cases, qualitative risk assessments can suffice for identifying key uncertainties.

Recommendations

To the extent possible, the stock assessment process should be streamlined to reduce unnecessary demands and duplication of review. The incorporation of environmental data could reconcile some of the inconsistencies that exist in stock assessments, to the extent that these inconsistencies are caused by environmental changes, as opposed to errors in input data. Moving from a vicious spiral to a virtuous cycle will require strong scientific leadership in the population dynamics branch and at the center director level.

Stock assessment reviews and benchmarks could group ecologically related species as has been done in ICES (WKBALT and WKART). This could be a first step toward managing with a functional group perspective.

Theme 4 – Incorporation into Management

Observations

NEFSC scientists are heavily engaged in the management system through their membership on plan development teams and the SSCs. They are pursuing simultaneously several approaches toward EBFM, including participation in Integrated Ecosystem Assessment within the context of the NEFSC, ICES, and NAFO. Working through the EBFM Plan Development Team, NEFSC scientists have been tasked by the NEFMC to develop an example of a Fishery Ecosystem Plan that is based on fundamental ecosystem properties, as well as being realistic enough and with enough specification that it could be implemented.

Management agencies need to be responsive to ecosystem and climate-induced change while at the same time striving for stability in the fisheries by avoiding abrupt changes in the management system.

The fishery management councils have different immediate needs and priorities for ecosystem based advice. Both councils and the ASMFC are concerned with the effects of climate change on fish productivity. An ongoing need is to determine and incorporate the relationship between essential fish habitat and productivity of marine resources into management. Thermal habitat modeling of pelagic species is important, particularly in the Mid-Atlantic.

The NEFMC urgently needs catch advice that works. The stock assessments are the place that ecosystem information needs to be integrated in a concerted manner. This approach could create less competition for stock assessment scientist time, although it could create a greater burden.

Presently, there is reluctance to pass the results of multiple models to the fishery management councils in a risk-assessment framework. Instead, the evaluation of model variants is occurring in the NEFSC and SARC/SAW. At the same time, some of the preferred models are not passing review, leaving the SSC in the position of setting ABCs on the fly with data-limited models with little review. There is a need for SSCs to be provided A, B and C models, in the event that model A fails review. The SSCs contain the scientific expertise to consider the output of multiple models, including ecosystem-based models.

The MAFMC has deliberately chosen an incremental approach to EAFM. Important information for MAFMC and the ASMFC is the proper accounting of trophic interactions. The focus to date has been on estimating the predation mortality on Atlantic menhaden, with tools such as MSVPA-X and statistical multispecies age-structured models. As the set of modeled species expands, multiple feedbacks between prey and predator species will need to be measured.

Recommendations

Use the results of management strategy evaluations to identify multispecies models that are ready to be considered for tactical decision making (i.e. can estimate biomass in the terminal year and make short-term projections with corresponding uncertainty measures). These models could be provided as alternatives in the SAW/SARC process and passed on to the SSCs for their consideration in setting ABCs.

Theme 5 – Communication and Peer Review

Observations

The NEFSC has made major strides in communicating ecosystem status and trends through the development of web-based products and data sharing with research partners and stakeholders. The main outlet for public access is the NEFSC Ecosystem Considerations website. The Executive Summary constitutes a "State of the Ecosystem" report that is regularly presented to regional fishery management councils to keep them apprised on the state of the ecosystem as it may influence decisions related to fishing measures.

Data and model visualization tools are being used to engage stakeholders in model formulation (e.g. mental modeler), to communicate the output of complex multispecies and ecosystem models, and as education tools.

The NEFSC is heavily engaged in education and outreach. The NEFSC works with a consortium of minority-serving undergraduate institutions. The Woods Hole Partnership Education Program targets minority students and women as college juniors and seniors. The Marine Resource Education Program trains fishermen in the fundamentals of fisheries science.

NEFSC scientists have a strong record of publishing their research in peer-reviewed publications. External peer review is the "gold standard" for evaluating whether the results of scientific research are appropriate for making management decisions (i.e. CIE). Yet the cost and time requirements for peer review can delay the uptake of novel ecosystem-based approaches.

Recommendations

There is a need to explain to fishery managers how management advice is likely to change with EBFM. This communication would help to dispel the fear that the incorporation of ecosystem considerations would automatically lead to more risk-averse policies (e.g. a "climate tax").

Other

Priority Action 8 of the Northeast Regional Action Plan is to develop short-term (day-to-year) and medium-term (year-to-decade) living marine resource forecasting productions. It is important to distinguish between projections and forecasts. The complexity of marine ecosystems and the nonlinear connections between ecosystem components limits the ability to forecast living marine resources beyond one or two years. Forecasting skill in the Northeast US shelf ecosystem is lower than other U.S. regions, for example the west coast.

Conclusions

NOAA Fisheries has clearly embraced the mandate for EBFM coming from the National Ocean Policy. Both regional fishery management councils and the ASMFC are committed to EBFM, though with slightly different approaches. The NEFSC 2016-2021 Strategic Plan centers on EBFM. Although the goals of the NEFSC and the management agencies are clearly aligned, the Acts that govern fisheries management do not provide a legal mandate, nor base funding to support EBFM. NEFSC center scientists are engaged in cutting-edge ecosystem science, which is being published in primary fisheries journals. To date, the results of ecosystem science are being used primarily for strategic purposes. The challenge for the next five years is to identify opportunities to incorporate ecosystem science into tactical decision making. It is recognized that the pathways for incorporating ecosystem science into management advice will ultimately need to be streamlined to function within budgetary constraints.

Reviewer 2 Report on Program Review of Ecosystem Science
NOAA Northeast Fisheries Science Center (NEFSC)
Woods Hole
6-10 June 2016

Background:

The purpose of this review, as outlined in the final terms of reference dated September 16, 2015, was to evaluate the current scientific programs of the Northeast Fisheries Science Center (NEFSC) that provide information relative to the management, protection and restoration of resilient and productive ecosystems. The scope of the ecosystem related science discussed included efforts that investigate ecological, oceanographic, climate, and habitat-related processes linked to Living Marine Resources (LMRs) and done in accordance with NOAA's legislative and other mandates (e.g., Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, Marine Mammal Protection Action).

The ecosystem science efforts within NEFSC were communicated to the reviewers through three days of presentations, roundtable discussions, and public comments. Supporting materials were also provided prior to the review and supplemented during the meeting as requested. The reviewers were asked to provide advice (observations and recommendations) on the direction of ecosystem science research programs across a progression of five themes: 1) management context and strategic planning; 2) ecosystem data; 3) ecosystem modeling and analysis; 4) incorporation into management; 5) communication and peer review. Reviewers were also asked to consider eight over-arching sets of questions:

1. Does the NEFSC have clear goals and objectives for an ecosystem-related science program? Is ecosystem-related science integrated with the other science activities across Divisions within the NEFSC? Are NEFSC's ecosystem science and research activities appropriately prioritized and evaluated as part of an overall strategic plan?
2. Does the NEFSC's ecosystem-related science programs focus on information to address the priority needs of the Regional Offices, other NOAA managers, Fishery Management Councils and Commissions, and other partners that require ecosystem-related information to achieve their mission?
3. Has the NEFSC appropriately established a Regional Action Plan to identify the major climate threats to the ecosystem, identify major vulnerabilities of living marine resources with respect to climate, address the core science needs to address impacts from a changing climate, and integrate this information into management advice, congruent with the NOAA Fisheries Climate Science Strategy?
4. What is the status of oceanographic, habitat, climate and ecological data required to fulfill ecosystem-related science needs? Has the NEFSC developed strategies to obtain and manage such data?
5. Is the NEFSC appropriately analyzing and modeling ecosystem-level processes? Are cumulative and integrative ecosystem-level analyses being conducted? If not, is there a plan in place to initiate or contribute to the science needed to address cumulative impacts?
6. Is the NEFSC's oceanographic, habitat, climate and ecological advice sufficiently included into living marine resource management advice? Are there suitable mechanisms to determine when such inclusion is warranted?

7. Are the NEFSC's ecosystem-related science programs and products adequately peer-reviewed relative to their purpose and use? If not, has the NEFSC developed a strategy for peer-review?
8. Does the NEFSC appropriately communicate research results and resource needs to conduct ecosystem-related science to various managers, partners, stakeholders and the public?
The panel chair was tasked with summarizing review proceedings in this report, highlighting salient issues and recurring themes. This report, however, is not a consensus document.

General observations and Recommendation

The organisation, time-tabling and content of the review were effectively and transparently linked to the Terms of Reference. Documentation was very well organised and available when it was needed. I valued the opportunity to meet a wide range of staff involved in the program during a formal poster session as well as in the margins of the talks. The poster session was an important component of the review because it provided essential background on the data streams that supported research and advice on ecosystem and climate science and allowed NEFSC staff to talk candidly and in some depth about their work.

NEFSC has a small, productive and innovative group working directly on delivery of ecosystem and climate science and advice. They are supported by appropriate infrastructure, monitoring and data management. Monitoring spans many ecosystem components and attributes as well as the physical environment. This group of scientists actively publish research on marine ecosystems, climate impacts and ecosystem-based fishery management in peer review journals. They are innovative, productive and well known and regarded nationally and internationally, as evidenced by their influence beyond NOAA (e.g. ICES). Ironically, the many challenges faced by the management system on this coast (rapid climate change, a wide range of environments and fisheries, historical overfishing, strong mixed fishery and multispecies interactions and two Fishery Management Councils (FMC) with different fisheries and fisheries issues to address) spur scientific innovation and methodological development, but they also place NEFSC under significant pressure to deliver scientific advice.

The work of NEFSC work is planned and performed in collaboration with many partners. Close relationships with NOAA Fisheries Headquarters, the Mid-Atlantic Fishery Management Council (MAFMC), New England Fishery Management Council (NEFMC), Atlantic States Marine Fisheries Commission (ASMFC), Cooperative Institute for the North Atlantic Region (CINAR) and Greater Atlantic Regional Fisheries Office (GARFO) were strongly highlighted during the review. There are also active relationships with the NOAA Climate Program Office and many academic institutes, which add value to the program. From evidence available at the review, and personal interactions observed during the meeting, these relationships are based on respect and supported by high levels of communication (but not always on shared understanding of issues, please see comments relating to Theme 1).

NEFSC scientists and advisers play an important role developing strategies, documents and approaches relating to climate and ecosystem science. NEFSC are recognised as well informed advisers on these topics. NEFSC advisers have contributed significantly to laying out the pathways now described in global, national, and regional initiatives to achieve a transition from single-stock focused management to an Ecosystem Approach to Fisheries (EAF) and on to Ecosystem-based Fishery Management (EBFM) and Ecosystem-based management (EBM).

The NEFSC presented ecosystem and climate science as having a high priority and being supported by policy drivers and high level strategies (e.g. NOAA Climate Science Strategy). This science, and the advice that results, was also viewed as a necessity given the particularly rapid warming of the ocean in the northwest Atlantic and the extent multispecies interactions. In their Strategic Science Plan, with the strapline "Ecosystem-based science supporting stewardship of living marine resources under changing climatic conditions" NEFSC outlines its priorities for ecosystem and climate-related science and advice in the period 2016-2021. The plan includes a specific target to "Advance capacity for bringing ecosystem considerations to bear in stock assessments by developing extended single species assessments that incorporate climate, ecosystem, and habitat considerations". In May this year NOAA published a clear policy statement on EBFM and principles to guide it. This is being developed into a "road map". Locally NESFC has established a "Climate, Ecosystem, Habitat and Assessment Steering Group" which has the role of bringing together, and applying, climate, ecosystem, habitat, survey, and stock assessment work to support EBFM. Contributions from NEFSC staff are Cross-Divisional.
There are clear NEFSC and NOAA aspirations and commitments to address climate and ecosystem issues. But many of the existing demands of the MAFMC, the NEFMC, the ASMFC and GARFO are strongly focused on delivery of stock assessments and advice to meet requirements of, primarily, the Magnuson-Stevens Fishery Conservation and Management Act (MSA). These tactical demands clearly place NEFSC staff under significant day to day pressure. Consequently, there appears to be:
(a) little investment in testing, adopting and developing a shared understanding (with FMC) of alternate approaches to stock assessment that would reduce staff overload in the longer term and
(b) little opportunity for core assessment scientists to develop and understand methods that include climate and ecosystem considerations and to test their performance in relation to existing methods.
Inconsistencies between tactical demands and longer term aspirations to address ecosystem and climate issues are evident in the differing focus of guiding documents (e.g. focus on assessment needs as opposed to incorporation of ecosystem and climate information in documents such as the GARFO Strategic Plan).
The main challenge for NEFSC is to balance the demands for delivering existing tactical work with the need to address climate and ecosystem issues. The need to address these issues is couched in aspirational language in many documents that guide the direction of science and advice, but it was almost universally recognised as essential by those users of NEFSC science advice present at the review. The science evidence presented indicated that changing climate is, and will be, substantially impacting the fisheries and ecosystems of the NW Atlantic. It is inevitable that managers and industry will have to adapt to these changes and that the existing advice and management process will not meet all their needs (e.g. responding to changing stock distributions, changes in choke species, mixed and multispecies fisheries issues).
The review process also highlighted the view that some users of NEFSC science advice saw the transition from receiving single species advice to EAF and to EBFM as a fundamental change in the management system. This was not the same message conveyed by NOAA staff who were describing their plans for the development of EAF and EBFM during the same review. They described a more progressive transition.

From discussions at the review I could not fully judge the extent to which the perception of a fundamental change was influencing support for transition. But the different perspectives were sufficiently strong to suggest that more interaction between NOAA-NEFSC, users of advice and affected stakeholders was needed to clarify the transitional process in operational terms and to emphasise potential benefits as well as any potential costs.

Throughout the review there were few clear demonstrations of cases where the inclusion of climate or ecosystem information in an assessment (often the first step in the transition process) was shown to provide better performance in relation to some specified criterion (e.g. long-term value of yield, inter-annual variation in catch). Such demonstrations, may help to increase and broaden support for operational progress towards addressing climate and ecosystem issues. They might usefully be supported by efforts to highlight the need, and expectation, that the change to EAFM and EBFM will be progressive and well-considered, rather than a fundamental step change to the existing system.

To realise the aspirations in their Strategic Science Plan and to deliver "Ecosystem-based science supporting stewardship of living marine resources under changing climatic conditions" the review suggested that the managers of NEFSC will need to put in place the structures and actions to ensure that staff can prioritise the development, advisory and communications work needed to achieve this. The evidence presented at the review suggested that it was not an option to squeeze additional climate and ecosystems work into the existing workload. Consequently, resources will need to be freed from other areas of work (if current trends in overall budget persist). These resources would allow NEFSC to demonstrate the value of emerging methods in an operational context, to apply them and to actively communicate the process, and pros and cons, of including climate and ecosystem issues in advice.

Resources for operationalising climate and ecosystem science and advice may be freed if existing stock assessments could be simplified (e.g. alternate assessment models, wider adoption of management procedures) and if FMC and the SSC take a greater role in supporting simplification of the assessment process. Achieving such change will be challenging given current expectations for advice in this region. With the implementation of the new NEFSC Divisional structure the Director will need to facilitate strong and dynamic management of the Resource Evaluation and Assessment Division and engagement with the FMC to achieve shared understanding and commitment to the process of progressive and evidence-based operationalisation of EBFM. Progressive introduction of climate and ecosystem concerns into the assessment process will need to be based on rigorous evaluation of the pros and cons of doing this, and with a focus on carrying the FMC and other stakeholders in this process.

Theme 1: Management context and strategic planning

Observations:

Ecosystem-related science is well integrated with the other science activities across Divisions because NESFC have established an active "Climate, Ecosystem, Habitat and Assessment Steering Group". This brings together climate, ecosystem, habitat, survey and stock assessment work. Contributions from NEFSC staff are Cross-Divisional. The ecosystem science and research activities were prioritized and effectively justified in response to questions during the review. But, given the aspiration to address climate and ecosystem issues in the NESFC Strategic Science Plan and elsewhere, it seemed that the research and advisory components of these issues were not clearly prioritised in relation to the swathe of other work within NEFSC.

Conflicts between the delivery of stock-assessments (and serving day to day needs of the FMC in general) and the need to transition towards EAFM and EBFM were particularly apparent. Resources to support the research and advisory work relating to climate and ecosystem issues were very limited given long-term commitment or aspiration to address these issues.
The NEFSC ecosystem-related science programs focus on information to address the priority needs of the Regional Offices, other NOAA managers, FMC and Commissions. NEFSC scientists and advisers were shown to have played a key role developing strategies, documents and approaches relating to climate and ecosystem science. The programs on these topics are highly productive given the resources invested. NEFSC staff are conducting work to high standards; but allocation of resources to research and advice is very limited given strategic aspirations to adopt EBFM. This is because the short-term priorities of MAFMC, NEFMC, ASMFC and GARFO are largely linked to the conduct and receipt of stock assessments and associated advice, and these demands tend to drive the priorities of, and hence resource allocations by, the NEFSC.
The NEFSC has established a Regional Action Plan (RAP) to identify the major climate threats to the ecosystem. This is the Northeast RAP which was developed jointly with GARFO. It is intended to guide the approach used to increase the production, delivery, and use of climate-related information: to reduce impacts and increase resilience of fish stocks, fishing-dependent communities, and protected species. The draft of this RAP was published in May 2016 and is now available on the web as part of the consultation process. Review of the plan indicated that it does identify major vulnerabilities of living marine resources with respect to climate and address the core science needs to address impacts from a changing climate. The RAP supports the NOAA Fisheries Climate Science Strategy and has the potential to support the development of science-based strategies to sustain marine resources and people as the climate changes. As commented in relation to Theme 4, it will still require significant investment of expertise and time to operationalise these strategies and strict prioritisation of actions will be essential to make them achievable rather than aspirational.
Recommendations to address issue:
To deliver “Ecosystem-based science supporting stewardship of living marine resources under changing climatic conditions” NEFSC should develop a plan to prioritise the development, advisory and communications work needed to achieve this ambitious goal, taking into account the more detailed recommendations presented below.
NEFSC should consider developing a communications strategy that would clarify the transitional process from single species management to EBFM (a progressive and evidence-based operationalisation of EBFM). The groups to engage would be MAFMC, NEFMC, ASMFC, GARFO and associated groups and stakeholders. NEFSC should consider supporting the strategy with demonstrations of cases where the inclusion of climate or ecosystem information in an assessment (often the first step in the transition process) is clearly shown to provide better performance than existing assessment approaches in relation to some specified criterion (e.g. long-term value of yield, inter-annual variation in catch).
NEFSC should consider how NEFSC staff, external experts, FMC and other relevant stakeholders could be used to reduce the time used for stock assessments and to balance demands for existing tactical work with the need to address climate and ecosystem issues.
With the implementation of the new NEFSC Divisional structure, NEFSC should facilitate strong and dynamic management of the Resource Evaluation and Assessment Division and

engagement with the FMC to achieve shared understanding of the process for progressive and evidence-based operationalisation of EBFM. This is essential if (a) NEFSC is to work with its partners to reduce current stock assessment demands by adopting new methods and processes and (b) stock assessment scientists and ecosystem and climate scientists are to work productively to achieve progressive and evidence-based operationalisation of EBFM. Progressive introduction of climate and ecosystem concerns into the assessment process; should always be based on rigorous evaluation of the pros and cons of doing this and with a focus on carrying the FMC and other stakeholders in this process.

Theme 2: Ecosystem data

Observations:

NEFSC has put in place effective processes to acquire and manage the range of data required to fulfil current and proposed ecosystem-related science needs. The organisation is relatively data rich and the processes for collection, handling and quality control of data were effective and robust based on information gained during discussions with those involved in these processes. The people we met had clear sense of purpose and understood the role of their data in assessment and management processes. Especially important in context of the science discussed in this review were the bottom trawl survey, the EcoMon survey and collection of diet data. An increasing range of data are collected with industry but these data were not always used for a clearly stated purpose and outcomes were not always fed back to industry. Many of the data collected and collated by NEFSC contribute directly to ongoing ecosystem status reporting. The main outlet for public access to (processed) NEFSC data is the NEFSC Ecosystem Considerations website. This draws on inputs from 60+ scientists across Divisions. Review of the website showed it was structured around Ecology of the NE Shelf, Climate Change, Ecosystem Status, Current Conditions, Spatial Analyses and Modelling. The structure was logical and the presentation clear. The existence of this site showcases the role of NEFSC in marine ecosystem and climate science. The website focuses of reporting standard indicators rather than user manipulation.

Recommendations to address issue:

NEFSC should continue their efforts to improve access to climate and ecosystem data across NEFSC and externally.

NEFSC should highlight the purpose of collecting industry data and detail the uses of those data. They should consider how more processed data and products could be fed back to industry (in near real-time to the extent possible) based on understanding of their needs.

NEFSC should consider surveying users of their Ecosystem Considerations website to determine whether it meets their needs, their suggestions for modifications and to ask what related information and data services NEFSC might provide. If progressed, this survey should include consideration of methods for user manipulation of products (e.g. map thermal habitats based on temperature ranges provided by the user).

Theme 3: Ecosystem modelling and analysis

Observations:

NEFSC have an innovative and productive group of modellers who are actively working with, as well as developing, several multispecies and ecosystem models. Their work is a strength of NEFSC and leads to strong and positive international recognition. Several multispecies and ecosystem models were described during the review and the choices of models being

developed and used were well justified by the presenters and in supporting documentation. Modelling capacity and research output are remarkably high for a relatively small group. The group have good links to academia and internationally (e.g. roles in relevant ICES groups).
The review showed that NEFSC was appropriately analyzing and modeling ecosystem-level processes and ecosystem-level analyses were being addressed with three main classes of ecosystem model. These models have the capacity to address a range of impacts although the main focus has been on climate and fishing to date.
The rationale for the modelling work was clearly outlined during the review and those involved understand what they are trying to achieve. Data collectors and processors I met during the poster session clearly understood the wider role of their work in supporting community and ecosystem modelling. Some work on operationalising the models in a management context is underway.
Recommendations to address issue:
All the recommendations surrounding these models are linked to 'Incorporation into management' and are addressed in Themes 1 and 4.

Theme 4: Incorporation into management

With the exception of the advice generated to support single species stock assessment the oceanographic, habitat, climate and ecological science generated by NEFSC is not extensively used in living marine resource management advice; although it does contribute substantially to status and climate impact reports, website reporting (see Theme 2) and publications. To date multispecies models or single-species models with environmental drivers are not considered core to the assessment and management process. However, there are examples (e.g. butterfish assessment) where ecosystem and climate considerations supported advice. Looking forward, as commented in the response to Theme 1, the NEFSC has developed the Northeast RAP with GARFO that will guide the approach used to increase the production, delivery, and use of climate-related information and to reduce impacts and increase resilience of fish stocks, fishing-dependent communities, and protected species. This has the potential to drive significant uptake of climate and ecosystem data into management advice. But it will still require significant investment of expertise and time to operationalise the RAP and strict prioritisation of actions will be essential to make them achievable rather than aspirational.
Recommendations to address issue:
Recommendations linked to 'Management context and strategic planning' in Theme 1 are also relevant to this Theme.
NEFSC should further use Management Strategy Evaluation (MSE) to test the performance of single species models accounting for climate drivers as well as multispecies models that could be used to provide advice. If the models provide benefits in relation to defined criteria they should make the models available for benchmarking (initially in the Stock Assessment Review Committee, but other structures may be needed to support this benchmarking as more climate and ecosystem issues are addressed) and start to use the models to provide advice into the management system. Further development work on MSE, perhaps drawing on national and international expertise in MSE, should be considered as a means of supplementing existing skills in the NEFSC.
NEFSC should investigate the extent to which the timing of benchmarking exercises for groups of stocks which interact, or are likely to respond similarly to climate, could be harmonised. This

is proposed as a way to make the testing of methods to include climate and ecosystem considerations more efficient, recognising the structure of the existing benchmarking system. Once consultation is complete, NEFSC should strictly prioritise actions in the RAP to ensure that at least some of them can be achieved in the short- to medium term.

As well as taking advantage of the new NEFSC Divisional structure to promote interaction between stock assessment and ecosystem science (Recommendation Theme 1), NEFSC should consider the development of a longer term strategy to recruit and train innovative assessment scientists who (a) combine delivery and research roles, (b) have received training and support that allows them to assimilate climate and ecosystem considerations in their work and (c) to test when such considerations would add to the rigour of advice.

Theme 5: Communication and peer review

Observations:

The NEFSC ecosystem-related science programs and outputs are adequately peer-reviewed. It is expected that peer review will necessarily be intensified if the recommendation to benchmark the performance single species models accounting for climate drivers as well as multispecies models is adopted.

In general, the NEFSC appropriately communicates research results and resource needs to conduct ecosystem-related science to managers, partners, stakeholders and the public. Relevant research outputs and analyses of data are now posted on a new Fisheries and Climate website and on a redesigned Ecosystem Considerations site. There are strong drivers for increased communication and the “NEFSC Science and Research Director's Annual Guidance Memo for Fiscal Year 2017” asks “New this year, to the extent possible, I ask that each of our activities incorporate an explicit commitment to communication, transparency, outreach, and engagement with our partners in the academic, NGO and fishing communities.” Internally, NEFSC have established a “Climate, Ecosystem, Habitat and Assessment Steering Group” that has served to increase levels of internal communication about the transition to EBFM.

The NOAA Fisheries Priorities and Annual Guidance for 2016 indicates that “We will strive toward a “no surprises” approach to communicating with our stakeholders and, where practicable, build consensus on expectations and on identifying critical factors to measure success.” But during the review we observed that some users of NEFSC science advice saw the transition from receiving single species advice to EAF and to EBFM as a fundamental step change in the management system. This was not the same message conveyed by NOAA staff who were describing their plans for the development of EAF and EBFM during the same review. They described a more progressive transition (even if the overall start and end points would ultimately differ widely). The different perspectives were sufficiently strong to suggest that more interaction and communication between NOAA-NEFSC, users of advice and affected stakeholders was needed to clarify and develop shared understanding of the transitional process in operational terms. This would help all parties to appreciate that the change to EAFM and EBFM is intended to be progressive and well-considered, rather than a fundamental step change to the existing system.

Recommendations to address the issue:

These repeat recommendations that also addressed issues raised in Themes 1 and 2.

As commented for Theme 1 NEFSC should consider developing a communications strategy that would clarify the transitional process from single species management to EBFM (a progressive

and evidence-based operationalisation of EBFM). The audience for the resulting communications would be MAFMC, NEFMC, ASMFC, GARFO and associated groups and stakeholders.

As discussed and commented in Theme 2, NEFSC should make greater efforts to highlight the purpose of collecting industry data and the uses of those data. NESFC should feed processed data and products back to industry (in near real-time to the extent possible), and to other users based on understanding of their needs.

As commented in Theme 2, NEFSC should survey users of their Ecosystem Considerations website to determine whether it meets their needs, their suggestions for modifications and to ask what related information and data services NEFSC might provide. This survey should include consideration of methods for user manipulation of products (e.g. map thermal habitats based on temperature ranges provided by the user).

Reviewer Report on Program Review of Ecosystem Science – Reviewer 3

Science Center: Northeast Fisheries Science Center (NEFSC)

Address: Wood Hole Laboratory, Woods Hole, MA
June 6-10, 2016

Background

The National Marine Fisheries Service's Northeast Fisheries Science Center (NEFSC) in Woods Hole, Massachusetts, conducted an external review from June 6 to 10, 2016, to examine and evaluate current ecosystem scientific programs at NEFSC that provide information to support the management, protection, and restoration of resilient and productive ecosystems. The purpose of this review, as outlined in the final terms of reference dated September 16, 2015, was to evaluate the current scientific programs of the Northeast Fisheries Science Center (NEFSC) that provide information relative to the management, protection and restoration of resilient and productive ecosystems. The scope of the ecosystem related science discussed included efforts that investigate ecological, oceanographic, climate, and habitat-related processes linked to Living Marine Resources (LMRs) and done in accordance with NOAA's legislative and other mandates (e.g., Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, Marine Mammal Protection Action). The focus of the review was on the (1) management context and strategic planning, (2) ecosystem data, (3) ecosystem modelling and analysis, (4) incorporation of ecosystem science into management, and (5) communication and peer reviews.

The review meeting was exceptionally well organized. The background materials were linked to the agenda and provided on a website well in advance of the review. The presentations were focused and provided background material at the right level of detail. All presentations were posted to the website, and a booklet folder with copy of all presentations was provided to the Panel. The NEFSC had done an exceptional job of providing the most relevant background material for conducting the review, without overloading reviewers. Links to publications and more detailed reports on each topic where made available within documents that provided overview and summaries. The NEFSC Ecosystem Assessment program website (http://www.nefsc.noaa.gov/ecosys/) provided a particularly useful overview of the ecosystems science at NEFSC. The poster session was an effective way to provide essential background on the data streams that supported research and advice on ecosystem and climate science. This also allowed the review panel to talk directly with NEFSC staff to get more detailed information about their work.

During informational presentations each day there were specific intervals included for public comment. Stakeholders were invited to participate as observers and to comment during the daily public comment sessions.

Reviewers were asked to consider eight over-arching sets of questions:

1. Does the NEFSC have clear goals and objectives for an ecosystem-related science program? Is ecosystem-related science integrated with the other science activities across Divisions within the NEFSC? Are NEFSC's ecosystem science and research activities appropriately prioritized and evaluated as part of an overall strategic plan?

2. Does the NEFSC's ecosystem-related science programs focus on information to address the priority needs of the Regional Offices, other NOAA managers, Fishery Management Councils and Commissions, and other partners that require ecosystem-related information to achieve their mission?

3. Has the NEFSC appropriately established a Regional Action Plan to identify the major climate threats to the ecosystem, identify major vulnerabilities of living marine resources with respect to climate, address the core science needs to address impacts from a changing climate, and integrate this information into management advice, congruent with the NOAA Fisheries Climate Science Strategy?

4. What is the status of oceanographic, habitat, climate and ecological data required to fulfill ecosystem-related science needs? Has the NEFSC developed strategies to obtain and manage such data?

5. Is the NEFSC appropriately analyzing and modeling ecosystem-level processes? Are cumulative and integrative ecosystem-level analyses being conducted? If not, is there a plan in place to initiate or contribute to the science needed to address cumulative impacts?

6. Is the NEFSC's oceanographic, habitat, climate and ecological advice sufficiently included into living marine resource management advice? Are there suitable mechanisms to determine when such inclusion is warranted?

7. Are the NEFSC's ecosystem-related science programs and products adequately peer-reviewed relative to their purpose and use? If not, has the NEFSC developed a strategy for peer-review?

8. Does the NEFSC appropriately communicate research results and resource needs to conduct ecosystem-related science to various managers, partners, stakeholders and the public?

At the close of the review, the Panel and Center Directorate met to discuss the results of the review in closed session.

General Observations and Recommendation

The NEFSC has maintained a long-standing commitment to ecosystem monitoring and analysis and has made substantive progress towards ecosystem-based fishery management (EBFM) for the commercial and protected species that the Center monitors and assesses. Ecosystem science is integrated into most of the activities of the NEFSC. The 2016-2021 Strategic Plan is broadly centered on supporting ecosystem based fisheries management and the Climate, Ecosystems and Habitat Assessment Steering Group (CEHASG) will strengthen the coordination of the multidisciplinary, cross-cutting science that will be necessary to achieve this goal. NEFSC has a small, productive, and nationally and internationally highly regarded group of scientists that focus their research on marine ecosystems, climate impacts and ecosystem-based fishery management. This is evidenced in a large number of publications by NEFSC scientists in climate and ecosystem science over the last 10 years.

NEFSC has world class time series of data on oceanography, habitat, climate, and ecology to support ecosystem and climate research needs and a very strong team of scientists that manages to integrate these streams of data. This puts NEFSC in a very strong position to advance the science and advice needed to move toward NOAA's Ecosystem Assisted Fisheries Management (EAFM), Ecosystem Based Fisheries Management (EBFM) and Ecosystem based Management (EBM) objectives and to develop the operational management regimes that are required. The well documented rapid environmental

changes, strong multi-species interactions, and growing demand for competing ocean uses in the region strongly suggest that new management strategies will be required. NEFSC scientists have contributed significantly to international, national, and regional initiatives to achieve a transition from single-stock focused management to an Ecosystem Approach to Fisheries (EAF) and on to Ecosystem-based Fishery Management (EBFM) and Ecosystem-based management (EBM). However, the current commitments to support regional fisheries management councils with stock assessments and scientific advice on allowable biological catch (ABC) for nearly 60 stocks, and the associated demanding review processes poses a very heavy work-load on many of the quantitative scientists at NEFSC. This poses a significant strategic challenge. Modelling development and research required to incorporate and operationalize ecosystem-based science into fisheries management will require that significant more resources be devoted to collaborative research between the ecosystem dynamics and assessment groups. It could be advantageous to shift more efforts towards the development and implementation of relatively parsimonious statistical models that include climate effects on stock range and productivity, and significant multi-species interactions.

Key (Specific) Findings and Recommendations (as reviewer has comments on)

Theme 1 – Management Context and Strategic Planning

- Observations

The NEFSC ecosystem and climate science programs to support ecosystem management is being developed within a complex management context nationally and regionally. Ecosystem-based management (EBM) is an integrated approach that incorporates the entire ecosystem, including humans, into resource management decisions, responds to a changing marine climate, and is guided by an adaptive management approach. The NEFSC has clear goals and objectives for an ecosystem-related science program that is reflected in the NEFSC strategic science plan for 2016-2021 and its research programs are designed to contribute to this plan by incorporating ecosystem science into the four division.

The NEFSC strategic science plan focuses on Sustainable Fisheries, Protected Resources, Science to Support Ecosystem Based Fisheries Management, and Organizational Excellence. The NEFSC has also a vision statement to conduct ecosystem-based research and assessments of living marine resources, which shows a strong commitment, but but relatively few staff are dedicated to this research as compared to a large amount of effort devoted to stocks assessments by the Population Dynamics Branch. Also, NOAAs Fisheries Priorities and Annual Guidance for 2016 has identified several challenges and risks that could affect the ability to carry the mission, such as inadequate ship time, dated infrastructure that will degrade scientific and management capabilities, and increases in mission responsibilities without commensurate improvements in authorities and resources.

The timeline and resources that is dedicated by NEFSC to research for supporting EBM and EBFM is strongly dependent on the management context. The NEFSC research and advice is responsive to the Magnusson-Stevens Fishery Conservation and Management Act, the Endangered Species Act, Marine Mammal Protection Act, and the National Environmental Policy Act. None of these acts specifically mandates EBM or EBFM. The mandate for EBFM comes from the President's (2010) National Ocean Policy. At the agency level, NOAA Fisheries is committed to EBFM, but the absence of a clear legal mandate makes it challenging to develop EBFM in parallel with other demands. Regionally, the NEFSC

supports the NOAA Fisheries Greater Atlantic Regional Fisheries Office (GARFO), the Mid-Atlantic Fishery Management Council, the New England Fisheries Management Council (NEFMC), the Atlantic States Marine Fisheries Commission (ASFMC), and the NOAA Cooperative Institute for the North Atlantic Region (CINAR). The NEFMC, MAFMC, and ASMFC have adopted the EBFM approach, but are at very early stages of implementation. NEFSC scientists have been directly involved in the development and execution of five regional workshops associated with Council meetings to advance ecosystem and climate research and to draft Ecosystem Approach to Fisheries Management. Social and economic considerations have been integrated within all of the workshops, white papers, and the draft EAFM Policy Guidance Document. At the same time as NEFSC spends significant efforts to support priority needs of regional partners related to advice on FMPs and Allowable Biological Catch (ABC) of single stocks. The Population Dynamics Branch at NEFSC conducts assessment of around 60 species caught in commercial and recreational fisheries to support fisheries management by regional councils. As was pointed out in the 2014 Stock Assessments Program Review, the data preparation, analysis, and the comprehensive review process that is part of the assessment process is very demanding. Although progress has been made in terms of improving the efficiency of the stock assessment process it appears that this demand limits the research effort NEFSC can spend to develop and implement solutions to some of the challenges related to climate change and changes in the ecosystem. The Scientific and Statistical Committees (SSCs) of the regional management councils have strong expertise that could help NEFSC advance the development and implementation of EBFM. However, the SSCs can at this time only respond to demands from the Councils, and are not formally linked to NEFCS.

- Recommendations to address issue

  - Continue efforts to improve efficiency in stock assessments to free scientific staff time for developing and operationalizing methods for EBFM
  - In collaboration with NEFMC and MAFMC set up direct collaboration with SSCs and NEFSC to advance EBFM.
  - Ambiguities between the statutory versus "soft" mandates for EBFM should be clarified.

- **Theme 2 – Ecosystem Data**

- Observations

NEFSC has world class data on oceanography, habitat, climate, and ecological data required to support ecosystem and climate research needs. The NEFSC has maintained a long-standing commitment to ecosystem monitoring and analysis. Ecosystem data are being widely used for spatial analyses of fish distributions, and to parameterize multispecies and ecosystem models. The current data collections encompass physical oceanography, lower trophic processes (including primary and secondary productivity), living marine resource dynamics, habitat ecology, and protected resource dynamics. Monitoring programs of the NMFS (generally) and NEFSC (specifically) are in the position to provide long-term data on the both the physical and biological components of regional marine ecosystems; the biological data in particular is unique and should be valued as a critical component of

Integrated Ocean Observing Systems (IOOS). Long time series of biological data on fish and shellfish including diet data to analyze food-webs (from stomach sampling) are available from annual regional long-term spring and fall bottom trawl surveys. Additional ecological data area provided through the Ecosystems Monitoring cruises (EcoMon). Shelf-wide Research Vessel Surveys are conducted 6-7 times per year over the continental shelf from Cape Hatteras, North Carolina to Cape Sable, Nova Scotia, using NOAA research ships or charter vessels. Three surveys are performed jointly with the bottom trawl surveys in the winter, spring and autumn. An additional four cruises, conducted in winter, late spring, late summer and late autumn, are dedicated to plankton and hydrographic data collection., longline surveys, and marine mammal surveys. In addition, temperature and salinity data are collected on almost all Northeast Fisheries Science Center cruises to monitor the seasonal and inter annual variability in the water properties on the northeast continental shelf.

NEFSC also collaborates with the fishing industry to collect data for ecosystem studies. Information on seascape dynamics, catch, and bycatch are also obtained throughout the fishing season through study fleets of commercial fishing vessels. One limitation of fisheries-dependent data is that it is often difficult to extrapolate the data to the regional scale since fishing locations are not representative, but rather based on economic considerations.

- Recommendations to address issue

  - Maintaining time series of data collections from scientific surveys and quality assurance of the data streams are critical to the development of EBM and EBFM.
  - It is recommended that collaboration with the fishing industry be augmented to include an element of fisheries-independent data collections that are focused on research questions that support the EBFM. This could for example include collections of biological data from standardized trawling at fixed stations that are initially selected systematically or randomly in a spatial management area. The collections of stomachs at representative fixed stations over the season, for example, could provide valuable information on consumption and species interactions over time, which would augment snap-shot food-web data from the spring and fall trawl scientific trawl surveys for selected species.

Theme 3 – Ecosystem modeling and analysis

- Observations

The NEFSC has made impressive advancement in the analysis and modelling of ecosystem analysis and in the development and implementation of models to address cumulative impacts. There are a number of different modeling initiatives to support EBM and EBFM at the Northeast Fisheries Science Center (NEFSC) that make use of the extensive ecological and environmental data sets available in the region. NEFSC are developing a wide range of models and also use multi-model comparison to serve a range of needs, and have demonstrated the capacity to implement and test these models. The models to support

EBFM span the spectrum from single species to aggregate species to full ecosystem models. NEFSC has developed several versions of multispecies production and delay-difference models, including Kraken, a multispecies production model. Kraken takes aggregate survey biomass and catch time series as inputs (currently assumes that catch is known without error) and estimates intrinsic growth rate and Type I interaction parameters. In this simple formulation, all interactions between species are parameterized as predation with no feedback from prey on their predators. The SAS models are process error only models that do not estimate survey catchability.

NEFSC has also developed and age-structured multispecies statistical catch at age (SCAA) model that is implemented in ADMB and includes 9 fish species from Georges Bank and 27 predator-prey interactions. The SCAA model inputs included age structured commercial catch, survey catch, and predator food habits data.

Another multispecies model, Hydra, implemented in ADMB simulates ten species with length-structured population dynamics, predation, and fishery selectivity with fishing mortality coming from three effort-driven multispecies fleets. Multiple forms for growth and recruitment are implemented in the operating model so that each species may have different combinations within the model structure (e.g. von Bertalanffy growth with Ricker recruitment, exponential growth with Beverton Holt recruitment) and environmental covariates for each function can also be included. There is no feedback between prey consumption and predator growth in Hydra. Hydra is being used as an operating model to test the performance of the Kraken and SAS models.

Moving toward the full ecosystem approach, NEFSC and the Alaska Fisheries Science Center (AFSC) have jointly been working to develop an R package named "Rpath" that implements Ecopath with Ecosim. In addition to developing the Rpath tool, development of four ecopath models representing the four ecological production units (EPUs) is underway.

Finally, NEFSC has implemented an end-to-end model in Atlantis that incorporates physical processes (e.g. sunlight, geochemistry, water flows, temperature, salinity, nutrients), biological processes for phytoplankton through whales (e.g. age structure, multiple recruitment functions, predation, natural mortality), and human dimensions (e.g. fishing effort, vulnerabilities of fish to a fishery, discard, bycatch, ports). This model is used for integrative ecosystem level analyses and contributes to the scientific evaluation of cumulative impacts.

Atlantis and Rpath are designed for use as full ecosystem operating models in management strategy evaluations (MSE), and multispecies models such as Kraken, SCAA, and Hydra can be used as multispecies operating models in MSEs.

It should be noted that this impressive effort in model development has been achieved with the efforts of relatively few staff being dedicated to ecosystem modelling.

To date it appears that multispecies models or single-species models with environmental drivers have not been integrated into the assessment and management process for several

reasons. One reason appears to be that the current benchmark process for introducing new methods on stock assessments and management mostly focuses on precision when evaluating estimates of parameters used in quota advice for single stocks, although variable biases (as reflected in problematic retrospective patterns) that most likely are related to environmental drivers, species interactions, and variable catchability in the surveys may drive the accuracy. Another reason is that the heavy work-load related to stock assessments leaves little time for staff to be involved in EAFM and EBFM methods development. The failure of several assessments of important stocks recently suggests the need for alternative methods that can incorporate environmental drivers and species interactions.

- Recommendations to address issue

  - Given the current resources and a flat budget it is recommended that NEFSC focus on fewer models that are developed in close collaboration with the management councils to move towards operational EBFM.
  - NEFSC should consider the involvement of more staff with expertise in statistics and statistical programming in the model development to support EBFM.
  - For several models implemented in ADMB it is recommended that NEFSC also explore the use of Template Model Builder (TMB) as an alternative to ADMB. Experience at Institute of Marine Research is that the use of TMB instead of ADMB (where applicable) dramatically speeds up computation time for complex models.
  - It is recommended that NEFSC first focus on the development of relatively simple multispecies models (e.g., simultaneous modelling of ecologically related species) that could be operationalized in stock assessment and management and thus reduce the number of single species stock assessments.
  - Global sensitivity analysis (Saltelli et al. 2008) may be used to assess the contributions of single factors/parameters and interactions between parameters to the overall variability in model output. For models to be used in operational EFBM sensitivity analysis could be an effective approach to identifying the parameters that drive the accuracy of model output. This would help NEFSC prioritize data collections to support EFBM. Anderson et al. (2011) provide an excellent overview of the literature, and many examples of applications of global sensitivity analysis to Integrated Assessment Models in climate research, and some of these are likely to be applicable to the models to be used in support of EAFM and EBFM.
  - NEFSC should target MSEs (which are very demanding on staff) to answer specific questions related to choice of methods in the move towards operationalizing EBFM in the assessment and management process.

Theme 4 – Incorporation into Management

- Observations

Substantial efforts in climate and ecosystem research have demonstrated large variability and shifts in the spatial distribution of many fish stocks. However, it is not clear how the Center´s research on ecosystem and climate is included into living marine resources management advice. The New England and Mid-Atlantic Fishery Management Councils and the Atlantic States Marine Fisheries Commission are developing strategies for integrating ecosystem considerations into their respective management programs. Initiatives are also underway in New England and the Mid-Atlantic regions to frame ocean management plans under the provisions of the U.S. National Ocean Policy, implemented in 2012. The Northeast Fisheries Science Center is providing scientific support for each of these initiatives while also working closely with the NMFS Greater Atlantic Regional Fisheries Office to meet requirements for protected species management, habitat protection, and fisheries management. NEFSC report on their EFBM research to the New England Council through a 10 member EBFM Plan Development Team (PDT), and not through a triad of interactions (Council, NEFSC, SSC). NEFSC scientists have also been directly involved in the development of the draft Ecosystem Approach to Fisheries Management Guidance Document completed in April 2016. Nevertheless, fisheries management advice to the two regional management councils, for example, appears to largely be based on stock assessments for single stocks. Results from the extensive efforts on multispecies and ecosystem modelling at NEFSC are currently not integrated in the advice provided to the fishery management councils for use in the risk-assessment framework. Instead, the evaluation of alternative models is occurring in the NEFSC and SARC/SAW review processes.

The Mid-Atlantic Fisheries Management Council has chosen EAFM as an an incremental approach to move towards EBFM. NEFSC is developing capacity for using MSEs to help incorporate ecosystem-based fisheries management and respond to the current needs and priorities of the Mid- Atlantic and New England Fishery Management Councils and the Atlantic States Marine Fisheries Commission, as well as other potential management organizations. An MSE for Atlantic herring to explore ABC control rules that consider herring's role as forage within the ecosystem has been initiated with the New England Fishery Management Council.

- Recommendations to address issue

- It is recommended that NEFSC and the management councils facilitate a direct dialog between NEFSC modelers and SSCs to determine how to identify the best modelling tools for incorporate ecosystem and climate science in fisheries management. As a start, preferred alternative models could be provided in the SAW/SARC process and passed on to the SSCs for their consideration in setting ABCs.
- It is recommended that the NEFSC work with the councils and SSC through the PDT to define practical (operational) management regimes that could be implemented as a result of decisions to move towards ecosystem based management.

- It is recommended that MSE be conducted in close collaboration with the councils to identify models that can be operationalized within practical management regimes.
- Current knowledge from climate and ecosystem research suggest that models that include climate effects on productivity and spatial range of stocks, and significant species interactions, be prioritized during the next five years.

• **Theme 5 – Communication and Peer Review**

o Observations

The NEFSC shows strong commitment to climate and ecosystem research in support of core NOAA mandates. The NEFSC communicates research results and resource needs to conduct ecosystem-related science to managers, partners, stakeholders and the public through many channels. The NEFSC Ecosystem Considerations website provides a very well organized overview of the climate and ecosystems science at NEFCS. This website had about 25000 hits during the last year, and provides stakeholders and the public access to Northeast Fisheries Science Center ecosystem science. The website provides a popularized overview of current knowledge related to climate and the ecosystem to the broad spectrum of stakeholders who will be engaged in the discussion of policy alternatives to meet the needs for Ecosystem-Based Management in the region. Focus is on the ecology of the Northeast continental Shelf, climate change, assessment of ecosystem status, threats and impacts, and spatial analysis and modelling approaches to support EAFM, EBFM, and EBM. An overview of the critical time series of oceanographic, environmental, and ecological data to support climate and ecosystem research is missing.

NEFSC scientists have strong publication record in peer-reviewed publications. The methods being developed for supporting. NEFSC research is also subject to external peer reviews through for example Center of Independent Experts (CIE) to evaluate whether the results of scientific research are appropriate for making management decisions.

The cooperative research partnerships with industry is an important program for building trust between scientists and the fishing industry, and is praised by regional managers.

The NEFSC has a strong program in education and outreach that range from kindergarten through postdoctoral studies. The NEFSC has long-term strategy to diversify staff by exposing students from minority backgrounds to the science at NEFSC. NEFSC recruit students to a summer school program in Woods Hole in collaboration with a consortium of minority-serving undergraduate institutions, and the Woods Hole Partnership Education Program also targets minority students and women. The Marine Resource Education Program trains fishermen in the fundamentals of fisheries science.

o Recommendations to address issue

- There is a need to explain to fishery managers how management advice is likely to change with EBFM
- This will likely require more interaction and communication between NEFSC, regional fisheries management councils, and affected stakeholders to develop shared understanding of the transitional process to operationalize EAFM and EBFM.
- It is recommended that the NEFSC Ecosystem Considerations website be expanded to also include a section that provides an overview of the data streams and quality assurance required to advance climate and ecosystem science. These times series and their importance should be highlighted since their continued funding is critical to an operational EBFM regime.

• **Other**

o Observations

There have been many spatial delineations applied to the Northeast U.S. Continental Shelf Large Marine Ecosystem (NES LME) depending on their usage, from the broader-scale NAFO statistical areas, to sampling strata, to purely management-based delineations between the New England and Mid-Atlantic management regions. NEFSC has done innovative work to delineate Ecological Production Units (EPUs) based on objective biogeophysical characteristics of the NE LME. One challenge with the EPUs in terms of their use in integrated management plans is that the EPU boundaries do not conform to the borders of jurisdiction for the councils. Also, the boundaries of the EPUs are likely to change in the long-term response to climate changes due to temperature changes, and shifts in species distributions. In the spatial analysis, post-stratification is used to obtain estimates for EPUs. If stations within PSUs have unequal inclusion probability, the inclusion of a factor for (original) strata belongings of stations will be required to support iid error assumptions in models.

o Recommendations to address issue

- It is recommended that NEFSC consider proportional to area allocation of stations to survey strata in the spring and fall trawl surveys. This will have the advantage of stations having equal inclusion probability within EPUs, which will reduce the complexity of models since a factor for strata can be eliminated.

Conclusions

The NEFSC have made impressive advances towards EAFM and EFMB. However, results of ecosystem science at NEFSC have not yet been incorporated into an operational fisheries management regime. The challenge for the next five years is to identify case studies were models that incorporate climate effects and species interactions are used in fisheries management decisions. It would be particularly advantageous of these case studies introduced models that eliminated a number of single stock assessments. It is recognized that the pathways for incorporating ecosystem science into management advice will ultimately need to be streamlined to function within budgetary constraints.

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Reviewer 4 - Report on Program Review of Ecosystem Science

Science Center: Northeast Fisheries Science Center (NEFSC)
Address: Woods Hole, MA
Dates: 6-10 June 2016

Background

The NEFSC has a long and stellar history of establishing fundamental ecosystem and fishery science and management approaches while working in a challenging jurisdictional environment. It has long been recognized as one of the leading Fisheries Science Centers in the world. Management of individual fisheries (commercial and recreational) and has been balanced with attention to ecosystem components. Recently, attention to fisheries/harvest "crises" has been compounded by attention to warming trends, species shifts and other large-scale environmental signals along the NE U.S. continental shelf, the Gulf of Maine and neighboring areas. The NEFSC's Vision Statement[1] to

> *"Conduct ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources, and to generate social and economic opportunities and benefits from their use."*

explicitly recognizes the interplay between ecosystem considerations, quantitative assessments and advice to management as part of the Science Center's core approach to providing science advice. The integration of the NEFSC's vision in all presentations, poster session and discussions was clear throughout the review.

General Observations and Recommendation

The review of NEFSC's "Ecosystem Science" was presented over a 3-day period (6-8 June 2016). In addition to the NEFSC scientists and staff, representatives from GARFO, and management bodies (the MAFMC, NEFMC, ASMFC), the presence at the review by representatives from NMFS Headquarters (HQ) enables comments below to be provided (i) with a regional focus, to address the review's immediate objectives to examine and evaluate the NEFSC's ecosystem science information needs, priorities and research activities, and (ii) in a broader sense, some of the comments below are offered in support of the consideration of nationally coordinated ecosystem science programs that can provide more integrated information to management, protection and restoration of resilient and productive ecosystems. Ecosystem science and its inclusion in ecosystem-based fisheries management (EBFM) are being developed simultaneously at local and national levels. As such, it is neither a top-down nor a bottom-up approach, but rather it is a process that will be determined from trial and error at both levels, and one from which both – local and national – levels can build on each other.

The presentations and structure of the NEFSC oral and poster presentations addressed the five themes in the Review Panel's Terms of Reference (TORs)[2]

1. Management Context and Strategic Planning
2. Ecosystem Data

[1] http://www.nefsc.noaa.gov/mission.html
[2] http://www.nefsc.noaa.gov/program_review/pdfs/TOR%20for%20Ecosystem%20Program%20Review_16%20Sept%202015.pdf

3. Ecosystem Modeling and Analysis
4. Incorporation into Management
5. Communication and Peer Review

The presentations were all of very high caliber and the information was delivered clearly. The high level of science conducted at the NEFSC is evident as is the passion and enthusiasm of all involved. Again, thank you to all involved at the NEFSC in preparing the review of such complex topics and also for representatives from the management bodies, NMFS HQ and the general public for providing their insights.

Specific Findings and Recommendations

Theme 1 – Management Context and Strategic Planning. Three questions in the TORs help frame the comments that follow below.

1. Does the Center have clear goals and objectives for an ecosystem-related science program? Is ecosystem-related science integrated with the other science activities across Divisions within the Center? Are the Center's ecosystem science and research activities appropriately prioritized and evaluated as part of an overall strategic plan?

The short answer is yes. Starting with the its Vision Statement (see above) through the various documents [Science Strategic Plan[3], Climate Vulnerability Analysis (CVA)[4], Draft Regional Action Plan (RAP)[5], the Integrated Ecosystem Assessment (IEA)[6], etc.] the NEFSC has identified the inclusion of ecosystems and their components as part of the core of their approach. There is one *target* in the Strategic Science Plan that perhaps warrants highlighting as being simultaneously important and particularly challenging (target *F5*, p. 14 of the NEFSC's Strategic Science Plan):

> *"Advance capacity for bringing ecosystem considerations to bear in stock assessments by developing extended single species assessments that incorporate climate, ecosystem, and habitat considerations."*

This target is one that the whole of fisheries science faces collectively. As such, this target should be supported and elevated to national (and international) attention through targeted and sustained workshops and devoting science staff time to address. The challenge is non-trivial and should not be underestimated.

<u>Recommendations:</u>
To bring ecosystem considerations in stock assessments will require a concerted effort at local (within Center) and broader (national and international) levels.

- At the Center level one of the aspects is how to integrate stock assessment scientists and those taking on ecosystem considerations. It was made clear during the

[3] http://www.nefsc.noaa.gov/rcb/stratplan/
[4] Hare et al. 2016. A Vulnerability Assessment of Fish and Invertebrates to Climate Change on the Northeast U.S. Continental Shelf. PLoS One. February 3, 2016. 10.1371/journal.pone.0146756
[5] http://www.nefsc.noaa.gov/press_release/pr2016/news/dnr1604/Northeast_Regional_Climate_Science_Action_Plan_DRAFT_9May2016.pdf
[6] http://www.noaa.gov/iea/regions/northeast/index.html

presentations that staff in the NEFSC in these areas are already working at capacity. In other words, unless there is a redirection or realignment in their workloads, it is not clear how they will be able to devote the time needed to make the needed advances in "*extended single species assessments that incorporate climate, ecosystem, and habitat considerations".* The national response to the 2014 Stock Assessment Reviews[7] offers a possible way to carve out the needed time on p.6: *"Annual performance plans for stock assessment scientists will include a minimum of 20 percent time allocated for research to improve assessment methods, conduct research on factors affecting fish stocks, and publish research findings."* Redirection of some of the assessment staff at the Center could provide a way and time needed to devote to advancing the assessment-ecosystem bridge. Note that this will require simultaneous efforts from the stock assessment groups as well as the ecosystems groups, hence possibly requiring additional realignments. Since the NEFSC has just undergone reorganization in 2016, some of the pieces are likely in the right place, as are the already existing cross-divisional Working Groups, e.g., the Climate, Ecosystem and Habitat Steering Group.

- At a national/higher level, the efforts made at the various Fisheries Science Centers' level could be coordinated via workshops, or perhaps via exchanges between Centers and internationally. Working with the identified 20% time-dedication above, allows for one year out every five (or a few months every 3 years) for staff to dedicate to this important activity.

2. Do the Center's ecosystem-related science programs focus on information to address the priority needs of the Regional Office, other NOAA managers, Fishery Management Councils and Commissions, and other partners that require ecosystem-related information to achieve their mission?

As above, the answer is also yes, although it may take time for the impact of these programs to fully take hold in the management bodies' deliberations. The IEA, CVA and RAP are three of the elements in the broader EBFM policy that the Center is developing in collaboration with the management bodies.

Recommendations:

- At the Center level there will be a need to "pace" the various efforts. Excellent groundwork has been laid in the development of ecosystem-related priorities, but further fine-tuning would be helpful in implementing these. For example, the RAP identifies 15 priority areas (more on the RAP below), but further prioritization may be needed to ensure gradual, steady and quantitatively demonstrable progress. The call is for a more deliberate process to achieve a balance between workload, careful development of ideas, and the proper ingestion of new approaches.

[7] https://www.st.nmfs.noaa.gov/Assets/science_program/NationalProgramReviewResponse_2014_final.pdf

- Nationally, sustained communication of progress at the various Centers/Regions should be encouraged. In other words, there could be a formal "lessons learned" dialogue as each region makes progress in learning how ecosystem science information is generated and how it is used in management. This could be encouraged as a Theme Session in a national conference (e.g., of the American Fisheries Society).

3. Has the Center appropriately established a Regional Action Plan (RAP) to identify the major climate threats to the ecosystem, identify major vulnerabilities of living marine resources with respect to climate, address the core science needs to address impacts from a changing climate, and integrate this information into management advice, congruent with the NOAA Fisheries Climate Science Strategy?

A draft RAP has been developed and is now in public comment period. The RAP reads very well, it is well organized and it takes into account viewpoints from the NEFSC as well as its partner management bodies (parts of the RAP having been co-authored with collaborators from the management bodies). As mentioned above, one point that should not be overlooked is the need to be deliberate and proceed at a pace that allows Center scientists to take on new taks as well as the time needed by management bodies and constituents to evaluate and understand the new ecosystem-based science advice.

Recommendation:
A challenge and a recommendation are to "prioritize the priorities". The RAP's 15 Priority Actions are all appropriate, but a simple Gantt chart in a future version of the RAP could help define and rank-order the steps in time, how long they will take, as well as provide the strategies to achieve these. This is admittedly "tricky" since on the one hand the community has identified the need for incorporation of EBFM and Climate Science, but on the other, it has to be in a way that can be properly assimilated.

Theme 2 – Ecosystem Data. From the TORs to the Panel, the question relevant to this Theme is:

4. What is the status of oceanographic, habitat, climate and ecological data required fulfilling ecosystem-related science needs? Has the Center developed strategies to obtain and manage such data?

The Center has a long and established history of collecting ecosystem-relevant data. The challenge the Center faces is shared with other sea-going scientific efforts (in government and academia), and that is shrinking ship time. This results in data collection efforts related to fisheries (e.g., abundance, presence of target spp.) outweighing ecosystem-relevant data (e.g., measurements of lower trophic levels, biogeochemistry, etc.). While there is a recognition by all that both types of data are needed, fisheries needs, together with reduced ship schedules results at times in ecosystem data being sacrificed so that fishery (and protected species) surveys can be completed. The result is that ecosystem "context" for the fishery (and protected spp.) data can be compromised. Several approaches are suggested

below to make up some of the shortfalls, assuming that future access to ship time will continue to be reduced.

Recommendations:

- Continue the development of sampling through collaborative work with industry. A pilot program was described where joint efforts with industry fishing vessels provided information at scales that complement normal fishery surveys, i.e., at scales that are close to "process studies". It is not clear if these can be formalized and sustained, but they offer an interesting opportunity to make up some of the observational shortfalls. Again, there is a proof of concept on the table but "the devil may be in the details" in terms of making these collaborations significant to scientific advice and decision-making.
- Continue the collaboration with other government and academic partners (e.g., MARACOOS, NERACOOS and OOI) to operationalize advanced technologies, and to test new advanced technologies (e.g., gliders, AUVs, ecogenomic sensors) that would make up for shortage of survey time. Admittedly, the cost of these collaborations is a factor. Cross-agency collaboration identifying common areas of curiosity-driven research and mission-agency research needs to be established. Past examples of such NOAA-NSF collaboration are the GLOBEC and CAMEO Programs. Similar examples could be explored with the NSF's OOI and NOAA's IOOS.
- Invest in laboratory work to improve upon intrinsic model parameters (e.g., vital/metabolic rates of organisms, behaviors, etc.). The modeling community as a whole relies on parameterizations that were developed – some several decades ago – under different oceanic conditions/regimes. Climate models (see below) offer us a good idea of what we can expect conditions to be and it would be of great value to develop new parameters within expected future environmental conditions such as changes in pH, temperature, oxygen, etc., to aid in the projections presently being developed.

Theme 3 – Ecosystem modeling and analysis. The answer will be framed within the TOR question:

5. Is the Center appropriately analyzing and modeling ecosystem-level processes? Are cumulative and integrative ecosystem-level analyses being conducted? If not, is there a plan in place to initiate or contribute to the science needed to address cumulative impacts?

The Center's modeling approaches are comprehensive, very strong and their breadth impressive. They include multispecies models, "Atlantis" models, climate models – and a host of approaches in between. They each address different aspects of ecosystem-related information needs. In addition, the development of MSE approaches that build on some of the models as operating models is also proceeding on solid footing, as are advances in socioeconomic considerations.

Recommendations:

- The 2011 CIE review provided a thorough assessment of the modeling capabilities and several of the recommendations have been acted on. It seems that several of these models are mature enough to be considered in an operational arena, i.e., implemented in tractable settings that can provide quantitative demonstrations of their value, perhaps through SARC/SAW reviews. No additional recommendations are offered beyond those of the CIE; but the CIE's recommendations should be revisited to ensure they are being acted on.
- The collaborative work with NOAA/OAR's GFDL has generated valuable insights into future scenarios that would not have been possible with in-house capabilities. The relationship with GFDL should be continued and strengthened. Presently there is an NEFSC scientist "embedded" at GFDL. An alternative option, should there be opportunity for growth, is to have someone on site at Woods Hole or Narragansett to enhance the interaction with the assessment scientists.
- As with previous recommendations, the NEFSC is not alone in these challenges. Work with other Centers nationally, and within PICES/ICES in the international arena should be supported as the modeling community's advances are strengthened through joint work and comparative analyses.

Theme 4 – Incorporation into Management. Two TOR questions are relevant to this Theme and they are addressed below.

2. Do the Center's ecosystem-related science programs focus on information to address the priority needs of the Regional Offices, other NOAA managers, Fishery Management Councils and Commissions, and other partners that require ecosystem-related information to achieve their mission?

6. Is the Center's oceanographic, habitat, climate and ecological advice sufficiently included into living marine resource management advice? Are there suitable mechanisms to determine when such inclusion is warranted?

There is a strong and healthy relationship and communication between the Center and the region's management bodies. Similarly, there is support from management bodies for the ecosystem science conducted within the Center. As such the answer to the Question 5 is largely "yes" in that the Center's ecosystem programs focus on needs of the management bodies, but it is more challenging to say, for Question 6, that there are "suitable mechanisms to determine when such inclusion is warranted."
On the first point and in the short term, one way to bring the ecosystem-related information into the management deliberations is through management strategy evaluations (MSEs). Using MSEs to identify multispecies models developed and already in place at the NEFSC should be considered for tactical decision-making. These models could offer alternatives in the stock assessment process and evaluated by the Councils' SSCs. Additionally, case studies should be selected that, while not necessarily simple, should be

tractable and the results of the ecosystem-based approaches should (hopefully) be demonstrably better that single species approaches.
Expanding on the second aspect of Question 6 (re suitable mechanisms in the longer term): during the review some representatives from the management bodies stated their need to adhere to statutory responsibilities, some of which are embodied by the National Standards Guidelines[8]. In particular, National Standard 1 (NS1) states *"Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry."* As stated, NS1 seeks an "optimum" on a fishery basis, which admittedly makes it challenging to make decisions based on optima that explicitly include ecosystem definitions and considerations. One approach to including ecosystem considerations in management decisions is revisiting NS1. As EBFM is embraced nationally, "statutes" such as NS1 will need to be revisited to better define reference points that include ecosystem targets (including socioeconomic considerations) and facilitate the ecosystem science-management links. Again, the latter is not a recommendation for the NEFSC to address on its own, but is directed at a higher level, national dialogue.

Theme 5 – Communication and Peer Review. Two relevant TORs are addressed below.

7. Are the Center's ecosystem-related science programs and products adequately peer-reviewed relative to their purpose and use? If not, has the Center developed a strategy for peer-review?

Yes – the Center has its communications appropriately peer-reviewed. That includes the peer-review that takes place within bodies such as the Councils' SSCs and other management advisory panels, as well as primary science journal peer reviews. The productivity of the Center's staff in ecosystem science is high and it takes place in highly regarded fisheries science and oceanographic journals.

8. Does the Center appropriately communicate research results and resource needs to conduct ecosystem-related science to various managers, partners, stakeholders and the public?

Again the answer is yes. There are several elements that are worth mentioning:

i) Internally, to the Center's staff via the Annual Guidance Memo[9] the Center's commitment to *"Scientific investigations that support progression toward ecosystem-based fisheries management"* is unambiguous;
ii) the Ecosystem Status Report and related documents on the Ecosystem Assessment Program's website (http://www.nefsc.noaa.gov/ecosys/);
iii) the outreach efforts through the Woods Hole Partnership Education Program (that targets minority students and women as college undergraduates), and the Marine Resource Education Program that has established a dialogue with fishermen in the fundamentals of fisheries science. These include the use of the "Mental Modeler" approach and elements of Cooperative Research partnerships

[8] http://www.fisheries.noaa.gov/sfa/laws_policies/national_standards/index.html
[9] http://www.nefsc.noaa.gov/program_review/background2016/3Intro%20to%20NEFSC%20Sci/KARP/AGM%20on%20template.pdf

with industry that have been found to generate information relevant to fisher and scientists, as well as building trust through transparency.

Recommendation:
The main advice on this Theme is to stay the course. Continued sustained communications will be necessary to achieve EBFM objectives, and to overcome stakeholders' perceptions of enhanced uncertainties (and hence possibly reduced fisheries) when incorporating ecosystem information in management advice.

Concluding remarks

The ecosystem science efforts at NEFSC are solid and cutting edge. In addition to science challenges, the NEFSC (with GARFO) also faces challenges jurisdictionally in that it works with two Fishery Management Councils (with sometimes differing targets), twelve States and their associated Fisheries Commission, and is also challenged in that its staff faces heavy workloads internally while also supporting the various management bodies in their advisory panels, SSCs, etc. Despite these challenges, the NEFSC is well poised to take on, and in several instances, lead the next steps in ecosystem/EBFM science. Among others, (i) NEFSC scientists have developed a very good and realistic draft of the Climate Regional Action Plan, (ii) over the past years the NEFSC has implemented a successful Integrated Ecosystem Assessment Program and associated products, such as the NE Ecosystem Status Report, (iii) they have developed a wide range of multi-species and ecosystem modeling approaches to evaluate management strategies, (iv) they have begun to integrated ecosystem information in the management components of protected species as well to examine future projections of Northwest Atlantic ecosystems under IPCC climate change scenarios, (v) they have developed a strong relationship with stakeholders, and (vi) have carried out sustained significant field efforts related to ecosystems on the northeast U.S. continental shelf. The comments and recommendations offered above are meant to help grow and bridge key areas of the NEFSC's already strong and vibrant ecosystem science programs.